

Dual Chamber Antitachycardia Cardioverter Defibrillators. Another Step for the Treatment of High Risk Patients

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The implantable antitachycardia cardioverter defibrillators (IACD) are devised for the prophylaxis of high risk patients, aiming mainly at the abortion of sudden cardiac death (SCD), due to unexpected invasion of sustained ventricular tachyarrhythmias, more specifically sustained ventricular tachycardia degenerated to ventricular fibrillation or primary ventricular fibrillation¹⁻⁵. A series of recent studies regarding primary and secondary prevention of SCD with the implantation of these life saving devices have established their ability to extend patient survival⁶⁻¹¹. Thus, among the candidate patients for the implantation of an IACD, apart from those who survived one or more episodes of sustained ventricular tachyarrhythmias that could not pharmacologically controlled in the Electrophysiology Laboratory (secondary prevention), the candidates list also includes high risk cardiac patients with potentially lethal ventricular arrhythmias, i.e. complex ventricular arrhythmias in the form of pairs or bursts of non-sustained ventricular tachycardia, before they develop lethal ventricular arrhythmias or SCD (primary prevention)^{12,13}. In the latter patients, detailed risk stratification is required that includes invasive and non-invasive diagnostic techniques. Post-infarction patients with left ventricular dysfunction are well researched, while studies regarding patients with dilated or idiopathic hypertrophic cardiomyopathy

or arrhythmogenic cardiomyopathy of the right ventricle are still under way¹⁴⁻¹⁹. The importance of risk stratification in post-infarction and non post-infarction patients is rendered obvious when survival curves of high risk patients in whom IACD was implanted for primary prevention of SCD are analysed^{6-10,13}. Such patients present a considerably more favorable long term survival as compared to patients in whom an IACD was implanted for secondary prevention of SCD¹³. The advantage of an IACD versus the most optimal antiarrhythmic, empirically or not, pharmaceutical treatment (mainly amiodarone or sotalol) regarding protection from SCD in post-infarction patients with lethal or potentially lethal ventricular arrhythmias was also illustrated in the above mentioned studies. This excludes the pharmaceutical antiarrhythmic treatment in daily clinical practice. On the contrary, the combination of pharmaceutical treatment and IACD protection is likely to improve the survival curve of such high-risk patients even further, as compared to the results of randomized studies that compared the two methods¹³. Another limitation factor in the use of this new cardiological intervention is the appearance of complications in both the peri-operative period of implantation and the long-term follow-up^{13,20}. While such factors have been considerably limited as compared to morbidity and mortality during the period of cardiosurgical

implantation, such complications still exist despite the almost exclusively transvenous implantation by interventional electrophysiologists. Due to the larger size and weight of the implanted devices as well as to the more demanding implantation technique, such complications are more frequent than in antibradycardia pacemaker implantations and may lead to immediate or later complication in percentages respective to the antibradycardia pacemaker implantations during the first decade of their use. Apart from the favorable results of large multicenter randomized studies of SCD prevention, the rapid technological development of available defibrillating systems²¹ also significantly contributed to the continuously increasing use of IACDs today. Thus, apart from the decreased size and weight of devices, defibrillators had a fascinating course over the last twenty years, starting with the first generation defibrillators with a limited capability of defibrillation only, proceeding to the second generation ones with the addition of single chamber ventricular pacing, to the 3rd generation and its capability of interrupting sustained ventricular tachycardia with antitachycardia pacing and finally to the 4th generation defibrillators with dual chamber systems of antibradycardia and antitachycardia pacing.

Indeed, the introduction of the 4th generation dual chamber atrioventricular defibrillators constitutes an important technological achievement of the last 4 years in the more accurate treatment of life-threatening ventricular tachyarrhythmias^{20,22,23}. In fact, the administration of inappropriate electrical treatments, either in the form of antitachycardia pacing or defibrillation discharges, during periods of falsely-diagnosed ventricular tachyarrhythmia, when the clinical arrhythmia was in fact supraventricular, was not uncommon during the long-term follow-up of patients with single chamber defibrillators²⁴.

