

ORIGINAL ARTICLE

Biventricular Pacing for Atrioventricular Block and Systolic Dysfunction

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for the Biventricular versus Right Ventricular Pacing in Heart Failure
Patients with Atrioventricular Block (BLOCK HF) Trial Investigators

ABSTRACT

BACKGROUND

Right ventricular pacing restores an adequate heart rate in patients with atrioventricular block, but high percentages of right ventricular apical pacing may promote left ventricular systolic dysfunction. We evaluated whether biventricular pacing might reduce mortality, morbidity, and adverse left ventricular remodeling in such patients.

METHODS

We enrolled patients who had indications for pacing with atrioventricular block; New York Heart Association (NYHA) class I, II, or III heart failure; and a left ventricular ejection fraction of 50% or less. Patients received a cardiac-resynchronization pacemaker or implantable cardioverter–defibrillator (ICD) (the latter if the patient had an indication for defibrillation therapy) and were randomly assigned to standard right ventricular pacing or biventricular pacing. The primary outcome was the time to death from any cause, an urgent care visit for heart failure that required intravenous therapy, or a 15% or more increase in the left ventricular end-systolic volume index.

RESULTS

Of 918 patients enrolled, 691 underwent randomization and were followed for an average of 37 months. The primary outcome occurred in 190 of 342 patients (55.6%) in the right-ventricular-pacing group, as compared with 160 of 349 (45.8%) in the biventricular-pacing group. Patients randomly assigned to biventricular pacing had a significantly lower incidence of the primary outcome over time than did those assigned to right ventricular pacing (hazard ratio, 0.74; 95% credible interval, 0.60 to 0.90); results were similar in the pacemaker and ICD groups. Left ventricular lead–related complications occurred in 6.4% of patients.

CONCLUSIONS

Biventricular pacing was superior to conventional right ventricular pacing in patients with atrioventricular block and left ventricular systolic dysfunction with NYHA class I, II, or III heart failure. (Funded by Medtronic; BLOCK HF ClinicalTrials.gov number, NCT00267098.)

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TRIALS OF CARDIAC-RESYNCHRONIZATION therapy (CRT) have included patients with advanced systolic heart failure and prolonged QRS duration.¹ These trials have specifically excluded patients with a moderate-to-high degree of atrioventricular block who require ventricular pacing in order to evaluate the effects of CRT independently of the potentially confounding detrimental effects of right ventricular pacing. Whereas right ventricular pacing achieves the primary goal of restoring an adequate heart rate in patients with atrioventricular block, studies suggest that right ventricular apical pacing may lead to progressive left ventricular dysfunction and heart failure in patients with preexisting left ventricular dysfunction,^{2,3} presumably owing to the electrical and mechanical dyssynchrony that occurs with right ventricular pacing. Biventricular pacing with the use of standard CRT devices may avoid this problem and attenuate the development of heart failure.

Accordingly, we conducted the Biventricular versus Right Ventricular Pacing in Heart Failure Patients with Atrioventricular Block (BLOCK HF) study, a prospective, multicenter, randomized, double-blind trial involving patients with a standard indication for ventricular pacing for atrioventricular block, left ventricular dysfunction (left ventricular ejection fraction, $\leq 50\%$), and mild-to-moderate heart failure. We excluded patients with indications for CRT that were based on practice guidelines. We tested the hypothesis that biventricular pacing is superior to right ventricular pacing in this patient population, as measured by a composite outcome consisting of death from any cause, an urgent care visit for heart failure, or an increase of 15% or more in the left ventricular end-systolic volume index.

METHODS

PATIENTS

We enrolled eligible patients who had a standard class I or IIa indication for a pacemaker owing to high-degree atrioventricular block and who also had New York Heart Association (NYHA) class I, II, or III symptoms of heart failure and a left ventricular ejection fraction of 50% or less. Patients with permanent atrial arrhythmias and intrinsic atrioventricular block or atrioventricular block due to atrioventricular-node ablation could be enrolled

if they met all the other enrollment criteria. Exclusion criteria were previous receipt of a cardiac implantable electrical device (whether subsequently removed or remaining), unstable angina, acute myocardial infarction, percutaneous or surgical coronary intervention within 30 days before enrollment, valvular disease with an indication for valve repair or replacement, or an indication for a CRT device according to practice guidelines.

