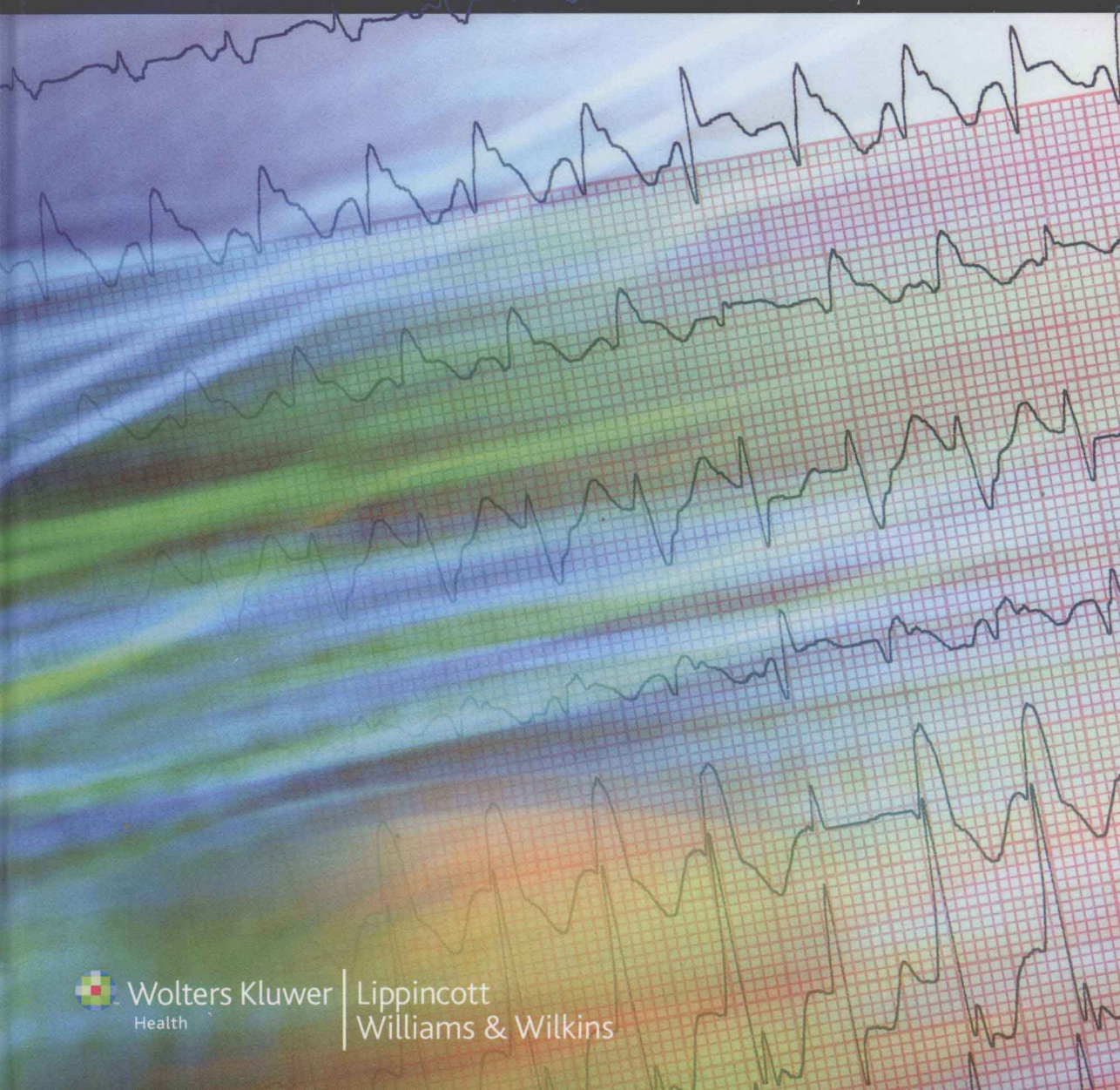
Practical Clinical Electrophysiology

Peter J. Zimetbaum | Mark E. Josephson



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To Ben, Molly, and Roberta—for your love, encouragement, and understanding

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Wolff-Parkinson-White Syndrome and Variants

Preface

The last decade has seen an explosion in the therapeutic options available for the management of cardiac arrhythmias. As a result, the focus of electrophysiology training has turned toward acquiring the technical skills necessary to perform catheter ablation and complex device implantation and away from the diagnostic skills required for arrhythmia management. Our goal in writing this book is to provide a succinct and practical clinical approach to the major arrhythmia disorders encountered in the clinic as well as the electrophysiology laboratory. We have focused on the clinical history, electrocardiogram and diagnostic electrophysiology study. More comprehensive texts are available, which delineate the details of diagnostic and therapeutic invasive electrophysiology studies. We hope it will prove equally useful to the internist evaluating syncope, the cardiologist deciding if a pacemaker is needed during a myocardial infarction complicated by complete heart block, and the electrophysiology fellow learning how to differentiate the various forms of supraventricular tachycardia in the electrophysiology laboratory.