The problem of IACD inappropriate activation

The possibility of a patient with implantable single chamber ventricular defibrillator to receive an unnecessary electrical intervention is estimated to exceed 30%, during long-term follow-up^{20,24}. Apart from the unpleasant feeling of the defibrillation discharge, the patient is also at risk of a proarrhythmic complication, as electrical intervention can convert a supraventricular tachycardia to sustained ventricular tachyarrhythmia²⁵. The more common forms of supraventricular arrhythmias that are likely to deceive

a 3rd generation defibrillator are sinus tachycardia and atrial fibrillation. Apart from these, atrial flutter, atrial tachycardia and tachycardias from reentry to the AV node or through a concealed AV bundle, constitute potential causes of inappropriate activation of a single chamber implantable antitachycardiac cardioverter defibrillator (IACD). Before the introduction of dual chamber IACDs, the problem was partially solved with the invention of more precise recognition algorithms that require stricter criteria, than that of frequency, for the diagnosis of ventricular tachyarrhythmias. Thus, criteria such as the stability of RR intervals during tachycardia, sudden onset of arrhythmia and change of intraventricular electrogram morphology during tachycardia have contributed to the problem²⁶. Nevertheless, such criteria may also be satisfied in supraventricular tachyarrhythmias with stable ventricular response and sudden onset. The problem is greater in patients with coexisting history of supraventricular tachycardias that receive IACD for primary prevention of sudden cardiac death. In these patients, due to the absence of clinical history of ventricular tachyarrhythmias, it is imperative to know that the electrical treatment was administered for ventricular tachyarrhythmia and not for coexisting supraventricular tachyarrhythmia (Figure 1). Apart from the immediate unpleasant consequences of improper electrical intervention, more important questions regarding the long-term pharmaceutical antiarrhythmic treatment of such patients arise. The precise extent to which the above mentioned algorithms of ventricular tachyarrhythmia recognition in 3rd generation single chamber IACD have limited the clinical problem, is unknown, as well designed clinical studies are absent.

Advantages and capabilities of 4th generation dual chamber IACDs

The addition of atrial electrode to dual chamber IACDs gives the possibility of permanent atrial activity detection. Thus, in cases of atrioventricular dissociation and provided the ventricular frequency is higher than the atrial, the diagnosis of ventricular tachycardia is safe (Figure 2). On the contrary, atrial fibrillation or atrial flutter are more likely when atrial frequency exceeds the ventricular and atrioventricular dissociation coexists. (Figure 3).

Of course, in such cases, the challenge lies in the exceptionally rare cases, where paroxysmal atrial and ventricular tachyarrhythmia coexist (Figure 4). In

