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Giuseppe Bagliani, Fabio M. Leonelli, and Roberto De Ponti

The History of Atrial Flutter Electrophysiology, from Entrainment to Ablation: A 100-Year Experience in the Precision Electrocardiology **357**

Giuseppe Bagliani, Roberto De Ponti, Fabio M. Leonelli, Michela Casella, Gemma Gaggiotti, Giovanni Volpato, Paolo Compagnucci, and Antonio Dello Russo

Atrial flutter (AFL) is a regular supraventricular reentrant tachycardia generating a continuous fluttering of the baseline electrocardiography (ECG) at a rate of 250 to 300 beats per minute. AFL is classified based on the involvement of the cavo-tricuspid isthmus in the circuit. The “isthmic” (or type 1) AFL develops entirely in the right atrium; this circuit is commonly activated in a counter-clockwise direction, generating the common sawtooth ECG morphology in the inferior leads (slow descendent–fast ascendent). AFL can be nonisthmus dependent (type 2), often presenting with faster atrial rate and most commonly a left atrial location.

Normal and Abnormal Atrial Anatomy Relevant to Atrial Flutters: Areas of Physiological and Acquired Conduction Blocks and Delays Predisposing to Re-entry **375**

S. Yen Ho

This article reviews the structure of the atrial chambers to consider the anatomic bases for obstacles and barriers in atrial flutter. In particular, the complex myocardial arrangement and composition of the cavotricuspid isthmus could account for a slow zone of conduction. Prominent muscle bundles within the atria and interatrial, and myoarchitecture of the walls, could contribute to preferential conduction pathways. Alterations from tissue damage as part of aging, or from surgical interventions could lead to re-entry.

Electrocardiographic Approach to Atrial Flutter: Classifications and Differential Diagnosis **385**

Giuseppe Bagliani, Fabio M. Leonelli, Roberto De Ponti, Michela Casella, Francesca Massara, Paolo Tofoni, Federico Guerra, Giuseppe Ciliberti, and Antonio Dello Russo

Atrial flutter (AFL) is a macro-reentrant arrhythmia characterized, in a 12 lead ECG, by the continuous oscillation of the isoelectric line in at least one lead. In the typical form of AFL, the oscillation is most obvious in the inferior leads, due to a macro-reentrant circuit localized in the right atrium, with the cavo-tricuspid isthmus as a critical zone.: This circuit can be activated in a counterclockwise or clockwise direction generating in II, III, and aVF leads, respectively, a slow descending/fast ascending F wave pattern (common form of typical AFL) or a balanced ascending/descending waveform (uncommon form of typical AFL). Atypical AFLs (scar-related) do not include the CTI in the circuit and show an extremely variable circuit location and ECG morphology.

Pathophysiology of Typical Atrial Flutter 401

Yari Valeri, Giuseppe Bagliani, Paolo Compagnucci, Giovanni Volpato, Laura Cipolletta, Quintino Parisi, Agostino Misiani, Marco Fogante, Silvano Molini, Antonio Dello Russo, and Michela Casella

Nowadays, the pathophysiology mechanism of initiation and maintenance of reentrant arrhythmias, including atrial flutter, is well characterized. However, the anatomic and functional elements of the macro reentrant arrhythmias are not always well defined. In this article, we illustrate the anatomic structures that delineate the typical atrial flutter circuit, both clockwise and counterclockwise, paying attention to the inferior vena cava-tricuspid isthmus (CTI) and crista terminalis crucial role. Finally, we describe the left atrial role during typical atrial flutter, electrophysiologically a by-stander but essential in the phenotypic electrocardiogram (ECG).

Pathophysiology of Atypical Atrial Flutters 411

Jacopo Marazzato, Raffaella Marazzi, Lorenzo Adriano Doni, Federico Blasi, Fabio Angeli, Giuseppe Bagliani, Fabio M. Leonelli, and Roberto De Ponti

Atypical atrial flutters are complex supraventricular arrhythmias that share different pathophysiological aspects in common. In most cases, the arrhythmogenic substrate is essentially embodied by slow-conducting areas eliciting re-entrant circuits. Although atrial scarring seems to promote slow conduction, these arrhythmias may occur even in the absence of structural heart disease. To set out the ablation strategy in this setting, three-dimensional mapping systems have proved invaluable over the last decades, helping the cardiac electrophysiologist understand the electrophysiological complexity of these circuits and easily identify critical areas amenable to effective catheter ablation.

Relationships Between Atrial Flutter and Fibrillation: The Border Zone 421

Ritesh S. Patel, Mohamed Khayata, Roberto De Ponti, Giuseppe Bagliani, and Fabio M. Leonelli

Atrial flutter and fibrillation have been inextricably linked in the study of electrophysiology. With astute clinical observation, advanced diagnostic equipment in the Electrophysiology Laboratory, and thoughtful study of animal models, the mechanism and inter-relationship between the 2 conditions have been elucidated and will be reviewed in this article. Though diagnosis and management of these conditions have many similarities, the mechanisms by which they develop and persist are quite unique.

Interpretation of Typical and Atypical Atrial Flutters by Precision Electrocardiology Based on Intracardiac Recording 435

Fabio M. Leonelli, Roberto De Ponti, and Giuseppe Bagliani

Atrial flutter is a term encompassing multiple clinical entities. Clinical manifestations of these arrhythmias range from typical isthmus-dependent flutter to post-ablation microreentries. Twelve-lead electrocardiogram (ECG) is a diagnostic tool in typical flutter, but it is often unable to clearly localize atrial flutters maintained by more complex reentrant circuits. Electrophysiology study and mapping are able to characterize in fine details all the components of the circuit and determine their electrophysiological properties. Combining these 2 techniques can greatly help in understanding the vectors determining the ECG morphology of the flutter waveforms, increasing the diagnostic usefulness of this tool.