As is true for most fields of medicine there is as much art as there is science in electrophysiology. We and the contributing authors to this book share a common "style" of arrhythmia management and passion for the clinical care of patients with arrhythmia disorders, which we hope will prove helpful to physicians caring for these fascinating patients.

Peter J. Zimetbaum, MD
Mark E. Josephson, MD

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CHAPTER 1

Anatomy in Clinical Electrophysiology

An understanding of cardiac anatomy is essential to the diagnosis and treatment of arrhythmias. This knowledge is required to allow recording of normal and abnormal electrical activity as well as anticipate electrophysiological consequences of various types of cardiac pathology.

RIGHT ATRIUM

Normal electrical activation of the heart begins in the sinus node complex located as a subepicardial structure at the junction of the high right atrium (RA) and the superior vena cava (see Fig. 1-1). The sinus node is a spindle-shaped complex of cells that generally lies in a superior and lateral location in the RA but occasionally extends posteromedially to the interatrial groove. The right phrenic nerve runs in close proximity to the sinus node on the epicardial surface of the RA. The sinus node is supplied by the right coronary artery (RCA) in 60% of patients and left circumflex artery (LCX) in 40% of patients (see Table 1-1). The sinus node is heavily innervated by parasympathetic and sympathetic inputs.

Once the impulse leaves the sinus node it travels inferiorly toward the atrioventricular (AV) node located in the low septal aspect of the RA. Conduction to the left atrium occurs through activation of the coronary sinus (CS) and through a series of fibers called the *Bachmann bundle* that extend from the crest

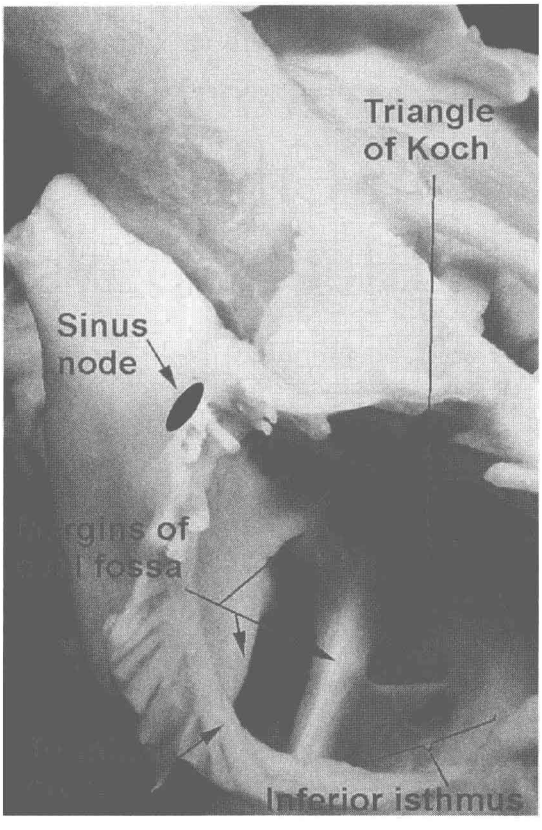

FIGURE 1-1. Right atrium opened, demonstrating the epicardial location of the sinus node in relation to the crista terminalis (terminal crest). The fossa ovalis and triangle of Koch are also demonstrated. (Courtesy Prof RH Anderson) (See color insert.)

TABLE 1-1 Vascular Supply of the Cardiac Conduction System

- Sinoatrial (SA) node: RCA (60%), LCX (40%)
- AV node: RCA (90%), LCX (10%)
- His bundle: RCA with small contribution from septal perforators of LAD
- Main and proximal left bundle branch block (LBBB): LAD (proximal), small collateral contribution from LCX or RCA
- Left anterior fascicle: anterior septal perforator, 50% of population has contribution from AV nodal artery
- Left posterior fascicle: proximal portion—AV nodal artery—distal portion—anterior and posterior septal perforators
- Right bundle branch block (RBBB): anterior septal perforators and collateral flow from RCA and LCX

RCA, right coronary artery; LCX, left circumflex artery, AV, atrioventricular node; LAD, left anterior descending coronary artery.