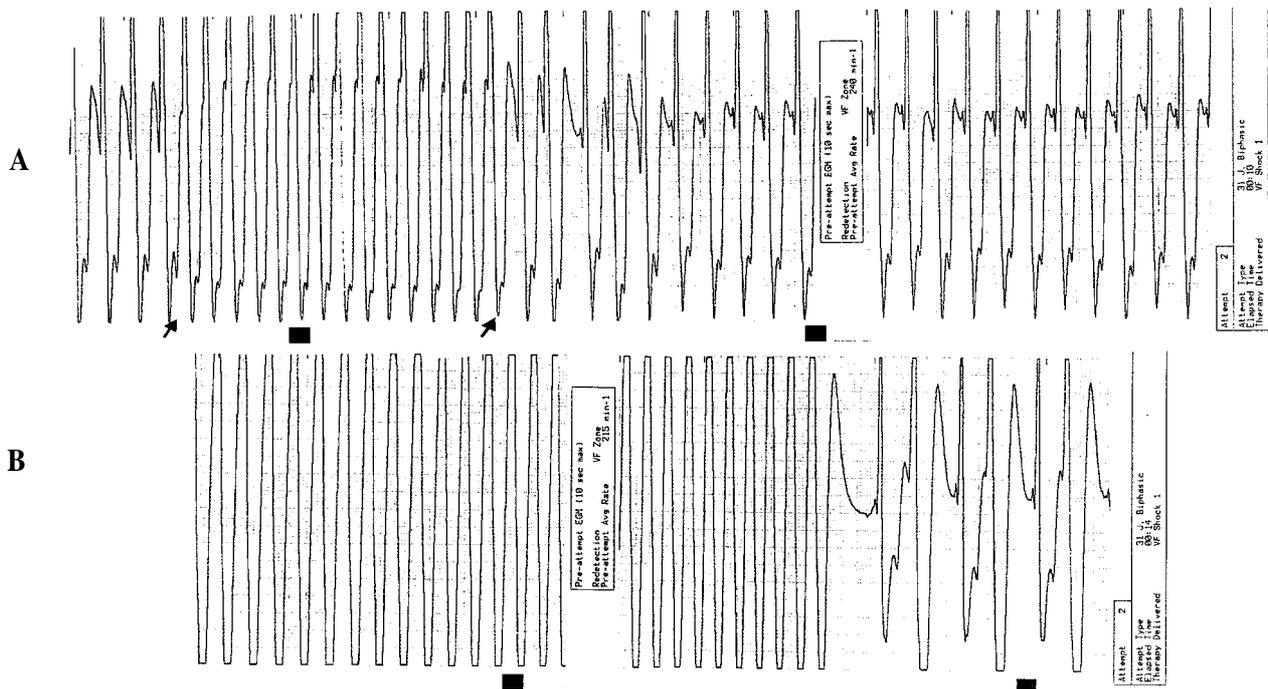


Figure 1. Fourteen year-old patient with idiopathic hypertrophic cardiomyopathy and multiple risk factors, in whom a single chamber defibrillator was implanted for primary prevention of sudden cardiac death. In Figure 1A the device is activated due to an episode of tachyarrhythmia, that for 4 sec (arrows) is accelerated with a small change in the morphology of ventricular electrograms. Given the likely coexistence of ventricular preexcitation (according to electrophysiology study findings), the possible diagnoses are: atrial fibrillation with rapid ventricular response, coexistence of atrial fibrillation with a burst of ventricular tachycardia or less likely ventricular tachycardia. In Figure 1B the device is activated after 2 months, during an episode of dizziness. This time, there is an appropriate electrical intervention in an episode of rapid, sustained monomorphic ventricular tachycardia (concerning the rhythm of ventricular electrograms and their different morphology before the termination).

such cases, the incorporation of the above-mentioned criteria of ventricular tachycardia recognition is expected to contribute decisively. Although dual chamber defibrillators were devised to differentiate the diagnosis of ventricular from supraventricular tachycardia more precisely, based on the correlation of atrial and ventricular activity during arrhythmia, incidents of improper treatment have however, been described²⁷. Thus, if the quality of detected atrial electrograms is marginal, particularly under conditions of exercise, it is possible that the device may falsely diagnose atrioventricular dissociation and if sinus tachycardia exceeds the frequency criterion of ventricular tachycardia detection, inappropriate electrical treatment can be administered (Figure 5). In addition, it is occasionally possible that the frequency of detected atrial activity can be doubled, provided that the atrial electrode remotely detects the ventricular activity (far field effect). In this case a ventricular tachycardia can be considered as supraventricular, deterring the administration of necessa-

ry electrical intervention (Figure 6). Such potential problems are solved with defibrillator reprogramming or with the application of new analysis software. The hemodynamic benefits of dual chamber IACDs are also considerable in patients with coexisting ventricular arrhythmias and disorders of electrical impulse formation and/or conduction (Figure 7). In such patients, dual chamber pacing maintains the benefits of atrial contraction and AV synchrony and increases the efficacy and safety of pharmaceutical treatment. Today, the introduction of biventricular pacemakers defibrillators for selected patients with advanced congestive heart failure and severe intraventricular conduction disorder, constitutes an alternative form of treatment. Another disadvantage of dual chamber defibrillators, apart from cost, is the increased possibility of post-operative complications, such as atrial electrode dislocation and contamination of surgical trauma. These complications are related to the device's larger size and the technically more difficult and demanding implantation. These

