Right ventricular pacing is associated with impaired overall survival, but not with an increased incidence of ventricular tachyarrhythmias in routine cardioverter/defibrillator recipients with reservedly programmed pacing

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Aims
Data from previous defibrillator studies raised concern about right ventricular pacing (RVP) promoting heart failure progression and mortality in implantable cardioverter/defibrillator (ICD) patients. The present observational study re-examined the association of RVP, survival, and ventricular tachyarrhythmias/ventricular fibrillation (VT/VF) in routine ICD patients with restrictively programmed pacing.

Methods and results
In 213 ICD patients [183 men, left ventricular ejection fraction (LVEF) 37 ± 15%, follow-up 37 ± 18 months, no advanced atrioventricular (AV) block], the RVP proportion, survival, and the time to a first appropriate VT/VF episode were assessed. Electrograms were validated and the overall survival was determined. The RVP prevalence was dichotomized at ≥30% (high RVP) vs. <30% (low RVP). High RVP (RVP 94%, n = 24) and low RVP (RVP 0%, n = 189) patients had similar LVEF, underlying heart disease, ICD indication, and medication. Multivariate Cox regression showed no difference in survival without appropriate VT/VF treatment [odds ratio (OR): 0.92, 95% confidence interval (CI): 0.41–2.04, P = 0.83]. Overall survival was significantly more favourable in low RVP patients (OR: 0.34, CI: 0.13–0.91, P = 0.03).

Conclusion
Frequent RVP is associated with impaired survival in ICD patients despite conservative pacing settings. Implantable cardioverter/defibrillator patients requiring concomitant bradycardia pacing should be cared for with particular attention to clinical worsening. Right ventricular pacing prevention and alternative modalities of ventricular pacing need prospective evaluation.

Keywords
Right ventricular pacing • Cardioverter/defibrillator • Overall survival • Ventricular tachyarrhythmia • Appropriate treatment episodes • Ventricular pacing prevention

Introduction
Treatment with an implantable cardioverter/defibrillator (ICD) has been demonstrated to improve survival in patients with symptomatic severe systolic heart failure when compared with exclusive optimal medical therapy. Owing to advanced structural heart disease and as a result of negative chronotropic and dromotropic drugs for antiarrhythmic and heart failure treatment,
patients at increased risk for sudden cardiac death (SCD) may also present with significant bradyarrhythmia.\(^5\) In the past, at least 15–20% of ICD patients were presumed to be candidates for added antibradycardia pacing.\(^{6,7}\) If a conventional DDD mode is applied, antibradycardia pacing is likely to produce high percentages of unintended right ventricular pacing (RVP)\(^8\) even in patients with sinus node dysfunction and preserved atrioventricular (AV) conduction. Recent data raised concern about possible adverse effects of RVP in heart failure patients. The dual-chamber vs. VVI implantable defibrillator trial (DAVID) compared dual- and single-chamber defibrillators in patients with severely depressed systolic left ventricular (LV) function and no indication for antibradycardia pacing. The study found a higher incidence of the combined primary endpoint (heart failure hospitalization or death) in the dual-chamber defibrillator group.\(^9\) This could be demonstrated to be an effect of unintended RVP occurring in the dual-chamber patients.\(^{10}\) It is unclear, however, whether the unfavourable effect of RVP in an ICD population also takes effect, when pacing is restricted to patients with justifiable indications like sinus node dysfunction and/or first-degree AV block, whereas RVP is most widely avoided in patients without pacing indication, or alleged indication for permanent ventricular pacing. The present population-based non-randomized study re-examines the relationship of the cumulative prevalence of RVP, overall survival, and adequate treatment episodes in consecutive routine ICD patients with at the most first-degree AV block at implant and restrictively programmed antibradycardia pacing.

**Methods**

**Study population**

The study population comprised 213 routine ICD patients with heart failure of any aetiology and an indication for ICD treatment based on previous symptomatic ventricular tachyarrhythmias (secondary prevention) or an anticipated important risk for SCD (primary prevention) according to current knowledge and guidelines.\(^{11}\) The patients were implanted at one tertiary referral centre (Charité, Campus Virchow-Klinikum, Berlin, Germany) from mid-2001 to 2005. During the inclusion period, a total of 360 patients received an ICD. All consecutive patients with complete follow-up data including RVP percentage were eligible. The majority of patients were followed at the implanting institution. Owing to incomplete follow-up information, 68 patients had to be excluded from the analysis. During the inclusion period, for 79 patients, a biventricular device was selected.