Initially, patients enrolled in the study received pacemakers only. However, with evidence supporting the use of implantable cardioverter-defibrillator (ICD) therapy in patients with heart failure and left ventricular dysfunction for the primary prevention of sudden cardiac death,⁴ the protocol was revised in December 2005 to allow ICD implantation in such patients.

STUDY PROCEDURES

At baseline, all patients had evidence that they would require a high percentage of ventricular pacing, either because of documented third-degree atrioventricular block or the demonstration of second-degree atrioventricular block or a PR interval of 300 msec or more when paced at 100 beats per minute (atrioventricular-node conduction test). Eligible patients underwent implantation of a pacemaker or ICD with biventricular-pacing capability. In patients without persistent atrial arrhythmias, an atrial lead was also implanted for atrial-synchronized right ventricular or biventricular pacing. After successful implantation, the devices were programmed to right ventricular pacing for 30 to 60 days, during which time appropriate pharmacologic therapy could be established.

Patients were subsequently randomly assigned in a 1:1 ratio to receive either biventricular pacing or right ventricular pacing, and this randomization visit was considered to be the baseline visit. Randomization was stratified according to center and device type, and the patients were followed every 3 months until a predefined trial-stopping rule was satisfied. Patients who underwent implantation of a device but were not randomly assigned to biventricular or right ventricular pacing continued in the trial and were followed every 6 months until the end of the trial.

Clinical assessments consisting of NYHA class, heart-failure stage, height, weight, quality of life, and device interrogations were performed every 6 months. Echocardiography was performed to

calculate the left ventricular end-systolic volume index and the left ventricular ejection fraction at randomization and at the follow-up visits at 6, 12, 18, and 24 months. The patients and the health care providers responsible for the management of their heart failure were unaware of the study assignments. Only the primary provider performing the device management and the study-center personnel responsible for data collection were aware of the study-group assignments.

OUTCOME MEASURES

The primary outcome was the time to a first event of death from any cause, an urgent care visit for heart failure that required intravenous therapy, or an increase in the left ventricular end-systolic volume index of 15% or more, as compared with the value at randomization. An urgent care visit for heart failure was defined as an unplanned outpatient or emergency department visit or inpatient hospitalization in which the patient presented with signs and symptoms consistent with heart failure and required intravenous therapy. Secondary outcomes included the composite outcomes of death from any cause or urgent care visit for heart failure and death from any cause or hospitalization for heart failure, as well as the separate outcomes of death from any cause and hospitalization for heart failure.

STUDY OVERSIGHT

The steering committee, comprising five of the academic authors, conceived and designed the trial. They interpreted the results and vouch for the integrity of the data. An independent adverse-events adjudication committee that was unaware of the study assignments adjudicated all deaths, hospitalizations, and adverse events. An independent data and safety monitoring committee reviewed the interim data analyses and the total incidence of adverse events approximately every 6 months. The University of Pennsylvania served as the core echocardiography laboratory.

The monitoring, data collection, and analysis were performed by research personnel at Medtronic in partnership with the steering committee. The first author wrote the first draft of the manuscript, with review by all the coauthors. All the authors vouch for the accuracy of the data and analyses reported and the fidelity of the study to the protocol. The study protocol is avail-

able with the full text of this article at NEJM.org. Additional details are provided in a previous report on the study design⁵ and in the Supplementary Appendix, available at NEJM.org.

STATISTICAL ANALYSIS

An adaptive Bayesian study design allowing up to 1200 patients to undergo randomization was used, featuring sample size reestimation and two interim analyses with prespecified trial-stopping rules (see the Supplementary Appendix). An intention-to-treat analysis served as the primary analysis for all outcomes.

The analysis of the primary outcome included data obtained up to the time of the first primary-outcome event for each patient, provided that data on the left ventricular end-systolic volume index were available at all required time points. If these data were not available at the randomization visit or a follow-up visit (at 6, 12, 18, or 24 months), data obtained after that visit were excluded from the survival analysis of the primary outcome in order to prevent artificial extension of event-free survival time due to missing data. All data were included in the analysis of secondary outcomes.

