Pacing within the Atrium Prevents Supraventricular Tachycardias

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Summary

Cardiac pacing that involves the atrium constitutes an important alternative to pharmacological and invasive therapy for the prevention of supraventricular tachycardia in patients with sinus node disease. It has long been recognized that atrial synchronized pacing increases the cardiac output (CO) and, thus, the physical performance of patients when compared to ventricular single-chamber pacing. Atrial pacing modes also have an antiarrhythmic effect in patients with preexisting atrial fibrillation (AF), considerably decreasing the incidence of AF episodes and the mortality rate. In contrast, limiting stimulation to the ventricle desynchronizes the cardiac action by causing retrograde atrial excitation. As a result, 12 to 15 % of ventricularly paced patients suffer from pacemaker syndrome. Other negative consequences are higher rates of atrial fibrillation (AF) and mortality. By highlighting the various benefits of the appropriate pacing modes (AAI, VAT, DDD) as opposed to solely ventricular pacing in the VVI mode, this article provides data supporting the wide implementation of pacemakers that offer atrial pacing.

Key Words

Atrial synchronous pacing, VVI, cardiac performance, arrhythmia, pacemaker syndrome

Introduction

Drug therapy used in treating supraventricular tachycardias and atrial fibrillation (AF) in particular is often characterized by inefficiency, side effects, and possible proarrhythmic consequences. The resulting risk of cerebral embolisms arising in patients with intermittent or permanent AF requires permanent anticoagulation medication, which is frequently infused with its own complications.

Therefore, non-pharmacological methods for the treatment of supraventricular arrhythmias have increasingly been the focus of clinical research. Such methods now include invasive procedures, e.g., radiofrequency ablation, surgical methods (maze procedure), and atrial defibrillation. As an alternative to individual applications of these dramatic procedures, the often neglected discussion of benefits from artificial cardiac pacing that includes the atrium is the focus of this article. Appropriate pacing, AAI or DDD, has a preventative antiarrhythmic effect, especially in patients with sick sinus syndrome (SSS).

The Hemodynamic Significance of the Atrial Contraction

Already in the early stages of pacemaker development, the importance of the atrial contraction for cardiac pumping performance was shown. In 1967, Nager [1] made a disappointing discovery: The initial increase in cardiac output (CO) in the wake of rate normalization by a ventricular pacemaker (VVI) in patients with third-degree atrioventricular (AV) block could no longer be detected after a short period of time. The pumping performance of the heart had regressed to the initial values prior to pacemaker implantation. Under otherwise identical study conditions, but this time synchronizing the atrial with the ventricular contraction via VAT pacemaker, Kappenberger [2] found an improvement in cardiac performance when compared to the unregulated ventricular stimulation and a lasting stability of the measured CO values (figure 1). This effect on the CO when reestablishing the AV sequence in cases of AV block has since been confirmed numerous times [3-16]. A range of studies have explored the effect of solely ventricular (VVI) and atrial synchronized (VAT or DDD) pacing on the CO (figure 2).

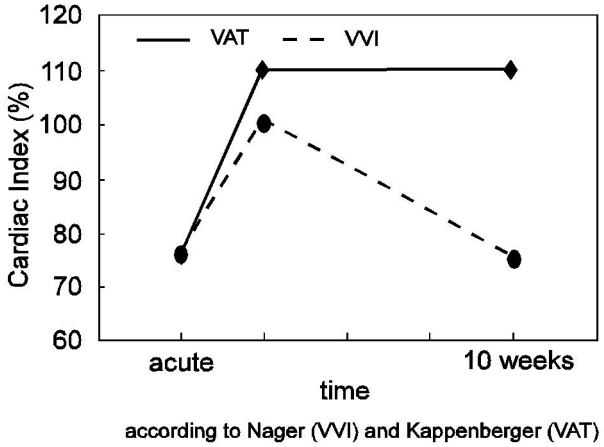

Figure 1. Cardiac output in third-degree AV block patients treated with VVI and VAT pacing.

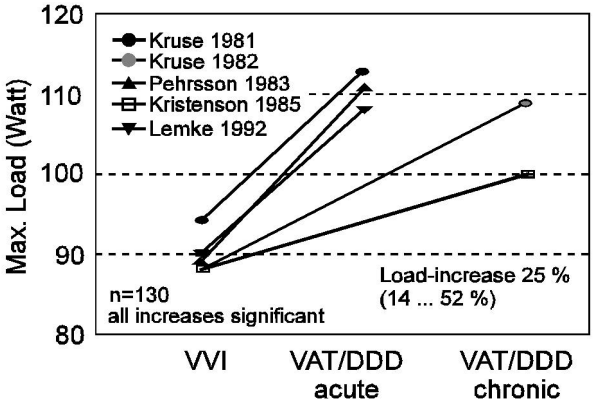

Figure 3. Physical performance of patients with third-degree AV block during VVI versus VAT/DDD pacing (accumulated statistics from several researchers).