**Selection of single- and dual-chamber implantable cardioverter/defibrillator candidates**

Patients without a detectable antibradycardic pacing indication received a single-chamber defibrillator, whereas dual-chamber ICDs were chosen for patients with spontaneous or drug-induced sinus node dysfunction and/or AV conduction disturbance. Patients with AV block \(\geq 11\) or atrial fibrillation (AF) and a persistent ventricular rate <50 bpm were considered candidates for biventricular pacing and not for RV DDD or VVIR pacing, whereas dual-chamber ICD therapy was anticipated to be appropriate for patients with sinus node dysfunction and at the utmost first-degree AV block. Patients with triple-chamber ICDs were not included in the study.

**Implantation procedure**

All implantations were carried out in the catheterisation laboratory under local anaesthesia and deep sedation only for defibrillation threshold testing. The defibrillation leads were placed within the RV apex. Manufacturers of the implanted devices included Biotronik (Berlin, Germany), Medtronic (Minneapolis, MN, USA), and Guidant (Saint Paul, MN, USA). Dual-chamber devices were not fitted with one of the newly developed bidirectional AAI–DDD switch modes.\(^{12,13}\)

**Antibradycardia settings**

A common objective of single- and dual-chamber ICD antibradycardia settings was to achieve an at most low ventricular pacing percentage. In single-chamber devices, a low ventricular rate (35–50 bpm) along with the VVI mode was programmed. In dual-chamber ICDs, the AV delay was prolonged until intrinsic ventricular activation resulted during the acute setting. In the absence of discernible AV conduction disease (i.e. PR interval \(\leq 200\) ms), manual AV prolongation was accompanied by disabling of tracking and setting of the DDi(R) mode, as was proposed for pacemaker patients with sinus node dysfunction.\(^8\)

**Antitachycardia settings**

In patients implanted for primary prevention of SCD, usually two tachycardia detection zones were programmed. A ventricular tachycardia (VT) zone was defined \(>170–180\) bpm, and a ventricular fibrillation (VF) zone was set beyond 200 bpm. Ventricular tachycardia detection was based on device-specific respective discrimination algorithms in order to increase diagnostic specificity. Treatment for VT-included burst and ramp overdrive pacing with subsequent shocks in the case of need. Tachyarrhythmias detected within the VF zone were treated by shocks. Secondary preventive patients with VF as the primary ventricular tachyarrhythmia were programmed in the same manner. If the primary arrhythmia was sustained VT, the VT detection rate was adapted according to the clinical VT cycle length.

**Follow-up**

Scheduled follow-up visits were carried out every 3–4 months. In addition to it, unscheduled device interrogations were performed in the case of symptomatic episodes and/or shock delivery and in the course of an unplanned hospitalization. The arrhythmia log and episode electrograms were printed out at each follow-up. The percentage of RVP was assessed at the single follow-up visits. The individual cumulative percentage of RVP was calculated taking into account values from each visit and respective follow-up periods. Ventricular tachycardia/ventricular fibrillation episodes were analysed and validated by three experienced examiners (M.S., A.N., and A.K.). On the basis of marker channels and stored electrograms, the detection and intervention of the device was classified as appropriate or inappropriate. The time from implantation to a first appropriate treatment episode was determined. In the hospital, deaths were documented and families and/or family doctors were contacted in the case that patients did not present for scheduled routine outpatient follow-up appointments. The time interval between implantation and death was documented. PR and QRS intervals were obtained from unpaced standard 12-lead surface ECGs at the time of implantation. The ECGs were recorded at a horizontal speed of 50 mm/s and a magnification of 10 mm/mV with a digital sampling rate of 1000 Hz using a computer-based system (Siemens MegaCart). The measurements were printed out according to the built-in software. The heart failure medication was documented at the time of hospital discharge after ICD

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implantation. The LV ejection fraction (LVEF) was obtained from pre-implant LV angiograms.

**Outcome measurements**

Outcome measurements of the study included the time interval to a first appropriate antitachycardia treatment episode and overall survival.

**Statistical analysis**

Categorical variables are reported as absolute numbers and percentages, the study population was dichtotomized for analysis according to the RVP proportion being very high RVP proportions, and most patients having very low RVP percentages, the study population was dichotomized for analysis according to the RVP proportion being ≥30% (high RVP group) or <30% (low RVP group). Unpaired Student’s t-test and Fisher’s exact test were used for horizontal comparisons as appropriate. Multiple variable Cox regression analysis was used to examine overall survival between the high and low RVP groups with a P-value of <0.10. A P-value of <0.05 was considered statistically significant.