A hierarchical Bayesian proportional-hazards model was used for analysis of the primary outcome. This model assumed a piecewise exponential hazard function for 10 follow-up periods but did not mandate that the hazard ratios for the device groups be equivalent. Markov chain Monte Carlo simulations were performed to calculate the posterior distributions for the hazard ratio with pacemaker, the hazard ratio with ICD, and the combined hazard ratio. These distributions define the likely set of values that the hazard ratios can take; the posterior probability that a variable falls in a given range is a number between 0 and 1 that serves as the estimated likelihood, on the basis of assumptions set before the trial and on accumulated trial data, that the value falls in that range. The superiority of biventricular to right ventricular pacing was established if the posterior probability of a combined hazard ratio of less than 1 was more than 0.9775.

Similar models were used to assess the composite secondary outcomes of death from any cause or urgent care visit for heart failure and death from any cause or hospitalization for heart failure, as well as the separate outcomes of death from any cause and hospitalization for

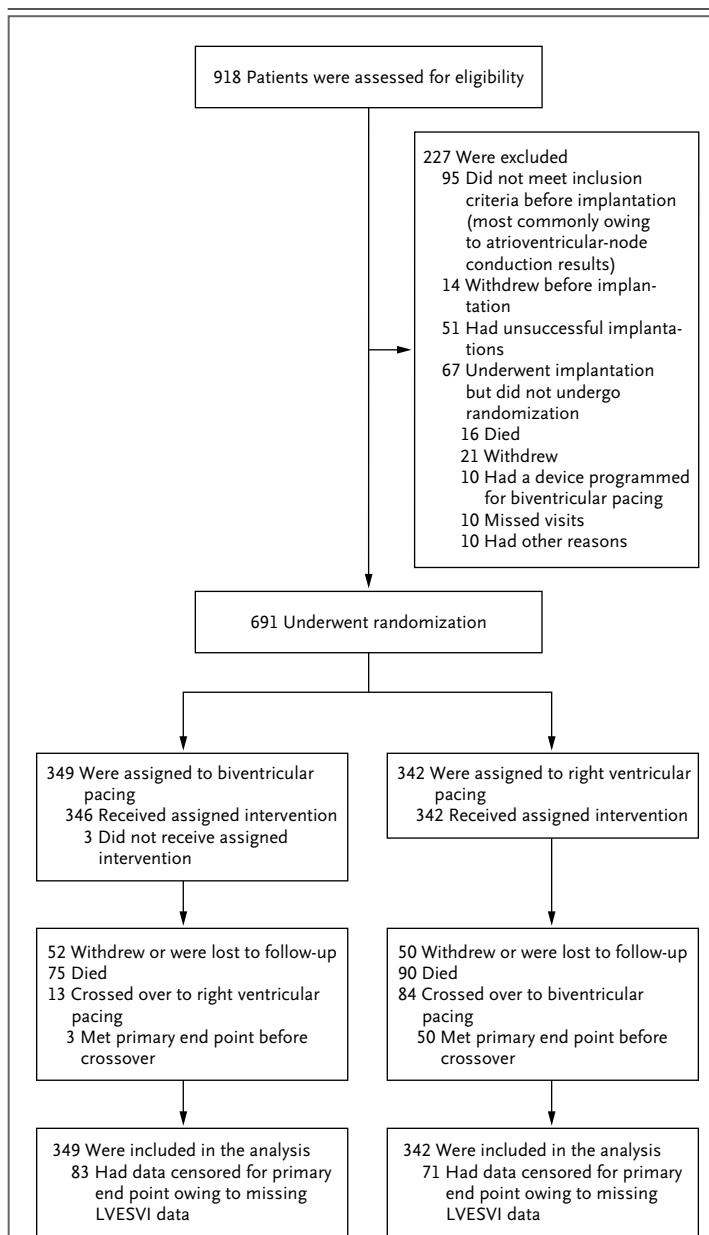


Figure 1. Study Enrollment, Randomization, and Follow-up.

Implantation of a pacemaker or defibrillator for cardiac-resynchronization therapy was attempted in 809 patients and was successful in 758 (93.7%). A total of 67 patients in whom a device was implanted did not undergo randomization; 691 patients underwent randomization. LVESVI denotes left ventricular end-systolic volume index.

Kaplan–Meier curves were generated for each outcome in each of the study groups. For all outcomes, hazard ratios were estimated as the median of the posterior distribution, and 95% two-sided credible intervals calculated from the 2.5th and 97.5th percentiles of the posterior distribution were generated for precision.

