CATHETER ABLATION OF ATRIAL FIBRILLATION

Edited by
Etienne Aliot
Michel Haïssaguerre
Warren M. Jackman

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Blackwell Futura is an imprint of Blackwell Publishing

Blackwell Publishing, Inc., 350 Main Street, Malden, Massachusetts 02148-5020, USA
Blackwell Publishing Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK
Blackwell Publishing Asia Pty Ltd, 550 Swanston Street, Carlton, Victoria 3053, Australia

First published 2008
1 2008

ISBN: 978-1-4051-6349-1

Library of Congress Cataloging-in-Publication Data

Catheter ablation of atrial fibrillation / edited by Etienne Aliot, Michel Haissguerre, Warren M. Jackman.
p. ; cm.
Includes bibliographical references.
ISBN 978-1-4051-6349-1 (Hbk trade version)
978-1-4051-8665-0 (Customised version, not for trade sale)
1. Catheter ablation. 2. Atrial fibrillation – Surgery. I. Aliot, Etienne. II. Ha?ssaguerre, Michel. III. Jackman, Warren M.
[DNLM: 1. Atrial Fibrillation – surgery. 2. Atrial Fibrillation – therapy. 3. Catheter Ablation – methods. WG 330 C3628 2008]

RD598.35.C39C383 2008
616.1′28–dc22 2007049865

A catalogue record for this title is available from the British Library

Commissioning Editor: Gina Almond
Development Editor: Beckie Brand
Editorial Assistant: Jamie Hartmann-Boyce
Production Controller: Debbie Wyer

Set in 9.5/12 pt Minion by Graphicraft Limited, Hong Kong
Printed and bound in Singapore by Fabulous Printers Pte Ltd

For further information on Blackwell Publishing, visit our website:
www.blackwellcardiology.com

The publisher's policy is to use permanent paper from mills that operate a sustainable forestry policy, and which has been manufactured from pulp processed using acid-free and elementary chlorine-free practices. Furthermore, the publisher ensures that the text paper and cover board used have met acceptable environmental accreditation standards.

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Introduction

Atrial fibrillation (AF) has long been a field for experimental, pharmacological, and clinical investigations. After initial surgical attempts to cure AF using multiple incisions, the observation that the pulmonary veins were mainly involved in the genesis of AF has promoted the use of catheter techniques for curative approaches.

This book provides a collective text that integrates advances in basic and clinical electrophysiology that have emerged in the last 10 years. Our goal is to produce a treatise that electrophysiologists, allied healthcare professionals, and industry personnel will use as a guide to assist in patient care, to stimulate research projects, and to continue the remarkable advances in the treatment of AF.

A major message appears to be the complexity of underlying factors initiating and perpetuating AF, and the need for combined approaches to involve these different mechanisms. Another message is to acknowledge the limitations of present technologies which, despite achieving dramatic termination of most AF, require additional interventions for tissue recovery or new substrate.

The book is divided into several parts. The first part (Chapters 1–7) is devoted to the fundamental concepts of AF, origin of signals, computer simulation, and updated reviews of ablation tools. The anatomy chapter is richly illustrated by numerous high quality images. This information is necessary for appropriate clinical practice. The second part (Chapters 8–12) provides the present practical approaches to the ablation of specific targets in the fibrillating atria including pulmonary veins, fragmented electrograms, and linear lesions and details the strategies in paroxysmal or chronic AF or facing left atrial tachycardias. The final part (Chapters 13–18) addresses the special challenge of heart failure patients, the impact of ablation on mortality, atrial mechanical function, and lessons from surgical AF ablation.

Each chapter is written by experienced and internationally recognized authors, most being the leading experts in this field.

We hope that this book may become a reference text for many and will be followed by future editions to provide up to date information in this rapidly developing area.