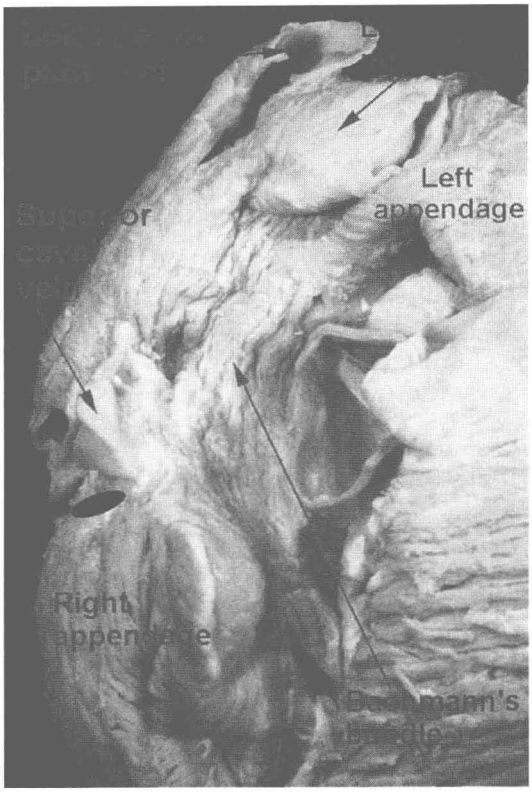

FIGURE 1-2. Right atrium demonstrating the location of the Bachmann bundle. The *blue oval* represents the sinus node. (Courtesy Prof RH Anderson) (See color insert.)

of the right atrial appendage through the transverse sinus behind the aorta and across the interatrial groove toward the left atrial appendage (LAA) (see Fig. 1-2). There is also some activation through the fossa ovalis.

The ostium of the CS lies in an inferior and posterior location in the RA. It forms the base of the triangle of Koch within which lies the compact AV node. The two sides of this triangle which emanate from this base include the septal leaflet of the tricuspid valve (TV) and the tendon of Todoro. The tendon of Todoro is a fibrous structure that forms as an extension of the Eustachian valve of the inferior vena cava and the Thebesian valve of the CS ostium (see Fig. 1-3). This tendon runs septally into the central fibrous body (CFB). The CFB is a confluence of fibrous tissue formed by the connection of the membranous septum with the fibrous trigones. The right and left fibrous trigones represent the areas of thickening at the edges of the connected or shared aspects of the aortic and mitral valves (*anterior* mitral leaflet). The right fibrous trigone connects with the membranous septum to form the CFB. The right coronary cusp of the aortic valve overlies and is continuous with the membranous septum. The noncoronary cusp overlies the right fibrous trigone and the left

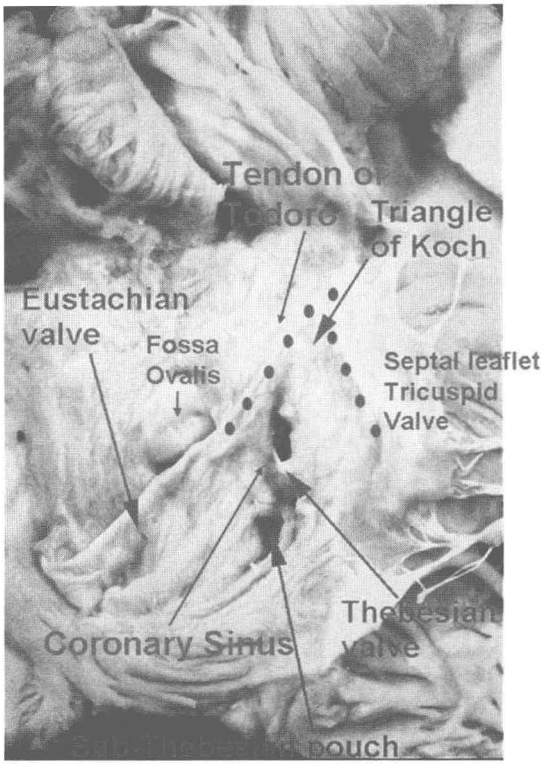

FIGURE 1-3. Demonstration of the boundaries of the triangle of Koch, right atrium, and fossa ovalis. (See color insert.)

coronary cusp overlies the left fibrous trigone. The aortic-mitral curtain is suspended between the trigones and forms the posterior aspect of the aortic outflow tract (see Fig. 1-4).

The fossa ovalis is the rim demarcating closure of the septum secundum and remnant of the septum primum. It is roughly at a 90-degree angle from but at the same level as the AV node/His bundle. The roof of the fossa ovale is formed by a muscular ridge called the *limbus*. Direct placement of a needle through the fossa will lead to the left atrium (Fig. 1-3). Penetration anterior to the fossa will enter the aorta. Penetration posterior and superior to the fossa will enter the invaginated groove or cleft between the right and left atria. This is the space commonly used by surgeons to access the left atrium and mitral valve.