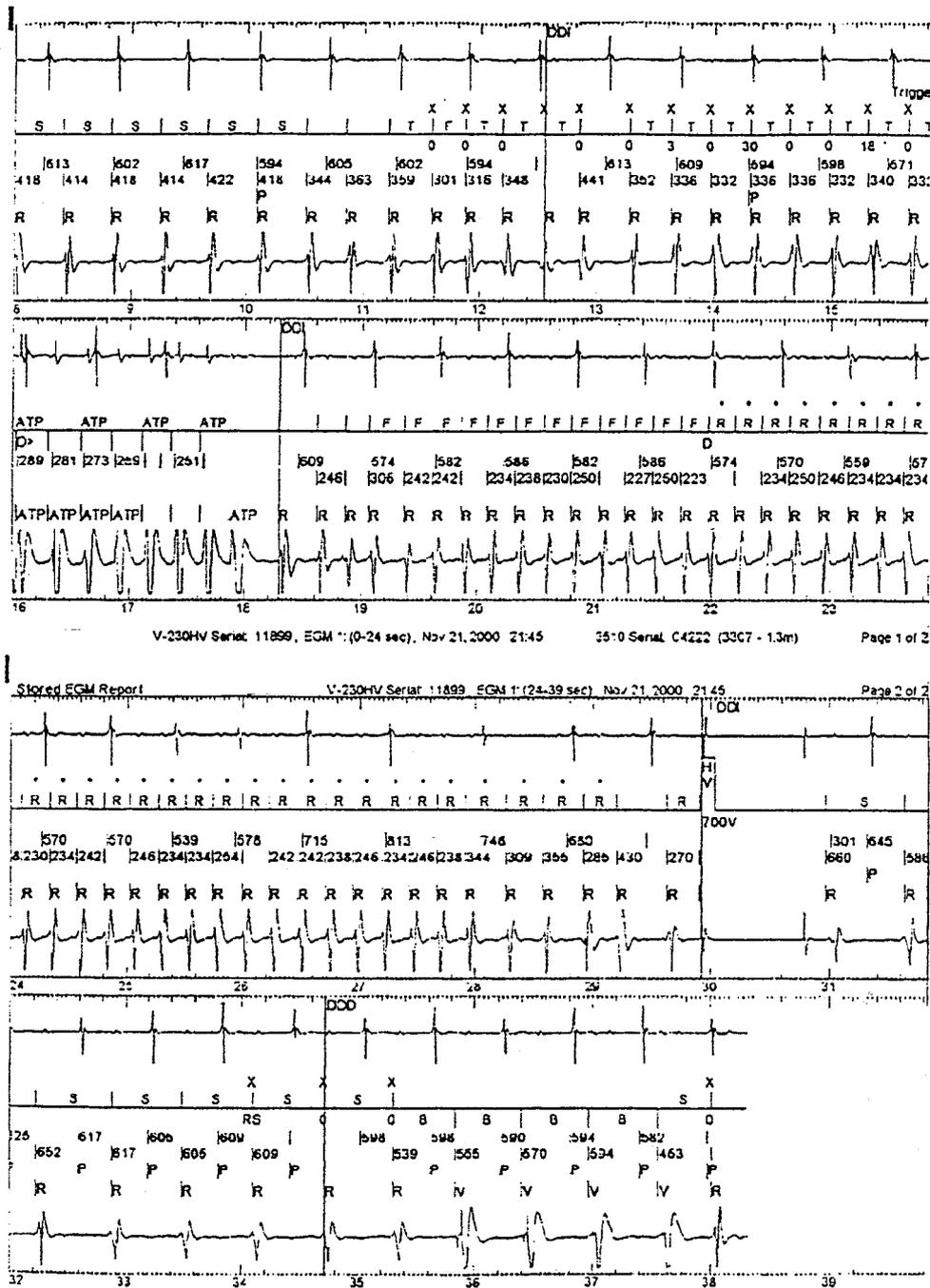


Figure 2. An interrupted sustained ventricular tachycardia episode, in a patient with dual chamber defibrillator. In the upper section atrioventricular dissociation is observed during ventricular tachycardia. An effort of antitachycardia pacing (ATP) accelerates ventricular tachycardia (from 350 to 240 msec) and arrhythmia is finally interrupted with a 700V defibrillation. In the lower section, the sinus rhythm has been restored (obvious change in the morphology of ventricular electrograms).

disadvantages are expected to be overcome as the implanting teams, clinical experience increase. The introduction of dual chamber IACDs in clinical practice during the last four years has led to an in-

crease in their use. Thus, in our own experience, after the first implantation of a dual chamber IACD in 1999, the majority of subsequent implantations were performed with dual chamber systems and today we

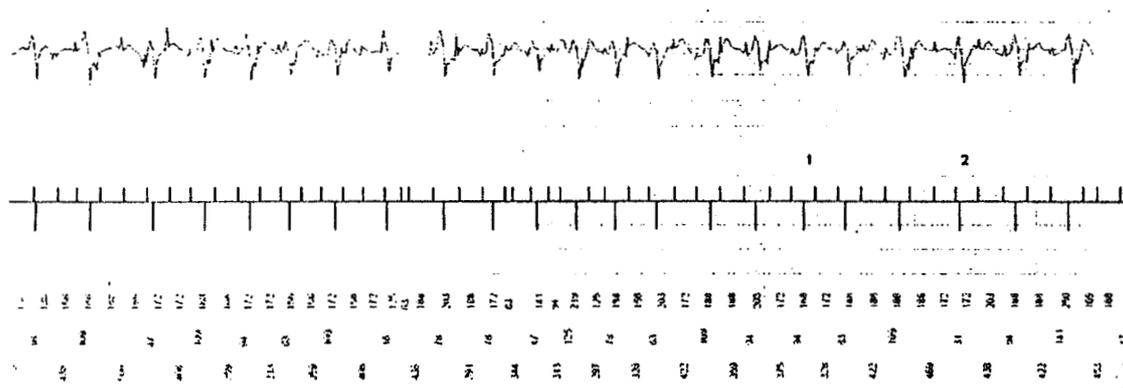


Figure 3. Patient with arrhythmogenic cardiomyopathy of the right ventricle and history of relapsing sustained ventricular tachycardia. Following the implantation of a dual chamber defibrillator, the device correctly “diagnoses” the presence of atrial fibrillation and deters the administration of improper electrical treatment. From top to bottom, electrograms followed by indicators of atrial and ventricular activity, with measurement of corresponding time intervals. It is obvious that atrial frequency exceeds ventricular by far.