Typical Atrial Flutter Mapping and Ablation 459

Francesco Notaristefano, Gianluca Zingarini, Claudio Cavallini, Giuseppe Bagliani, Roberto De Ponti, and Fabio M. Leonelli

Isthmus-dependent flutter represents a defeated arrhythmia. Possibly one of the most outstanding successes in terms of understanding the mechanism behind it has led to an effective, relatively simple, and safe targeted therapy. Technology, fulfilling a number of the clinical electrophysiologist's dreams, has linked diagnosis and therapy in computerized systems showing real-time imagines of the right atrium, the arrhythmia circuit, and the ablation target. The entire history of clinical electrophysiology is contained in its path and atrial flutter needs to be regarded with immense respect for a large amount of knowledge that its study always engenders.

Mapping and Ablation of Atypical Atrial Flutters 471

Jacopo Marazzato, Raffaella Marazzi, Lorenzo A. Doni, Fabio Angeli, Giuseppe Bagliani, Fabio M. Leonelli, and Roberto De Ponti

Atypical atrial flutters are complex, hard-to-manage atrial arrhythmias. Catheter ablation has progressively emerged as a successful treatment option with a remarkable role played by irrigated-tip catheters and 3D electroanatomic mapping systems. However, despite the improvement of these technologies, the ablation results may be still suboptimal due to the progressive atrial substrate modification occurring in diseased hearts. Hence, a patient-tailored approach is required to improve the long-term success rate in this scenario, aiming at achieving specific procedure end points and detecting any potential arrhythmogenic substrate in each patient.

Atypical Cases of Typical Atrial Flutter? A Case Study 483

Roberto De Ponti, Jacopo Marazzato, Fabio Angeli, Manola Vilotta, Federico Blasi, Giuseppe Bagliani, Fabio M. Leonelli, and Raffaella Marazzi

Ablation of typical atrial flutter has a high safety and efficacy profile, but hidden pitfalls may be encountered. In some cases, a longer cycle length with isoelectric lines is associated with a different or more complex arrhythmogenic substrate, which may be missed if conduction block of the cavotricuspid isthmus is performed in the absence of the clinical arrhythmia. Prior surgery may have consistently modified the atrial substrate and complex or multiple arrhythmias associated with an isthmus-dependent circuit can be encountered. In these cases, electroanatomic mapping is useful to guide the procedure and plan an appropriate ablation strategy.

Atrial Flutter in Pediatric Patients 495

Fabrizio Drago and Pietro Paolo Tamborrino

Atrial flutter (AFL) in pediatric patients is a rare condition as the physical dimensions of the immature heart are inadequate to support the arrhythmia. This low incidence makes it difficult for patients in this particular setting to be studied. AFL accounts for 30% of fetal tachyarrhythmias, 11% to 18% of neonatal tachyarrhythmias, and 8% of supraventricular tachyarrhythmias in children older than 1 year of age. Transesophageal overdrive pacing can be used, instead, with lower success rate (60%–70%). The recommended drugs are digoxin which can decrease the ventricular rate until the spontaneous interruption of the AFL. Digoxin can be combined with flecainide or amiodarone in case of failure.

Atrial Flutters in Adults with Congenital Heart Disease **501**

Alessandro Capestro, Elli Soura, Paolo Compagnucci, Michela Casella, Raffaella Marzullo, and Antonio Dello Russo

The macroreentrant atrial tachycardia is very frequent in the adults with congenital heart disease. The impact of the arrhythmias on this type of patients is related to several factors: the anatomy and physiopathology of the specific congenital heart disease (CHD), the sequelae of the corrective surgery or surgical palliation, the presence of residual lesions (shunt, regurgitation), and the age and the clinical status of the patient and the comorbidities. In turn, the mechanism of the MAT depends on the peculiar features of the conduction's system in the CHD and native and acquired (post-surgery) substrates.

Atrial Flutter in Particular Patient Populations **517**

Paolo Compagnucci, Michela Casella, Giuseppe Bagliani, Alessandro Capestro, Giovanni Volpato, Yari Valeri, Laura Cipolletta, Quintino Parisi, Silvano Molini, Agostino Misiani, and Antonio Dello Russo

Despite being one of the best understood cardiac arrhythmias, the clinical meaning of atrial flutter varies according to the specific context, and its optimal treatment may be limited by both the suboptimal response to rate/rhythm control drugs and by the complexity of the underlying substrate. In this article, we present a state-of-the-art overview of mechanisms, prognostic impact, and medical/interventional management options for atrial flutter in several specific patient populations, including heart failure, cardiomyopathies, muscular dystrophies, posttransplant patients, patients with respiratory disorders, athletes, and subjects with preexcitation, aiming to stimulate further research in this challenging field and facilitate appropriate patient care.

Antiarrhythmic Drug Therapy in the Treatment of Acute and Chronic Atrial Flutter **533**

Martina Amadori, Antonio Rapacciuolo, and Igor Diemberger

In the present article, we will focus on the pharmacologic treatment of atrial flutter aimed either at restoring/maintaining sinus rhythm or controlling the ventricular response during tachyarrhythmia. To provide a comprehensive description we will start discussing the electroanatomic substrate underlying the development of atrial flutter and the complex relationship with atrial fibrillation. We will then describe the available drugs for the treatment of atrial flutter on the bases of their electrophysiological effects and data from available clinical studies. We will conclude by discussing the general principles of rhythm and rate control treatment during atrial flutter.