Researchers have also examined these pacing modes in regard to the physical performance achieved by the patients [9][10]. The results of these studies are compared in figure 3.

Although this hemodynamic benefit of atrial pacing was recognized early, the detrimental consequences of desynchronizing the atrial and ventricular actions were examined only much later. Insights about the development of such a desynchronization have been gained in cases of supraventricular bradycardia, such as SSS, treated with a ventricular pacemaker (VVI). Mainly during the bradycardic resting phases, a reversal of the natural contraction sequence occurs. Retrograde atrial excitation is the cause and can be detected in over

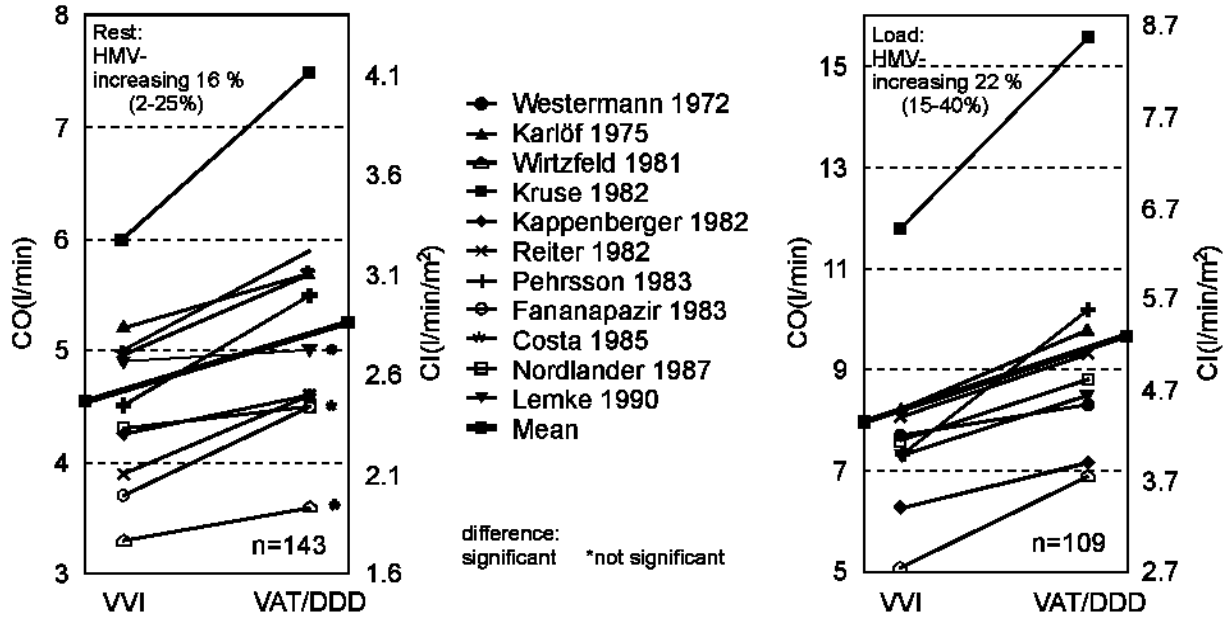

Figure 2. Cardiac output during rest and under load for VVI versus VAT/DDD pacing in cases of third-degree AV block (accumulated statistics of several researchers).

90 % of all examinations. In clinical practice, the circulatory function deteriorates in 12 to 15 % of the affected patients. Their state of health worsens acutely and dramatically with symptoms of dyspnea, dizziness, syncope, and a failing ability to endure loads. These symptoms usually surpass the patient's complaints which had occurred prior to the pacemaker implantation. This clinical picture is termed pacemaker syndrome and was first described by Haas [17]. The author's own studies comparing hemodynamics in patients with and without clinical symptoms of pacemaker syndrome during VVI stimulation [18] are summarized in figure 4.

In all cases, retrograde atrial excitation results in the phenomenon of atrial blocking, i.e., the atria contract while the AV valves are closed. As a consequence, an almost identical reduction in CO (20 to 25 %) was observed in all patients. The reaction of the peripheral circulation varied by degrees. In patients with pacemaker syndrome, the increased atrial wall tension reflexively leads to an insufficient increase in peripheral vascular resistance, thus resulting in a more or less severe hypotonia [19]. In animal experiments, the effect of the reversal in the contraction sequence was explored in more detail. Baller [20] studied 15 healthy dogs, stimulating the atrium and the ventricle alternately at the same frequencies. With ventricular stimulation, Baller determined that CO decreased by an average of 25 %, and that oxygen consumption increased by an average of 25 %. At higher stimulation rates, oxygen consumption increased by up to 60 %. The contractility parameters dp/dt_{max} and dp/dt_{min} worsened dramatically, and end-diastolic pressure rose in comparison to the values during atrial stimulation. Blood pressure was adapted to the reduced ejection performance of the heart by an increase in peripheral vascular resistance, which in turn was caused by a higher release of catecholamines.