almost exclusively use these systems in patients with sinus rhythm (Figure 8). The first retrospective results from published series of patients with a dual chamber IACD promise an important improvement

of ventricular tachyarrhythmias recognition and provide a specificity of more than 90% in avoiding inappropriate electrical intervention in cases of supraventricular tachyarrhythmias²⁰⁻²³.

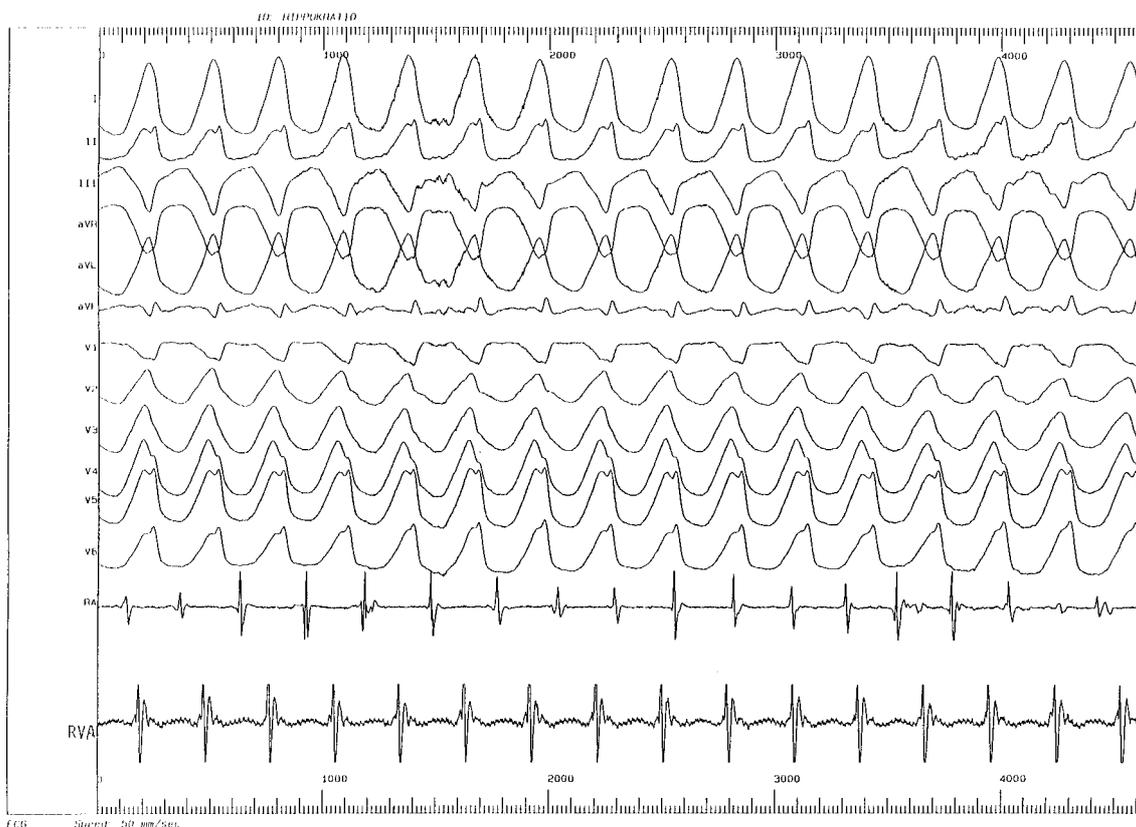


Figure 4. Coexistence of sustained monomorphic ventricular tachycardia with atrial flutter-fibrillation. Patient with an old myocardial infarction and episodes of non-sustained ventricular tachycardia. The frequency of atrial electrograms (RA) exceeds slightly this of ventricular electrograms (RVA) with coexisting atrioventricular dissociation. From top to bottom, body surface leads followed by intra-atrial (RA) and intraventricular (RVA) electrograms. Paper speed at 50 mm/sec.