Etienne Aliot
Michel Haïssaguerre
Warren M. Jackman

Contents

1

PART 1

Fundamental concepts of atrial fibrillation

CHAPTER 1

Anatomy of the left atrium relevant to atrial fibrillation ablation

José Angel Cabrera, Jerónimo Farré, Siew Yen Ho, & Damián Sánchez-Quintana

Introduction

Atrial fibrillation (AF) is an arrhythmia most likely due to multiple etiopathogenic mechanisms. In spite of a still incomplete understanding of the anatomo-functional basis for the initiation and maintenance of AF, various radiofrequency catheter ablation (RFCA) techniques have been shown to modify the substrate of the arrhythmia and/or its neurovegetative modulators, achieving in a high proportion of cases a sustained restoration of a stable sinus rhythm [1–26]. Catheter ablation techniques in patients with AF have evolved from an initial approach focused on the pulmonary veins (PVs) and their junctions with the left atrium (LA), to a more extensive intervention mainly, but not exclusively, on the left atrial myocardium and its neurovegetative innervation [27–32]. We firmly believe that progress is still required to refine the currently accepted catheter ablation approaches to AF. Because the LA is the main target of catheter ablation in patients with AF, in this chapter we review the gross morphological and architectural features of this chamber and its relations with extracardiac structures. The latter have also become relevant because of some extracardiac complications of AF ablation, such as injuries of the phrenic and vagal plexus nerves, or the devastating left atrioesophageal fistula formation [33–40].

Catheter Ablation of Atrial Fibrillation Edited by Etienne Aliot, Michel Haïssaguerre and Warren M. Jackman
© 2008 Blackwell Publishing, ISBN: 978-1-4501-6349-1.

Components of the left atrium

From a gross anatomical viewpoint the LA has four components: (1) a venous part that receives the PVs; (2) a vestibule that conducts to the mitral valve; (3) the left atrial appendage (LAA); and (4) the so-called interatrial septum. We want to emphasize that the true interatrial septum is the oval fossa, a depression in the right atrial aspect of the area traditionally considered to be the interatrial septum [41–46] (Figures 1.1–1.4). At the left atrial level, a membranous valve covers this region and conceptually represents the only true interatrial septum in the sense that it can be crossed without exiting the heart. The rest of the "muscular interatrial septum" is formed by the apposition of the right and left atrial myocardia that are separated by vascularized fibro-fatty tissues extending from the extracardiac fat. This is why we prefer to use the term *interatrial groove* rather than muscular interatrial septum, a concept that is not only of academic interest because trans-septal punctures to access the LA should be performed through the oval fossa (Figure 1.2). Thus, a puncture throughout the interatrial groove (the muscular interatrial septum)