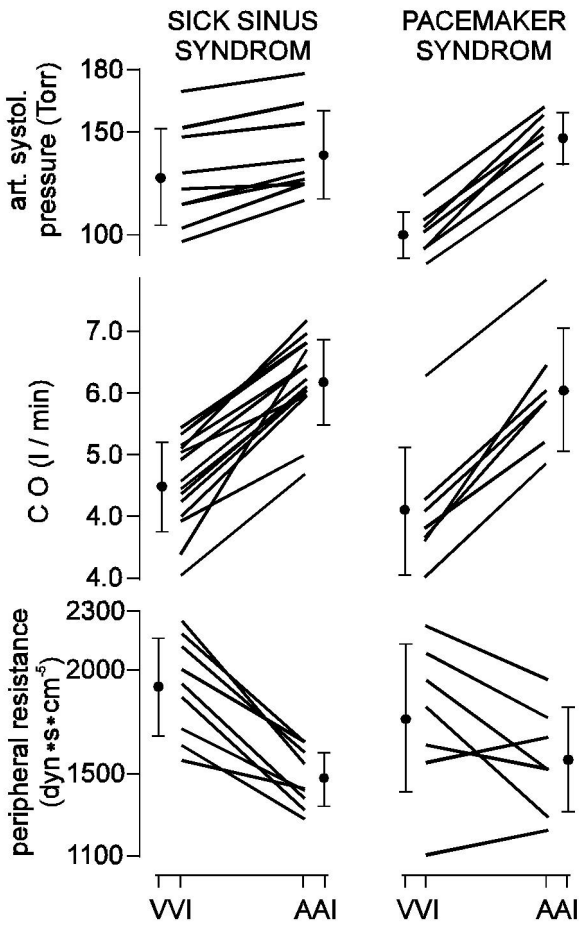

Figure 4. Response of the CO, arterial blood pressure, and peripheral vascular resistance to VVI and AAI pacing (at identical rates), showing values of patients with SSS (left) and with clinically diagnosed pacemaker syndrome (right).

The Effects of AV Synchronization/ Desynchronization on the Atrial Pressure Control Mechanism

Besides transporting additional blood volume to the ventricle and controlling the end-diastolic pressure, a timely atrial systole guarantees the maintenance of a low mean atrial pressure. This therefore leads to a decrease in pathologically high pressure in the pulmonary artery. Furthermore, the atrial systole supports AV valve closure, thus avoiding a regurgitation of ventricular blood into the atrium [21][22].

Of course, all of these mechanisms are no longer in place during purely ventricular pacing with retrograde atrial excitation. Retrograde conduction is present, at least temporarily, in approximately 25 % of the antegrade third-degree AV blocks. Rosenquist et al. [23] were the first to report the consequences of an increased pressure/wall tension in the atria. They compared SSS patients paced with the VVI or AAI modes in a retrospective study. In the VVI group, 47 % of the patients had chronic AF after 4 yr, compared to only 7 % in the AAI group. For patients with cardiac insufficiency the percentages were 37 % in the VVI group and 15 % in the AAI group, and the mortality

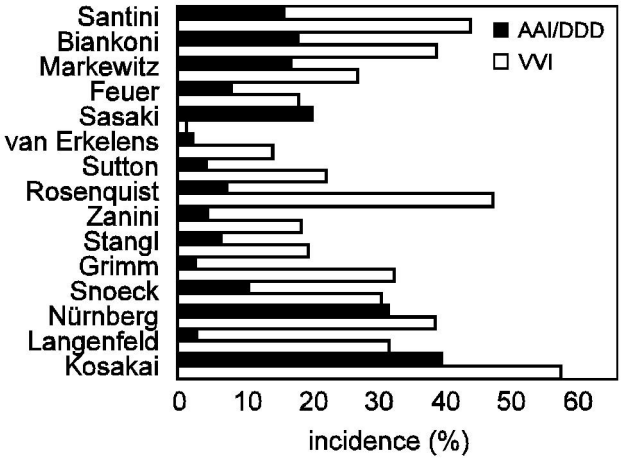

Figure 5. Incidence of AF in SSS patients paced with AAI/DDD versus VVI modes (accumulated statistics of retrospective studies covering follow-up periods from 2 to 6 years).