RESULTS

PATIENTS

We enrolled 918 patients at 58 centers in the United States and 2 centers in Canada from December 2003 through November 2011. All patients provided written informed consent. Patients were followed for a mean of 37 months. Implantation of a pacemaker or ICD was attempted in 809 patients and was successful in 758 (93.7%) (Fig. 1). The most common reasons for unsuccessful implantation of the left ventricular lead were inability to cannulate the coronary-sinus ostium (in 16 patients), dislodgement (in 11), and an unacceptably high pacing threshold (in 11). A total of 67 patients in whom a device was implanted did not undergo randomization; 691 patients underwent randomization.

The mean left ventricular ejection fraction for the cohort was $40.0 \pm 8.3\%$ (42.9% in the pacemaker group and 33.0% in the ICD group). Most patients had NYHA class II or III symptoms, and approximately half the patients had third-degree atrioventricular block (Table 1). A workup for the cause of left ventricular dysfunction was not required by the study protocol, so not all patients had a specific diagnosis for cardiomyopathy.

OUTCOMES

The primary outcome occurred in 186 of 349 patients (53.3%) in the biventricular-pacing group, as compared with 220 of 342 (64.3%) in the right-ventricular-pacing group. Owing to missing measures of the left ventricular end-systolic volume index, data for some patients were censored before a primary outcome event occurred. Thus, some events did not contribute to the analysis of the primary outcome. After accounting for censoring, 160 patients (45.8%) in the biventricular-pacing group and 190 (55.6%) in the right-ventricular-pacing group had events that were included in the analysis of the primary outcome (Table 2).

The incidence of the primary outcome over time was significantly lower among patients who

heart failure. For each secondary outcome defined as a study objective, a prespecified threshold of 0.95 for the posterior probability had to be exceeded for the superiority of biventricular pacing to be established.

Table 1. Baseline Clinical and Demographic Characteristics of Patients Who Underwent Randomization.*

Characteristic	Pacemaker (N = 484)		ICD (N = 207)		All Patients (N = 691)	
	Biventricular Pacing (N = 243)	Right Ventricular Pacing (N = 241)	Biventricular Pacing (N = 106)	Right Ventricular Pacing (N = 101)	Biventricular Pacing (N = 349)	Right Ventricular Pacing (N = 342)
Male sex — no. (%)	181 (74.5)	168 (69.7)	87 (82.1)	81 (80.2)	268 (76.8)	249 (72.8)
Age — yr	74.4±10.2	73.8±10.8	72.0±9.3	71.0±10.0	73.7±10.0	73.0±10.6
Left ventricular ejection fraction — %	43.4±6.5	42.5±6.6	33.0±7.8	32.9±8.0	40.3±8.4	39.6±8.3
Left ventricular ejection fraction >35% — no. (%)	213 (87.7)	215 (89.2)	30 (28.3)	25 (24.8)	243 (69.6)	240 (70.2)
Heart rate — beats/min	68.7±23.4	68.7±23.9	68.2±16.9	69.1±17.4	68.5±21.6	68.8±22.2
QRS duration — msec	125.4±32.8	124.5±31.1	122.5±30.1	119.3±30.2	124.6±32.0	123.0±30.8
NYHA class — no. (%)†						
I	35 (14.4)	47 (19.5)	11 (10.4)	16 (15.8)	46 (13.2)	63 (18.4)
II	141 (58.0)	126 (52.3)	67 (63.2)	58 (57.4)	208 (59.6)	184 (53.8)
III	66 (27.2)	68 (28.2)	28 (26.4)	27 (26.7)	94 (26.9)	95 (27.8)
Cardiomyopathy — no. (%)‡						
Ischemic	94 (38.7)	91 (37.8)	67 (63.2)	59 (58.4)	161 (46.1)	150 (43.9)
Nonischemic	47 (19.3)	65 (27.0)	26 (24.5)	25 (24.8)	73 (20.9)	90 (26.3)
Unknown	2 (0.8)	6 (2.5)	1 (0.9)	3 (3.0)	3 (0.9)	9 (2.6)
Other	9 (3.7)	6 (2.5)	2 (1.9)	2 (2.0)	11 (3.2)	8 (2.3)
CAD — no. (%)	151 (62.1)	147 (61.0)	82 (77.4)	72 (71.3)	233 (66.8)	219 (64.0)
Myocardial infarction — no. (%)	93 (38.3)	77 (32.0)	56 (52.8)	47 (46.5)	149 (42.7)	124 (36.3)
Hypertension — no. (%)	200 (82.3)	200 (83.0)	84 (79.2)	87 (86.1)	284 (81.4)	287 (83.9)
Atrial fibrillation — no. (%)	136 (56.0)	133 (55.2)	44 (41.5)	52 (51.5)	180 (51.6)	185 (54.1)
Diabetes — no. (%)	90 (37.0)	87 (36.1)	47 (44.3)	37 (36.6)	137 (39.3)	124 (36.3)
Atrioventricular block — no. (%)§						
1st degree	39 (16.0)	35 (14.5)	29 (27.4)	31 (30.7)	68 (19.5)	66 (19.3)
2nd degree	84 (34.6)	70 (29.0)	35 (33.0)	38 (37.6)	119 (34.1)	108 (31.6)
3rd degree	120 (49.4)	135 (56.0)	42 (39.6)	32 (31.7)	162 (46.4)	167 (48.8)
Bundle-branch block — no. (%)						
Left	86 (35.4)	75 (31.1)	37 (34.9)	27 (26.7)	123 (35.2)	102 (29.8)
Right	52 (21.4)	55 (22.8)	21 (19.8)	19 (18.8)	73 (20.9)	74 (21.6)