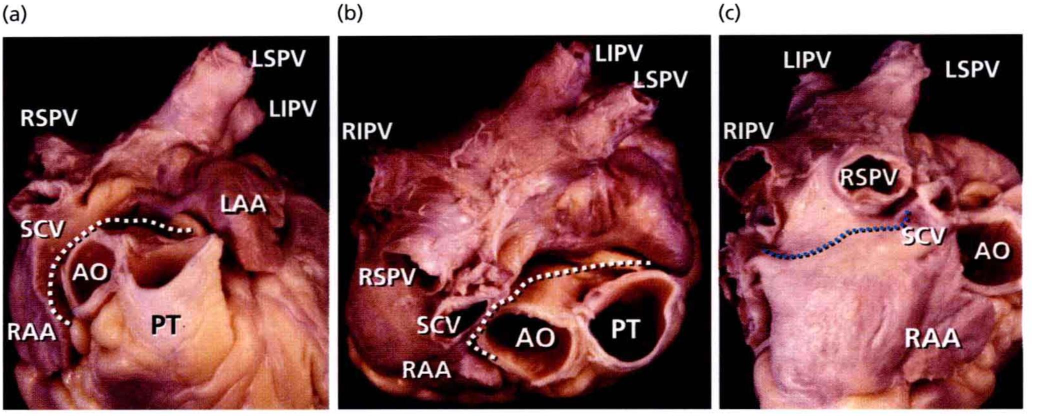

Figure 1.1 External appearances of the right and left atriums viewed from anterior (a), superior (b), and right lateral (c) views. Note the location of the transverse sinus (white dotted lines) and its relationship to the aorta and atrial walls (a, b). The superior and posterior walls of the LA were anchored by the entrance of one PV at each of the four corners. (c) Site of the interatrial groove (Waterston's groove, blue dotted line). AO, aorta; LAA, left atrial appendage; LIPV, left inferior pulmonary vein; LSPV, left superior PV; PT, pulmonary trunk; RAA, right atrial appendage; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein; SCV, superior caval vein.

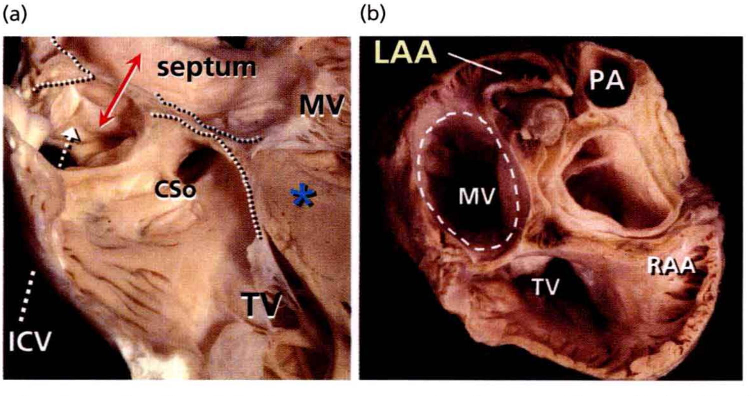

Figure 1.2 (a) Four-chamber section through the heart showing the offset arrangement of the mitral valve (MV) and tricuspid valve (TV) which produces the so-called muscular atrioventricular septum (*) and the deep infolding of the atrial wall superior to the floor of the oval fossa (dotted lines). The true septal area is considerably smaller. (b) The cardiac base (short axis) is dissected by removing most of the atrium's aspects. The right pectinate muscles skirt around the vestibule of the right atrium and reach the orifice of the coronary sinus. Note that the pectinate muscles in the LA are limited mostly within the appendage and the dotted line marking the vestibule of the mitral annulus. CSo, coronary sinus orifice; ICV, inferior caval vein; LAA, left atrial appendage; PA, pulmonary artery; RAA, right atrial appendage.

may result in hemopericardium in a highly anticoagulated patient because blood will dissect the vascularized fibro-fatty tissue that is sandwiched between the right and left atrial myocardium at this level [47–49].

The major part of the endocardial LA including the septal and interatrial groove component is relatively smooth walled. The left aspect of the interatrial groove, apart from a small crescent-like edge, is almost indistinguishable from the parietal atrial wall. The smoothest parts are the superior and posterior walls, which make up the pulmonary venous component, and the vestibule surrounding the mitral orifice. Behind the posterior portion of