The crista terminalis is a thick fibrous band of tissue that connects the inferior and superior vena cavae. It is located in the posterolateral aspect of the RA and can be identified by characteristic fractionated or split electrical recordings during electrophysiology study. This structure is a particularly common site for the development of atrial tachycardia.

The right atrial appendage is a relatively large structure which lies on the anterolateral surface of the left atrium. As is true of most of the RA it is full

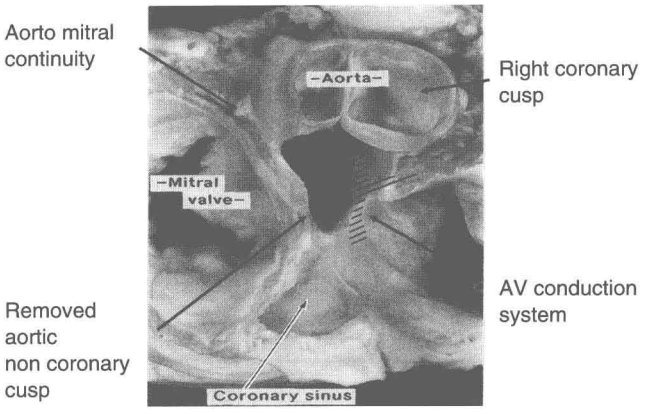

FIGURE 1-4. Cross-section of the heart with the noncoronary cusp of the aortic valve removed. The relationship of the mitral valve, aortomitral continuity, aortic valve, and atrioventricular (AV) conduction system is shown.

of pectinate muscles. The shape of this structure facilitates stable pacemaker lead placement; however, its proximity to the TV sometimes results in "far field" sensing of ventricular electrical activity.

LEFT ATRIUM

The left atrium lies posterior to the RA. Four pulmonary veins (right and left superior and inferior) drain into the posterior aspect of the left atrium. The branching structure and size of these veins can vary greatly (see Fig. 1-5). A series of autonomic ganglia is present around the base of the pulmonary veins. The LAA lies just lateral to the left superior pulmonary vein and is separated from it on the endocardial surface by a thick muscular ridge of tissue. The appendage is composed of pectinate muscles and is the site of most thrombus formation associated with atrial fibrillation. The left phrenic nerve travels along the LAA and down along the obtuse margin of the left ventricle. The surgeon must carefully avoid this structure when placing a left ventricular pacing lead. The left main artery arises from the left coronary cusp between the pulmonary trunk and the LAA with the left circumflex running in close proximity to the LAA and CS.

The AV groove forms the posterior separation of the left atrium and ventricle. The LCX runs in this space, as does the CS. The anatomy of the CS is of particular importance to the electrophysiologist because it is utilized for pacing and recording of electrical activity involving the left side of the heart. Both the left atrium and the left ventricle can be recorded and paced through the CS. The CS runs in the AV groove along with the LCX. The body of the CS typically receives branches, which overlie the left ventricle (see Fig. 1-6). The great cardiac vein or anterior intraventricular vein is the branch which lies in

FIGURE 1-5. Computed tomographic (CT) angiogram of the posterior aspect of the left atrium. (See color insert.)

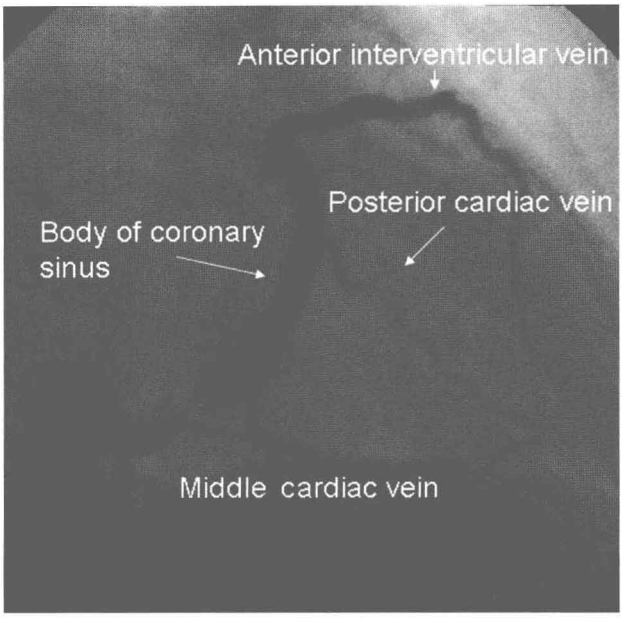

FIGURE 1-6. Right anterior oblique (RAO) coronary sinus venogram demonstrating the major branches of the coronary sinus. The posterior cardiac vein is the preferred target for coronary sinus lead placement.