**Results**

**Study population characteristics**

Demographic data of the study population are outlined in Table 1. The patients represent a considerably compromised heart failure cohort with a clear preponderance of male gender and a vast majority having ischaemic cardiomyopathy as the aetiology for LV dysfunction. Age, gender distribution, underlying heart disease, LVEF, QRS duration, PR interval, the proportion of patients treated for secondary prevention, and follow-up duration did not significantly differ between high and low RVP groups, although the high RVP group had non-significantly older age (P = 0.10) and longer PR interval (P = 0.18). At the time of implantation, 31 out of 213 patients (15%) had a history of AF. The prevalence of AF was not significantly different between high and low RVP groups. Patients who were not eligible for analysis due to incomplete follow-up data did not significantly differ from the study patients as regards the baseline parameters LVEF (37 vs. 36%, P = 0.56), age (60 vs. 59 years, P = 0.68), QRS (115 vs. 116 ms, P = 0.73), ischaemic/non-ischaemic aetiology (ischaemic 67 vs. 67%, P = 1.0), gender (male 86 vs. 75%, P = 0.06), indication (secondary prevention 48 vs. 52%, P = 0.68), and medication [beta-blockers 91 vs. 92%, P = 1.0, angiotensin-converting enzyme (ACE) inhibitors/angiotensin receptor blockers (ARB) 86 vs. 84%, P = 0.68, aldosterone receptor antagonists (ARA) 53 vs. 45%, P = 0.32, and diuretics 65 vs. 72%, P = 0.45].

**Medical treatment for heart failure**

Medical heart failure treatment corresponded to current guidelines. Beta-blockers were prescribed to 91% (194 out of 213) of the collective study group, and 86% (184 out of 213) were treated with ACE inhibitors or ARB. Still 53% (112 out of 213) of the patients received ARA. The heart failure medication did not significantly differ between high and low RVP groups, although ACE/ARB prescription (P = 0.10) and ARA treatment (P = 0.13) tended to be less prevalent in high RVP patients.

<table>
<thead>
<tr>
<th>Characteristics of the study population</th>
<th>High RVP group n = 24</th>
<th>Low RVP group n = 189</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>62 ± 15</td>
<td>59 ± 13</td>
<td>0.10</td>
</tr>
<tr>
<td>Men (n%)</td>
<td>20/83</td>
<td>163/86</td>
<td>0.76</td>
</tr>
<tr>
<td>Coronary artery disease (n%)</td>
<td>14/58</td>
<td>129/68</td>
<td>0.36</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>41 ± 17</td>
<td>37 ± 15</td>
<td>0.25</td>
</tr>
<tr>
<td>Secondary prevention (n%)</td>
<td>12/50</td>
<td>91/48</td>
<td>1.00</td>
</tr>
<tr>
<td>History of atrial fibrillation (n%)</td>
<td>5/21</td>
<td>26/14</td>
<td>0.36</td>
</tr>
<tr>
<td>QRS width (ms)</td>
<td>118 ± 27</td>
<td>114 ± 25</td>
<td>0.52</td>
</tr>
<tr>
<td>PR interval (ms)</td>
<td>187 ± 40</td>
<td>177 ± 35</td>
<td>0.18</td>
</tr>
<tr>
<td>Beta-blockers (n%)</td>
<td>22/92</td>
<td>172/91</td>
<td>1.00</td>
</tr>
<tr>
<td>Amiodarone (n%)</td>
<td>3/13</td>
<td>24/13</td>
<td>1.00</td>
</tr>
<tr>
<td>Digitalis glycosides (n%)</td>
<td>3/13</td>
<td>20/11</td>
<td>0.73</td>
</tr>
<tr>
<td>ACE inhibitors or ARB (n%)</td>
<td>18/75</td>
<td>164/87</td>
<td>0.10</td>
</tr>
<tr>
<td>Spironolactone/eplerenone (n%)</td>
<td>9/38</td>
<td>103/54</td>
<td>0.13</td>
</tr>
<tr>
<td>Diuretics (n%)</td>
<td>15/63</td>
<td>123/65</td>
<td>0.82</td>
</tr>
<tr>
<td>Follow-up duration (months)</td>
<td>42 ± 21</td>
<td>37 ± 18</td>
<td>0.25</td>
</tr>
</tbody>
</table>

ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; LVEF, left ventricular ejection fraction; RVP, right ventricular pacing.
Bradyarrhythmias
Concomitant bradyarrhythmias included sinus node dysfunction in 31 (15%) and a first-degree AV block in 40 (19%). In 42 patients (20%), a dual-chamber ICD was implanted. In three patients, AV block progressed to second or third degree over time. The baseline PR interval tended (P = 0.08) to be longer in dual- (188 ± 42 ms) vs. single-chamber (176 ± 33 ms) ICD patients. The average programmed AV interval after an atrial paced event amounted to 250 ± 57 ms and exceeded the average PR interval of dual-chamber patients (188 ± 42 ms) by 62 ms. In patients with progressive AV conduction disease, the AV delay was shortened to avoid the negative impact of long AV delays on LV filling. There was a weak tendency in the small dual-chamber subgroup favouring longer AV delays with regard to both outcome variables (survivors 256 ± 54 ms, non-survivors 218 ± 63 ms, P = 0.24; incident VT/VF: 212 ± 66 ms, no incident VT/VF: 258 ± 53 ms, P = 0.15).

Cumulative prevalence of right ventricular pacing
In the collective study population, the median RVP percentage was very low and amounted to 0% (interquartile range 0–2.5%). The distribution of RVP percentages was bimodal and considerably skewed (Figure 1). By definition, the low RVP group patients had a RVP prevalence of <30%, but the actual RVP proportion was much lower (median 0%, interquartile range 0–1%). The high RVP group was defined by an RVP prevalence of ≥30%, but the de facto median percentage was 94% (interquartile range 51–98%). Consequently, numerically unequal patient groups with very high vs. very low RVP proportions were analysed. Taking account of this, the dichotomization around the RVP percentage of 30% does certainly not define a reliable threshold value. Patients with dual-chamber devices had a higher RVP percentage (median 12%, interquartile range 0–81%) than those implanted with a single-chamber ICD (median 0%, interquartile range 0–1%, P < 0.001). Out of 24 patients pertaining to the high RVP group, 17 (75%) were implanted with dual-chamber devices. Patients with a first-degree AV block tended to have more RVP than those without (P = 0.14). As most of the frequently paced patients had dual-chamber ICDs, the effect of RVP on survival and VT/VF incidence could also have been expressed as a repercussion of dual-vs. single-chamber device use [for survival: odds ratio (OR): 0.28, 95% confidence interval (CI): 0.12–0.70, P = 0.008, for VT/VF incidence: OR: 1.61, CI: 0.76–3.40, P = 0.21].

Appropriate treatment episodes for ventricular tachycardia or ventricular fibrillation
During a long-term follow-up (37 ± 18 months for all patients), in 7 out of 24 (29%) high RVP group patients and 49 out of 189 (26%) low RVP group patients, appropriate antitachycardia treatment episodes occurred after an average arrhythmia-free interval of 13 months in both groups. The underlying arrhythmia was detected within the VT zone in 13 patients, whereas 43 patients had their first episode classified as VF and treated by an adequate ICD shock. Multiple variable Cox regression analysis accounting for age and ACE inhibitor/ARB treatment showed no significant difference between high and low RVP groups with regard to the time interval to a first appropriate treatment episode (OR: 0.90, CI: 0.40–2.04, P = 0.81, Figure 2). In 27 patients (12.6%), the episode validation revealed inappropriate antitachycardia treatment episodes. The occurrence of inappropriate treatment episodes (shock or ATP) was not significantly different (P = 0.98) among high (14.3%) vs. low RVP (12.7%) patients.

Long-term overall survival
During a long-term follow-up, 193 out of 213 (90.6%) patients survived. In the high RVP group 6 deaths and among low RVP patients 14 deaths occurred, corresponding to 25 and 7.4% of patients, respectively. Multiple variable Cox regression analysis accounting for age and ACE inhibitor/ARB prescription revealed a considerable and significant difference in overall survival to the advantage of low RVP patients (OR: 0.34, CI: 0.13–0.93, P = 0.03, Figure 3). Incorporation of incident appropriate antitachycardia treatment episodes into the multiple variable Cox model for survival analysis by RVP did not suggest an influence of appropriate VT/VF episodes on pacing-dependent survival (OR for incident VT/VF: 1.30, CI: 0.46–3.65, P = 0.62). The association of frequent RVP to impaired survival was similar and consistent in subgroups with (OR: 0.30, CI: 0.05–1.82, P = 0.19) and without (OR: 0.34, CI: 0.11–1.07, P = 0.065) appropriate VT/VF treatment, although—due to the relatively small subsample sizes—statistical significance was no longer reached. In addition, the occurrence of a VT/VF treatment...
episode (appropriate or inappropriate) per se was not significantly linked to survival (OR: 0.51, CI: 0.18–1.42, \( P = 0.20 \)). QRS duration was linked to survival and was wider among non-survivors (133 ± 32 ms) vs. survivors (113 ± 23 ms, \( P = 0.01 \)). However, as outlined in Table 1, baseline QRS was similar among high and low RVP groups, and hence the survival difference according to RVP cannot be attributed to variations in baseline QRS. As only a minority of lethal events occurred at our own institution, mortality assessment was not only based on direct knowledge and hospital records, but had largely to be grounded on information obtained from families and/or family doctors. As a consequence, the exact course of dying and the precise cause of death remained unclear in most cases, and specific analyses with regard to arrhythmic and non-arrhythmic mortality could not be undertaken.