* Plus-minus values are means ±SD. There were no significant differences between the randomized groups in any of the demographic or clinical characteristics. CAD denotes coronary artery disease, ICD implantable cardioverter-defibrillator, and NYHA New York Heart Association.

† Data were missing for 1 patient in the biventricular-pacing group who received a pacemaker.

‡ Cardiomyopathy was recorded at the time of enrollment. The case-report form instructed the study site to check cardiomyopathy if it was known as part of the patient's medical history and, if so, to check the primary cause (ischemic, nonischemic, unknown, or other). Several patients had more than one type of cardiomyopathy identified. Cardiomyopathy was not identified for 102 patients in the biventricular-pacing group (92 patients with a pacemaker and 10 with an ICD) and for 87 in the right-ventricular-pacing group (75 with a pacemaker and 12 with an ICD).

§ One patient in the right-ventricular-pacing group who received a pacemaker did not have a sufficiently high degree of atrioventricular block to satisfy the inclusion criteria and was incorrectly randomly assigned to a study group and underwent implantation.

were randomly assigned to biventricular pacing than among those assigned to right ventricular pacing (Fig. 2), with similar results in the pacemaker and ICD groups. Sensitivity analyses that included censored data yielded similar findings.

The number of patients who had a primary outcome event and the number who had a secondary outcome event are shown in Table 2, along

with the corresponding hazard ratios. Among patients who reached the end point for the left ventricular end-systolic volume index, the index increased by an average of 35.3%, from 56.1 to 74.5 ml per square meter of body-surface area. With the left ventricular end-systolic volume index removed from the analysis of the primary outcome, the hazard ratio for death from any

Table 2. Primary and Secondary Outcomes.

Outcome	Pacemaker (N =484)				ICD (N =207)		Hazard Ratio (95% CI)**		Posterior Probability of Hazard Ratio <1†
	Biventricular Pacing (N =243)	Right Ventricular Pacing (N =241)	Biventricular Pacing (N =106)	Right Ventricular Pacing (N =101)	Pacemaker (N =484)	ICD (N =207)	All Patients (N =691)		
	number of patients								
Primary outcome	108	127	52	63	0.73 (0.58–0.91)	0.75 (0.57–1.02)	0.74 (0.60–0.90)	0.9978	
Event related to left ventricular end-systolic volume index	56	79	31	36					
Urgent care visit for heart failure	40	38	16	23					
Death	12	10	5	4					
Secondary outcomes‡									
Death or urgent care visit for heart failure	78	95	39	44	0.73 (0.56–0.94)	0.73 (0.53–1.02)	0.73 (0.57–0.92)	0.9970	
Death or hospitalization for heart failure	76	89	39	40	0.77 (0.58–1.00)	0.80 (0.58–1.13)	0.78 (0.61–0.99)	0.9802	
Death	52	64	23	26	0.83 (0.59–1.17)	0.84 (0.55–1.28)	0.83 (0.61–1.14)	0.8588	
Hospitalization for heart failure	49	63	27	27	0.68 (0.49–0.94)	0.73 (0.50–1.11)	0.70 (0.52–0.93)	0.9922	