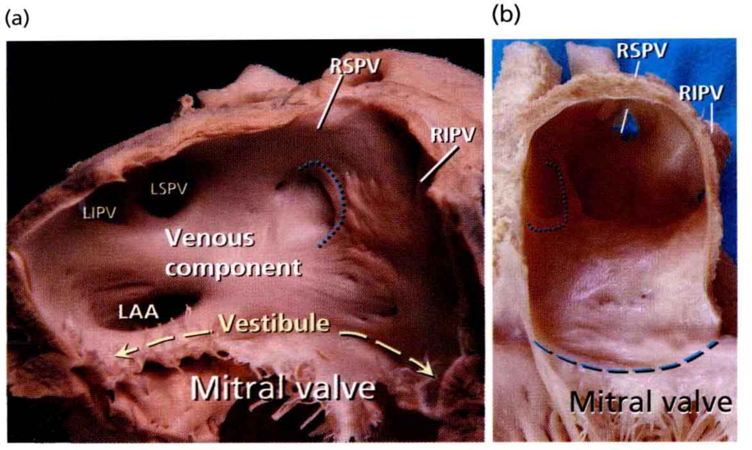

Figure 1.3 (a) Dissection of the posterior wall of the LA close to Waterston's groove. The smooth-walled venous component of the LA is the most extensive. The septal aspect of the LA shows the crescentic line of the free edge (dotted line) of the flap valve against the rim of the oval fossa. (b) The orifices of the right superior and inferior pulmonary veins (RSPV and RIPV) are adjacent to the plane of the septal aspect of the LA (dotted line). The dashed blue line marks the hinge of the mitral valve. LAA, left atrial appendage; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein.

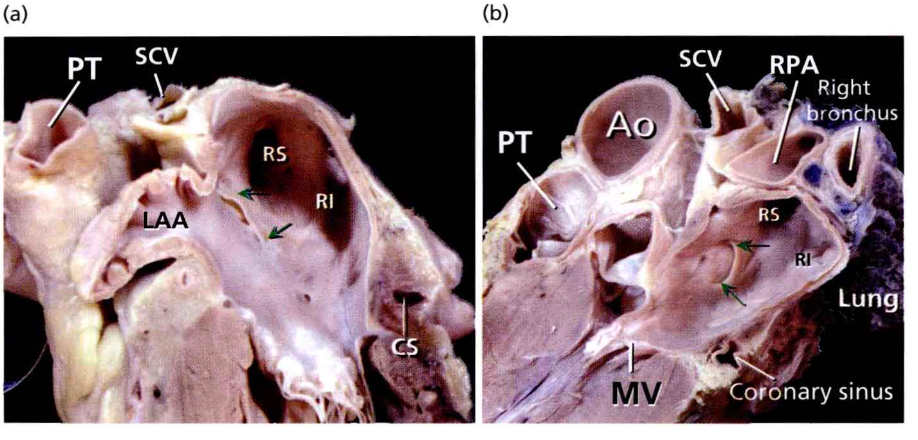

Figure 1.4 Longitudinal sections through the left atrial appendage (LAA) showing the orifices of the right PV; the flap valve of the oval fossa overlaps (arrows) the rim to form the septal aspect of the LA. Note the relation of the superior caval vein (SCV) to the right superior pulmonary vein (RS). (b) Longitudinal section to show the relationship of the roof of the left atrium with the right pulmonary artery (RPA) and right bronchus. Ao, aorta; CS, coronary sinus; MV, mitral valve; PT, pulmonary trunk; RI, right inferior pulmonary vein; RS, right superior pulmonary vein.

the vestibular component of the LA is the anterior wall of the coronary sinus [41] (Figures 1.3 and 1.4).

The walls of the left atrium and the septum

The left atrial wall and its thickness

The walls of LA, excluding the LAA, can be described as anterior, superior, left lateral, septal, and posterior. The anterior wall is located behind the ascending aorta and the transverse pericardial sinus. From epicardium to endocardium its width is 3.3 ± 1.2 mm (range 1.5–4.8 mm) in unselected necropsic heart specimens, but this wall can become very thin at the area near the vestibule of the mitral annulus where it measures an average of 2 mm in thickness in our autopsy studies. The roof or superior wall of the LA is in close proximity to the right pulmonary artery and its width ranges from 3.5 to 6.5 mm (mean 4.5 ± 0.6 mm). The thickness of the lateral wall ranges between 2.5 and 4.9 mm (mean 3.9 ± 0.7 mm) [41].