**Discussion**

Either caused by structural cardiac alteration or due to indispensable heart failure medication and antiarrhythmic drugs, a non-negligible proportion of patients with advanced systolic heart failure at high risk for SCD have at the same time depressed cardiac automaticity and/or slowed conduction at the atrial, AV, or intraventricular level. At the same time, patients with advanced systolic heart failure have recently been shown to be particularly affected by delayed LV electrical conduction through RV apical pacing and may be particularly exposed to adverse pacing effects. The DAVID study results intensified the scientific focus on possible detrimental consequences of RVP in patients with severe LV dysfunction. The patients in the DAVID study had no antbradycardic pacing indication, and ventricular pacing was an undesired side effect of the DDD pacing mode. The present study examined survival and VT incidence among routine single- and dual-chamber ICD patients, in whom a conservative antibradycardic pacing approach was applied. Patients with anticipated clear need of permanent ventricular pacing were excluded and were considered candidates for biventricular pacing according to current guidelines, although reliable data on the usefulness of biventricular pacing for the treatment of AV block are scarce and multicentric randomized controlled trials on biventricular pacing for AV block are still ongoing. Pacing was reserved for patients with sinus node dysfunction and/or first-degree AV block at baseline. In the presence of sinus rhythm and a presumed pacing indication, conventional dual-chamber devices were used. At the time of inclusion, dual-chamber ICDs provided with bidirectional AAI–DDD changeover modes were not yet available. Nonetheless, efforts were made to avoid ventricular pacing. Right ventricular pacing prevention was put into practice through programming long AV delays and disabling of tracking [DDI(R) mode] in the absence of obviously impaired AV conduction. Patients without apparent need for pacing received single-chamber devices and were set to the VVI mode with low basic rates.

**Study population**

The study included an undifferentiated ICD population and comprised patients implanted for primary and secondary prevention of SCD without advanced AV block at the time of implantation. Probably as a consequence of the exclusion of patients with left bundle branch block (LBBB) or advanced AV block, the average LVEF was slightly higher and the average QRS duration shorter than would have been expected from a typical mixed ICD population before the cardiac resynchronization therapy era. Although patients were not randomized, but specifically assorted according to their cumulative RVP percentages, the study groups did not significantly differ with regard to baseline characteristics. In particular, there was no discernable difference as to underlying heart disease and the prognostic predictors LVEF and QRS duration.

**Right ventricular pacing**

The goal to almost completely prevent RVP was met in the vast majority of patients, albeit a minority of ~10% still experienced significant ventricular pacing percentages. Not surprisingly, patients with dual-chamber devices had more RVP than those with single-chamber devices. But compared with the DDD ICD group from the Multicenter Automatic Defibrillator Implantation (MADIT) II trial, the antibradycardic dual-chamber programming resulted in a considerably lower median RVP proportion in the present study while incorporating long AV delays and the DDI(R) mode where possible.
Occurrence of ventricular tachycardia or ventricular fibrillation episodes

The time interval to a first appropriate ICD treatment episode did not differ between high and low RVP patients. The proportion of patients with recurrent VT or VF was slightly lower when compared with data from mixed populations during the 1990s. Possible reasons relate to medical heart failure treatment and patient selection. In particular, the proportion of patients treated with beta-blockers was ~90% in this study and below 40% in former studies. A more recent study with similarly high concomitant beta-blocker usage reported a comparable arrhythmia recurrence rate. A second reason for the relatively low VT/VF recurrence rate may be seen in the exclusion of the most severely diseased patients with wide LBBB and particularly depressed LV function. As to the association of RVP and VT/VF episodes, our data are in conflict with one recently published study by Gardiwal et al. that described detrimental effects of RVP not only on heart failure, but also on VT/VF occurrence. A likely reason for the different VT/VF incidence when compared with the present study may be seen in the predominance of patients with secondary preventive ICD indication in the population investigated by Gardiwal et al.

