Present Status and Future Concepts for Arrhythmia Treatment with Implantable Devices

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Introduction

Since the first implantation of an cardioverter/defibrillator in 1980 [12], ICD therapy has seen a rapid development that is based on new therapeutic concepts and technological progress. Up to the early nineties, the predominant goal was the prevention of sudden cardiac death in patients with life-threatening ventricular tachyarrhythmias with the highest possible efficacy. Since then, the optimization of therapy efficiency and the improvement of the quality of life of the patients have become more and more important. In the following paragraphs, I want to focus onto the latter aspects in the management of malignant cardiac arrhythmia. Progress in improvement of therapy efficiency and quality of life is being achieved by reducing the defibrillation threshold and by using antitachycardia pacing and dual chamber antitachycardia therapy. The logical extension of present concepts for the treatment of cardiac arrhythmia consists in a preventive closed loop therapy. This idea comprises recognition of precursor states of arrhythmias and application of specific therapy that is controlled by the effect it exerts onto the arrhythmogenic substrate.

,Role of the lead in defibrillation

From the very beginning, the lead concept played a crucial role for the development of ICD therapy because it largely determines the efficiency of the energy transfer from the device to the myocardium. Today, it is well appreciated that defibrillation requires the development of an adequate voltage gradient throughout a critical volume of the myocardium in order to excite the tissue and interrupt the multiple wavelets that sustain fibrillation [10][17][20]. It is obvious that the design of the electrode surface has to ensure that the voltage drop across the phase boundary is minimized. Theoretical considerations suggested to enlarge the active surface area by a fractal coating to achieve this goal, and indeed clinical results confirm the validity of this approach [5]. From a geometric point of view ideal electrode configuration should provide a uniform field distribution throughout the myocardium. The realization of this goal lead to the use of epicardial patch electrodes in the first ICDs. However, the perioperative mortality and morbidity associated with epicardial electrodes favored the usage of transvenous leads with one shock coil in the right ventricle and the second shock coil in the superior vena cava in spite of the apparently inhomogeneous field distribution [15]. The availability of devices that are small enough for implantation in a pectoral position enabled an important improvement: A unipolar configuration with the use of a right ventricular shock coil and the housing as active electrodes enabled a more homogeneous defibrillation field and reduced defibrillation thresholds to mean values below 10 J [5]. However, this configuration is still not ideal with respect to the left ventricle. The establishment of a sufficient potential gradient in this region requires from a model point of view an excess voltage gradient throughout the right ventricle. My personal experiences with low-energy defibrillation indicate that this shortcoming may be solved by introducing a transvenous lead via the coronary sinus in a suitable coronary vein. Inclusion of an electrode position in close vicinity of the left ventricle avoids the nonuniformity associated with a exclusively right ventricular electrode position and thus is expected to further reduce the defibrillation threshold by at least 2 J.

Avoid shock delivery – antitachycardia pacing

Current efforts to improve ICD therapy focus on avoiding shock delivery whenever possible. The inclusion of antitachycardia pacing into the first 3rd generation

ICDs in 1993 enabled for the first time an automatic non-shock treatment of recurrent sustained ventricular tachyarrhythmias [3][16] by the implantable defibrillator. This approach is based on the pioneering work of Wellens [18] and Josephson [7] who showed that sustained ventricular tachyarrhythmias can be safely and reproducibly terminated by programmed electrical stimulation of the heart in the catheterization laboratory. Antitachycardia pacing treats successfully between 80 and 90 % of the VT episodes detected by the implantable cardioverter defibrillator (confer paper of Strasberg and Kusniec in this issue of PBMR). Thus, the therapy efficiency is enhanced by avoiding shock induced damage to the myocardium and reducing the energy consumption of the device. The patients, of course, benefits from every single shock that may be avoided since any shock release and particularly the permanent immanence of a shock delivery substantially limits his quality of life. It is generally accepted that the risk associated with acceleration of the arrhythmia and prolonged therapy duration may be safely controlled by limiting the maximum number of subsequent ATP deliveries.

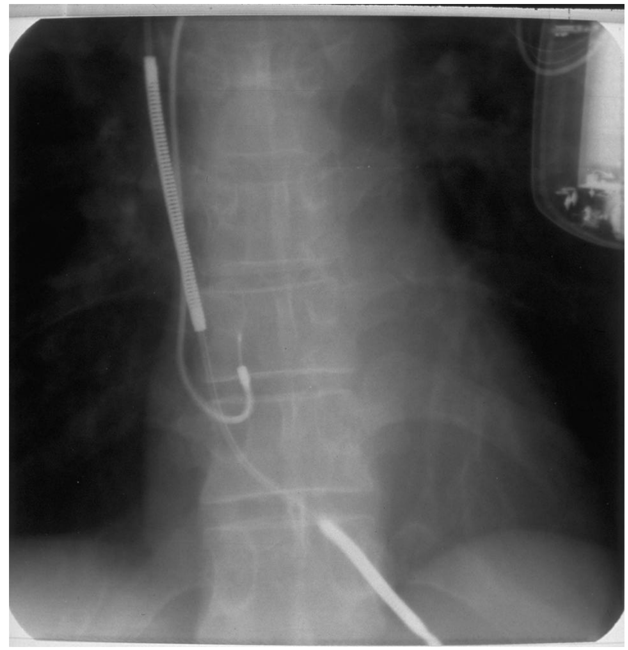

Figure 1. Lead configuration of DDD controlled ICD.