As already stated, an anatomic septum is like a wall that separates adjacent chambers so that perforation of a septal wall would enable us to enter from a chamber to the opposite one without exiting the heart. Thus, the true atrial septal wall is confined to the flap valve of the oval fossa. The flap valve is hinged from the muscular rim that, deriving from the septum secundum, is seen from the right atrial aspect of the interatrial wall. At its anteroinferior portion the rim separates the foramen ovale from the coronary sinus and the vestibule of the tricuspid valve [48] (Figure 1.2). On the left atrial aspect there is no visible rim and the flap valve overlaps the oval rim quite considerably and two horns mark the usual site of fusion with the rim (Figure 1.3 and 1.4). The measurement of the mean thickness of the atrial septum in normal hearts at the level of the anteroinferior portion of the muscular rim is 5.5 ± 2.3 mm, and the mean thickness of the flap valve is 1.5 ± 0.6 mm [41]. These results agree with previously published echocardiographic studies [50]. The major portion of the rim around the fossa is an infolding of the muscular atrial wall that is filled with epicardial fat. Superiorly and posteriorly there is an interatrial groove, also known as Waterston's groove, whose dissection permits the separation of the right and left atrial myocardial walls and to enter the LA without transgressing into the right atrium. Anteriorly and inferiorly, the rim and its continuation into the atrial vestibules overlies the myocardial masses of the ventricles from which they are separated by the fat-filled inferior pyramidal space [48,51] (Figures 1.2–1.4).

The posterior wall of the LA is a target of currently used ablation procedures in patients with AF. Early surgical interventions aimed at reducing the critical mass of atrial tissues created long transmural linear lesions incorporating the posterior LA wall. The posterior wall of the LA is related to the esophagus and its nerves (vagal nerves) and the thoracic aorta, and its inferior portion is related to the coronary sinus. In a previous study in 26 unselected human heart specimens the overall thickness of the posterior LA wall was 4.1 ± 0.7 mm (range 2.5–5.3 mm) [41]. In a subsequent study we measured the thickness of the posterior wall from the epicardium to endocardium, obtaining sagittal and transverse sections through the LA at three levels (superior, middle, and inferior close to the coronary sinus) in three different LA regions (right venoatrial junction, mid-posterior atrial wall, and left venoatrial junction) [52]. We also analyzed the myocardial content of the LA wall at all these predefined sites. The region with the thickest myocardial content was the mid-posterior LA wall (2.9 ± 0.5 mm, range 0.6–4.2 mm). The inferior level, immediately superior to the coronary sinus and between 6 and 15 mm from the mitral annulus, had the thickest posterior LA wall (6.5 ± 2.5 mm, range 2.8–12 mm). The latter thickness was due to a rather bulky myocardial layer (4.3 ± 0.8 mm) and the presence of a profuse amount of fibro-fatty tissue, both components being less developed at more superior levels of the posterior LA wall. The wall at the plane of the right or left venoatrial junction had the thinnest musculature (2.2 ± 0.3 mm, range 1.2–4.5 mm) and a very scanty content of fibro-fatty tissue [52]. In some samples of histological sections obtained at the PV and posterior atrial wall, the myocardial layer had small areas of discontinuities that were filled with fibrous tissue [42,53].

The myoarchitecture of the left atrial wall

Detailed dissections of the subendocardial and subepicardial myofibers along the entire thickness of the LA walls have shown a complex architecture of overlapping bands of aligned myocardial bundles [41,51] (Figures 1.5 and 1.6). The term "fibers" describes the macroscopic appearance of strands of cardiomyocytes. These fibers are circumferential when they run parallel to the mitral annulus and longitudinal when they are approximately perpendicular to the mitral orifice. Although there are some individual variations, our epicardial dissections of the LA have shown a predominant pattern of arrangement of the myocardial fibers [41]. On the subepicardial aspect of the LA, the fibers in the anterior wall consisted of a main bundle that was parallel to the atrioventricular groove. This was the continuation of the interatrial bundle (Bachmann's bundle) [54], which could be traced rightward to the junction between the right atrium and the superior caval vein. In the LA, the interatrial bundle