Long-term overall survival

Frequent RVP was associated with an important and significant impairment of overall survival, although pacing was applied conservatively and for justifiable indications. Apart from the pre-existent antibradycardic pacing indication of patients selected for dual-chamber treatment, which may—at least with regard to conduction delays—already be a hallmark of more advanced structural cardiac disease, the patients in the high RVP group were not recognizably sicker from the outset. Hence, the difference in survival does not seem to be mainly due to patient selection but may actually reflect adverse effects of RV apical pacing. Considering the sharply contrasting RVP prevalence between the study groups, dichotomization at 30% RVP does certainly not define a viable threshold value, below which undesired side effects of RVP would be unlikely to take effect. The potential of RVP to cause morbidity and/or mortality in heart failure patients is known from several unintended or post hoc analyses of ICD trials. A retrospective analysis from the MADIT II trial found the collective ICD treatment group, but in particular the patients implanted with a dual-chamber ICD, to be at increased risk for heart failure hospitalization. In addition, in the MADIT II trial, after a first heart failure hospitalization single-chamber ICDs did still reduce mortality, but dual-chamber ICDs did no longer improve survival. A second retrospective analysis demonstrated heart failure hospitalization or death to depend on the prevalence of ventricular pacing in MADIT II ICD patients. Whether dual-chamber treatment was based on a bradycardia indication in MADIT II cannot be derived from the published information. The DAVID trial found a higher incidence of death or hospitalization for heart failure in a treatment group randomized to dual-chamber ICD treatment and DDRR pacing vs. single-chamber controls. A secondary analysis of the DAVID trial results demonstrated patients with prolonged QRS to be particularly prone to heart failure or death while being paced frequently at the right ventricular apex. Probably as a consequence of the exclusion of LBBB patients and the limited sample size, a statistical interaction of QRS duration and adverse effects of RVP could not be reproduced in the present study. Our study results are in accordance with a very recently published secondary analysis derived from the DAVID study. This subanalysis defined a resting heart rate <60 bpm or first-degree AV block as ‘soft’ pacing indications and examined side effects of RVP in patients without any pacing indication vs. the subgroup with suchlike ‘soft’ pacing indications. In line with our data, the study found that RVP produced similar adverse effects as to hospitalization for heart failure or death, regardless of the presence or absence of sinus bradycardia or first-degree AV block. Hence, instead of justifying a reserved approach to conventional dual-chamber antibradyarrhythmic pacing in ICD patients, recent data including the present study results add more concern to the already discouraging results of earlier investigations on RVP and survival in heart failure patients. The hypothesis that a reserved and potentially more justifiable administration of pacing for bradycardia treatment produces more favourable clinical outcomes, when compared with the effects of evident overtreatment in the DAVID trial, is not supported by the present data. As a consequence, still more effective prevention of non-essential ventricular pacing, improved application of required ventricular pacing, and reliable differentiation between the former and the latter in ICD patients are of critical importance.

Study limitations

In view of the observational and non-randomized design of the study, and the unequal size of treatment groups, the data should be taken as hypothesis generating and cannot provide concluding evidence on adverse effects of RVP. But nonetheless we consider the data of our study meaningful, as the traditional application of pacing through conventional dual-chamber ICDs is raised to question not only in heart failure patients with apparent need for ventricular pacing, but also in those with primary sinus node dysfunction and first-degree AV block.

Conclusions

Heart failure patients with an implanted ICD and need for concomitant bradycardia treatment should be cared for with particular attention to clinical worsening. High RVP percentages are associated with impaired survival of ICD patients, even when pacing is reserved for potentially justifiable indications like sinus node dysfunction and/or first-degree AV block. Approximately 10% of ICD patients without advanced AV conduction disease at the time of implantation experience significant RVP, despite efforts made to avoid this, and may benefit from innovative strategies for ventricular pacing prevention. The time to a first appropriate VT/VF treatment episode does not vary according to RVP percentages. Hence, impaired overall survival, but not the promotion of ventricular tachyarrhythmias, can be hypothesized to result from
frequent RVP. Strategies for ventricular pacing prevention like the bidirectional AAI–DDD changeover modes and alternative modalities of unavoidable ventricular pacing should prospectively be evaluated in the context of ICD therapy.

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