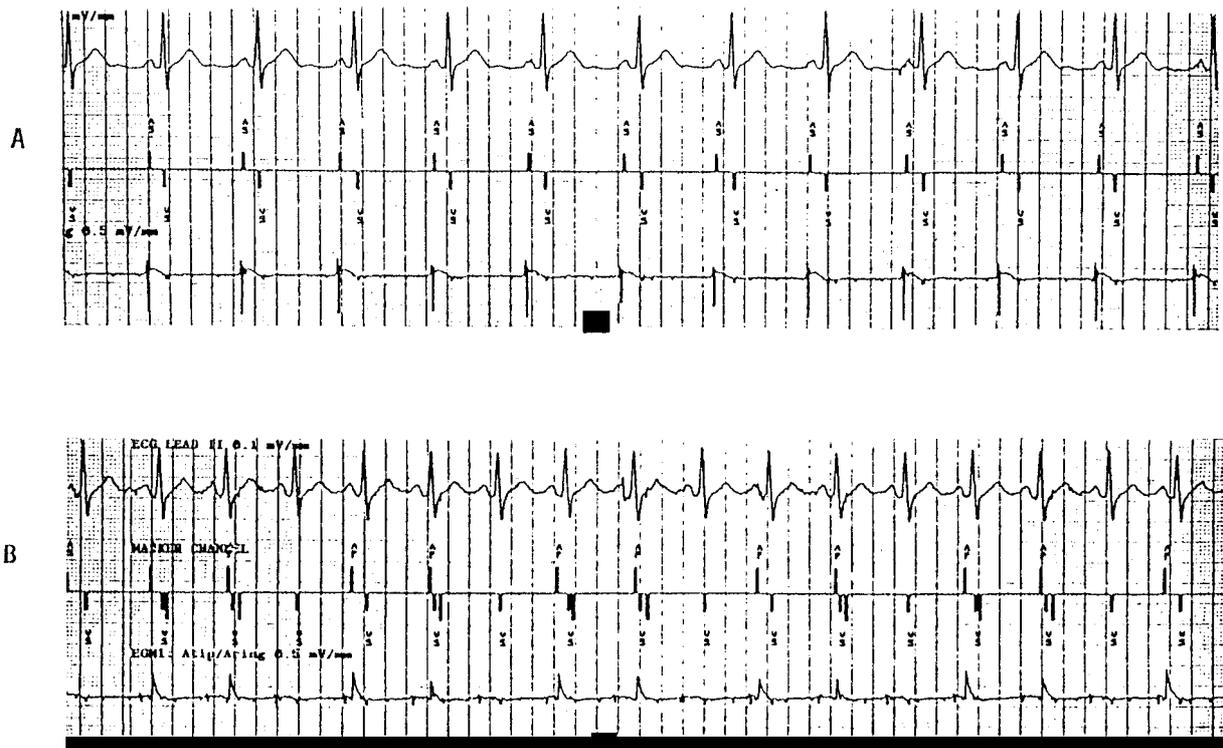


Figure 5. Patient with implantable dual chamber defibrillator that received electrical discharge during exercise due to sinus tachycardia. While in Figure 5A, at rest, there is sufficient sensing of atrial (AS) and ventricular (VS) electrograms, in 5B, casual loss of atrial sensing is observed, during moderate exercise and in result the device falsely diagnose atrioventricular dissociation. The device administers a discharge for the interruption of “ventricular” tachycardia, since ventricular frequency exceeds the limit for ventricular tachycardia diagnosis and atrial undersensing persists, giving false impression of atrioventricular dissociation (modified from ref. 7).

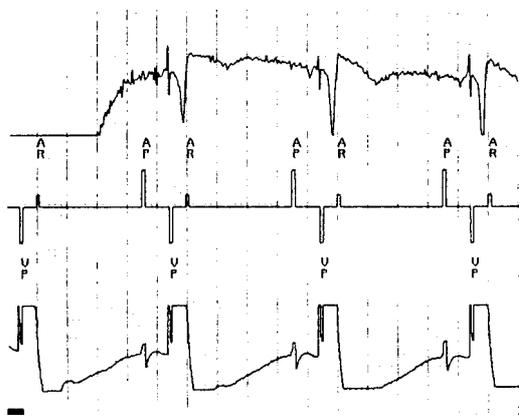


Figure 6. Dual chamber defibrillator. From top to bottom, electrograms followed by indicators of intra-atrial and intra-ventricular activity (AP, AR and VP respectively) and intra-atrial electrograms. The rhythm is obviously paced in DDD mode (AP-VP). However, the atrial electrode records atrial activity short after ventricular pacing (AR). It is the far field effect of ventricular activity.