* The hazard ratios reflect the comparison of biventricular pacing with right ventricular pacing for the listed outcome. The Bayesian hierarchical model allowed for the hazard ratios for the comparison of biventricular pacing with right ventricular pacing in the two device groups to differ. The model generated the hazard ratio for each device group, and the hazard ratio for all 691 patients is the overall hazard ratio for biventricular pacing, as compared with right ventricular pacing, derived with the use of a weighted average of estimates from the pacemaker and ICD groups. CI denotes credible interval.

† The posterior probability for each outcome corresponds to the hazard ratio for all patients.

‡ Data include outcome events that occurred after visits for which there were missing data on the left ventricular end-systolic volume index.

cause or urgent care visit for heart failure was also found to significantly favor the biventricular-pacing group, to a degree similar to that of the primary outcome (Table 2 and Fig. 3).

The secondary outcome of death or hospitalization for heart failure was less common among patients assigned to biventricular pacing than among those assigned to right ventricular pacing (Table 2). Rates of first hospitalization for heart failure and the composite outcome of death or hospitalization for heart failure differed significantly between the two pacing groups.

The median percentage of ventricular pacing during follow-up was 98.6% for all patients with third-degree atrioventricular block, 97.8% for those with second-degree atrioventricular block, and 97.0% for those with first-degree atrioventricular block, with no significant difference between the two pacing groups.

ADVERSE EVENTS

Within 30 days after the initial attempt to implant the device, 113 of the 809 patients in whom implantation was attempted (14.0%) had serious adverse events; 83 patients (10.3%) had events related to the procedure or CRT system. Lead dislodgements were the most common such event (in 3.0% of patients), followed by atrial fibrillation (in 1.1%). Left ventricular lead-related complications occurred in 6.4% of patients. Among the 758 patients in whom devices were implanted, 4.9% had the following serious adverse events related to the CRT system within 6 months after implantation: lead dislodgement, device lead damage, pacing failure ("failure to capture"), implantation-site infection, and inappropriate device stimulation of tissue. Most of these adverse events occurred within the first 30 days and were similar in distribution in the two pacing groups.

DISCUSSION

The results of the BLOCK HF trial showed that biventricular pacing provides superior ventricular-rate support, as compared with traditional right ventricular apical pacing, in patients with atrioventricular block, mild-to-moderate heart failure, and abnormal left ventricular systolic function. Patients receiving biventricular pacing had a lower incidence of the primary outcome of an urgent care visit for heart failure, death from any cause, or progression of heart failure, as measured by a