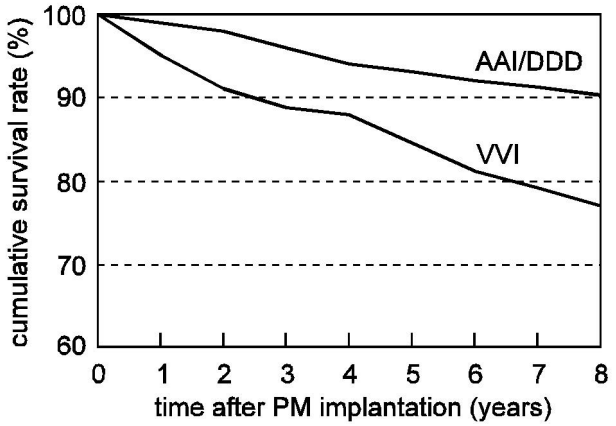

Figure 7. Mortality rate in SSS patients paced with AAI/DDD versus VVI modes (progress observation of 2484 patients over the course of 8 years).

rate for these patients was 27 % and 8 %, respectively. Several retrospective studies have confirmed these results subsequently. All researchers [24-29] reported a significantly higher rate of AF with ventricular pacing as compared to atrial or AV-sequential pacing (figure 5). The first prospective study [30] showed concurring results.

Since the connection between AF and cerebral embolisms has been studied and elucidated [31], the increased mortality resulting from unphysiologic VVI pacing can be at least partially explained. The most important retrospective studies investigating mortality rates have been summarized (figure 6). Again, the mortality rates are significantly higher for the VVI groups in the studies.

In this context, a study by the author comprising the largest patient group of all clinical trials should be mentioned: 2484 patients were observed over a long follow-up period of 8 years [34]. By pairing 1242 patients of the same age, gender, and implantation period, but with either AAI/DDD or VVI pacemakers, the study showed a survival rate of more than 91 % in the AAI/DDD group as compared to 79 % in the VVI group (figure 7). The survival rate of VVI patients is equivalent to that of a group of patients with SSS and without any therapy.

Another conclusion was drawn: Pacing that involves the atrium (AAI/DDD) has a pronounced antiarrhythmic effect on an already existing AF in patients with bradycardia-tachycardia syndrome, which is the most important and frequent manifestation of sinus node disease. After normalizing the atrial rate by artificial atrial or AV-sequential pacing, approximately 60 to 70 % of these patients were free of further AF attacks. Some medical professionals maintain the opinion that pacing involving the atrium is not indicated in cases of preexisting AF episodes, since the patients will eventually progress to permanent AF in any case. However, this author's results from treating more than 900 patients could not confirm this point of view. A progression to chronic AF under AAI/DDD stimulation

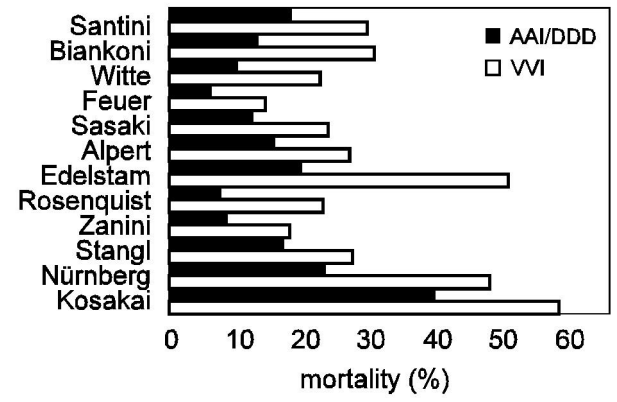

Figure 6. Mortality rate in SSS patients paced with AAI/DDD versus VVI modes (accumulated statistics of retrospective studies covering follow-up periods from 2 to 8 years).

occurred with a yearly rate of only 3 % in this group. It may be possible to reduce this low rate even further by applying new methods of bi-atrial stimulation [32][33].

Conclusions

In light of all the encouraging results discussed, a strong argument can be made in support of pacemakers that include atrial stimulation. Such "physiologic" pacemakers restore the natural contraction sequence and have great antiarrhythmic benefits. Implementation of the respective pacing modes, AAI and DDD, has been proven to lead to an optimization of the hemodynamic state, a reduction in arrhythmias, a decreased risk of embolism, a minimization of congestive symptoms, and a reduction in mortality.
Due to recent technological advances, a wide array of appropriate pacemaker systems and electrodes is available to the physician. With these resources, any center claiming to implement a modern standard of therapy should implant pacemakers with an atrial pacing function in about 70 % of all cases.

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