Dual chamber IACD with capability of atrial tachyarrhythmia treatment

The clinical usefulness of antitachycardia cardioverter defibrillators is under research; these devices not only treat ventricular tachyarrhythmias but are also capable of providing atrial antitachycardia pacing and defibrillation^{28,29}. Indeed, it is well known that a considerable number of patients at risk of sudden cardiac death have a history of paroxysmal atrial fibrillation. Although this supraventricular arrhythmia is usually hemodynamically well tolerated and not life-threatening, it affects the quality of life of these patients and slightly reduces their life expectancy. Thus, the implantation of atrial defibrillators was suggested in selected patients with frequent episodes of paroxysmal atrial fibrillation. However, the number of implantations worldwide is exceptionally limited due to both patients and do-

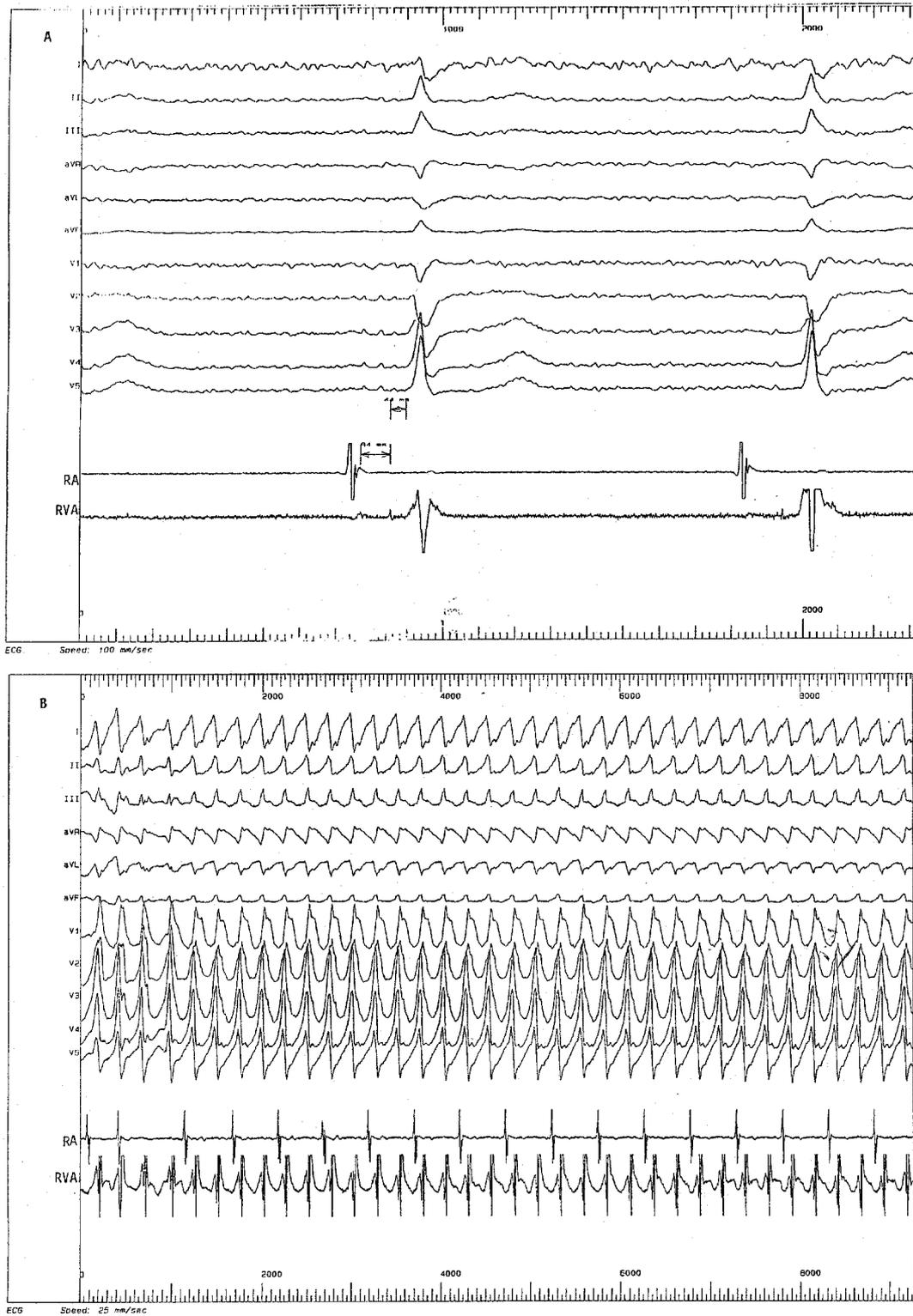


Figure 7. A 70-year-old patient with sick sinus syndrome, left posterior bundle branch block and complex ventricular arrhythmias. In the basic electrophysiology study, sinus bradycardia is obvious with coexisting conduction disorder, although HV interval is normal (Fig. 7A). In Fig. 7B there is easily inducible sustained monomorphic ventricular tachycardia. From top to bottom, body surface leads followed by intra-atrial electrograms (RA) and intraventricular electrograms (RVA).