Extension to atrial therapy

Being aware of the shortcomings of a ventricular-only ICD, it was my strong personal concern from my very earliest experiences with ICD therapy to extend detection and therapy delivery to the atria. Consequently, I committed myself to the development of a device providing AV discrimination and full atrial therapy resulting in the first implantation of a DDD controlled cardioverter/defibrillator in April 1996. The Phylax AV (BIOTRONIK) for the first time closed the gap of atrial sensing and pacing. This is the prerequisite for an algorithm for AV discrimination based on analysis of PP, PR and RR intervals and their stability. It overcomes the lack of specificity of detection in ventricular-only ICDs which leads to approximately one third of inappropriate shock deliveries [4][5]. The basic idea for the SMART algorithm was a very simple assumption: the chamber with the higher rate is the origin of the arrhythmia. The subtle problems involved in the case of equal atrial and ventricular rates require analysis of the stability of the respective intervals. To overcome the most challenging case, the discrimination between retrograde conducted VT versus supraventricular tachycardia, the use of an active discrimination method was investigated. It consists in applying ventricular stimulation at slightly decreasing coupling intervals. My results show, that the resulting shortening of the PP intervals in the case of ventricular origin of the arrhythmia provides excellent detection specificity without reducing sensitivity. The first Phylax AV where this active discrimination method is implemented was implanted at the Bakoulev Institute in April 1998 in two patients (confer paper of Revisvili in this issue of PBMR).

This device furthermore offers full atrial therapy and thus is very close to my vision of a tiered therapy dual chamber ICD for the treatment of concurrent atrial and ventricular arrhythmias as it is required in 10 to 35 % of patients [14]. Atrial antitachycardia pacing and atrial defibrillation enable specific and reliable therapy of supraventricular arrhythmias. In particular, the delay between detection of atrial fibrillation and therapy delivery may be reduced distinctly. Therefore, atrial remodeling [9] and thromboembolic risk associated with sustained fibrillation are reduced by prompt therapy delivery.

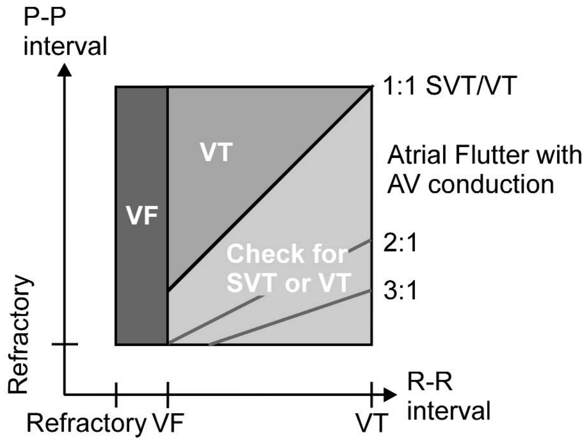

Figure 2. The diagramme schematically visualizes the SMART algorithm.

The biggest potential for further progress in arrhythmia therapy will certainly stem from the maintenance of an appropriate heart rate that takes into account balance of the cardiovascular system. Especially, in patients with

required cardiac output has to be provided with opti mal efficiency. The detrimental effect of VVI stimula tion on the cardiac output has been shown as early as

AV synchronous pacing increases the cardiac output
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Furthermore, it is generally appreciated that DDD
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associated with a loss of atrioventricular synchrony

AV synchronous pacing are perceived in the most

versus AAI/DDD pacing are considered: Witte et al.

the survival rate after 8 years of follow-up was 79 % in

Therefore, the availability of DDD pacing in implanta ble cardioverter/defibrillators is an important step

improved quality of life.

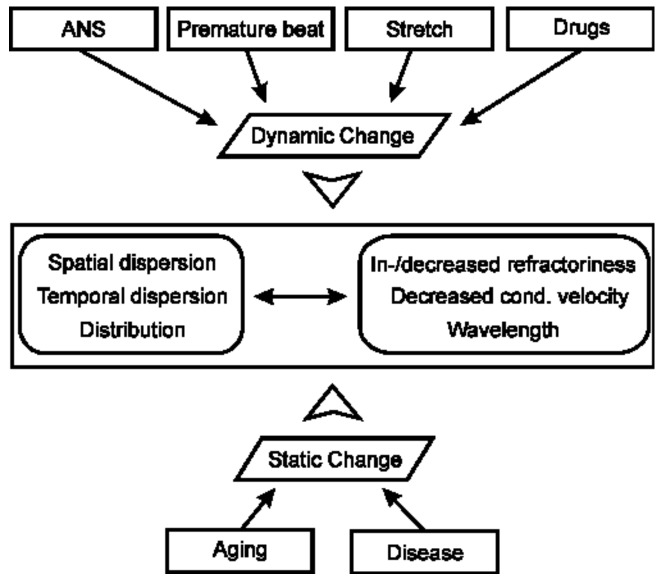

Figure 3. Factors that lead to changes in the electrophysiologic or structural properties predisposing the substrate for reentry tachycardia genesis (Modified after [11]).

ed to anomalies in the repolarization behavior and in the conduction velocity of electrical excitation propa gation through the heart. Simultaneous stimulation of right and left atrium using a coronary sinus electrode
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lation in patients with interatrial conduction block

A more generalized approach will have to include in addition to this example of a static change in substrate

arrhythmias. The fluctuations of autonomic tone have been recognized since long to be deeply involved into

exerts a protective influence in diseased hearts, howe-

tion has been observed [1][2]. New concepts for pre-

character of the mechanisms of arrhythmia genesis. This means that they have to provide dynamic thera peutic interventions that adapt strength and duration immediately to the acute state of the cardiovascular

monitor the state of the cardiovascular system by sui-

total atrial activation time, ...) or signals (MAP, VER, AER, ...). I believe that the realization of this concept of preventive closed loop therapy will reduce the necessity to terminate running arrhythmias drastically. Thus, future antiarrhythmia devices will resemble more to a cardiac pacemaker than to those cardioverter defibrillators known today.

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