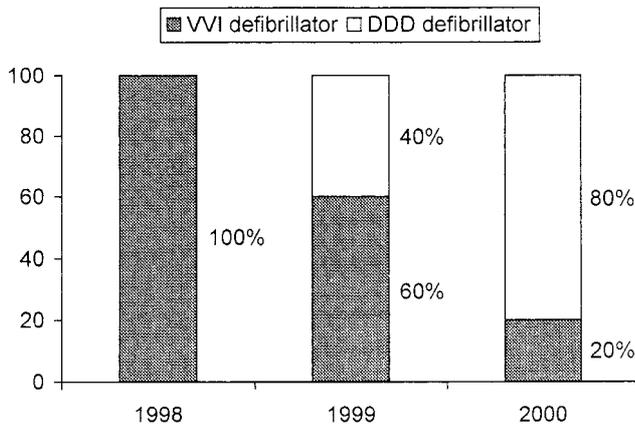


Figure 8. Implantations of dual chamber defibrillators in Hippokraton General Hospital of Athens. The preference to dual chamber systems over the last three years is obvious.

ctors considerations, as well as due to the proarrhythmic risk that accompanies these devices without the capability of automatic ventricular defibrillation. With the new dual chamber IACDs that are implanted in patients with a history of atrial and ventricular tachyarrhythmias, such considerations are more easily overcome. Many questions are raised. Is the atrial electrode capable of reliably and constantly detecting arrhythmic atrial electrograms of irregular size, during atrial fibrillation? Is it reliable to differentiate atrial fibrillation from atrial tachycardia? What is the percentage of converting supraventricular tachycardia with painless antitachycardia atrial pacing? The data of prospective studies have answered a few of these questions^{28,29}. Thus, in a study of 80 patients with complex ventricular tachyarrhythmia history and more than 2 episodes of atrial fibrillation or atrial tachycardia within three months before the implantation, 31 patients had episodes of atrial tachyarrhythmia within six months after the implantation²⁸. The supraventricular tachyarrhythmias recognition algorithms were new and different from those used in dual chamber pacemakers. It is worth noting that an overwhelming majority of atrial fibrillation or atrial tachycardia episodes were recognizable with exceptionally small possibility of false diagnosis when the device remotely recognized ventricular electrograms. It became obvious that the device was capable of recognizing persistent episodes of atrial tachyarrhythmia despite the periodical loss of sensing of the altered in size atrial electrograms. Surprisingly, according to the data of this study it was found that a significant percentage of

supraventricular tachyarrhythmias commences with characteristics of atrial tachycardia which can be treated with atrial antitachycardia pacing. Indeed, in 31 patients with relapses of atrial tachyarrhythmia, the device “diagnosed” episodes of atrial tachycardia in 8 patients and episodes of combined atrial fibrillation and atrial tachycardia in 10 patients. It is impressive that in 166 episodes of detected atrial tachycardia, 45% were interrupted with painless antitachycardia pacing. Although the above mentioned data are derived from the initial phase of clinical research and should be treated with consideration, they may modify the long established beliefs in the treatment of atrial fibrillation. Three dual chamber IACDs with the capability of atrial treatment have already been implanted in our Hospital, since we are involved in a multicenter international study. This study investigates the diagnosis effectiveness, the treatment of supraventricular tachycardias and the safety of using these promising defibrillators in clinical practice (Figure 9).

Conclusions

We may conclude that the introduction of dual chamber antitachycardia cardioverter defibrillators is expected to improve the diagnostical ability of differentiating supraventricular from ventricular arrhythmias and significantly limit the cases of inap-



Figure 9. Dual chamber antitachycardia cardioverter defibrillator in a patient with idiopathic hypertrophic cardiomyopathy and history of sick sinus syndrome.

appropriate activation. The advantages of dual chamber pacing in patients with accompanying history of sick sinus syndrome and/or conduction disorders are also obvious. The increasing interventional experience in combination with the expected reduction in size and weight of the devices will reduce long-term complications in the near future. Dual chamber IACDs with the capability of atrial tachyarrhythmias treatment are at the clinical research stage and wide application in the near future is possible.

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