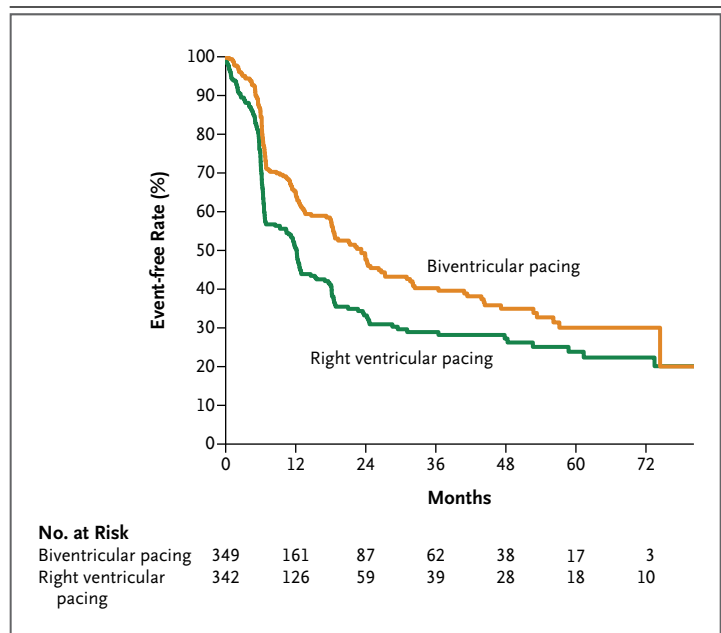


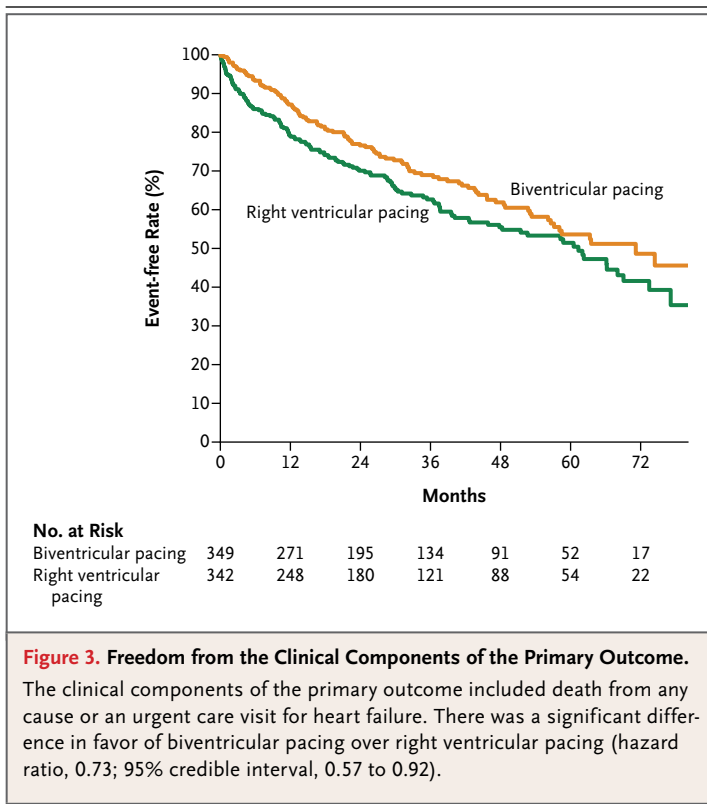
Figure 2. Freedom from a Primary-Outcome Event.

For the total cohort, the hazard ratio for the biventricular-pacing group versus the right-ventricular-pacing group was 0.74 (95% credible interval, 0.60 to 0.90). The posterior probability of a hazard ratio of less than 1 was 0.9978, which exceeded the threshold of 0.9775 for a significant difference between the two groups. When patients were stratified according to the type of device implanted (pacemaker or implantable cardioverter-defibrillator [ICD]), the hazard ratio with a pacemaker was 0.73 (95% credible interval, 0.58 to 0.91); the hazard ratio with an ICD was 0.75 (95% credible interval, 0.57 to 1.02).

significant increase in the left ventricular end-systolic volume index. The hazard ratios in the pacemaker and ICD groups in our study showed a remarkably similar clinical effect, despite a marked difference in the mean ejection fraction in these two groups, suggesting that the benefit of biventricular pacing is unlikely to be tightly linked to the ejection fraction.

These findings address the clinical need to determine the best possible pacing mode for patients with atrioventricular block and an abnormal left ventricular ejection fraction who do not have an established indication for biventricular pacing. This study adds to the body of evidence suggesting that biventricular pacing in patients with atrioventricular block preserves systolic function.⁶

Studies of the long-term effects of right ventricular pacing have lent support to the concept that such pacing may be associated with adverse outcomes related to heart failure. The Mode Selection Trial in Sinus-Node Dysfunction (MOST),²



which enrolled patients with sinus-node dysfunction who needed permanent pacing, showed that the risk of hospitalization for heart failure increased by 20% for every 10% increase in right ventricular pacing; patients who had ventricular pacing 40% or more of the time had a risk of hospitalization for heart failure that was 2.5 times as high as the risk among those who had pacing less than 40% of the time.⁷ The Dual Chamber and VVI Implantable Defibrillator (DAVID)³ trial enrolled 506 patients with indications for ICD therapy who had a left ventricular ejection fraction of 40% or less, no persistent atrial arrhythmias, and no indication for pacing. As compared with backup ventricular-demand pacing at 40 beats per minute, dual-chamber rate-responsive pacing at 70 beats per minute was associated with a higher risk of a combined outcome of death from any cause or hospitalization for heart failure.³

For patients with an intermittent or minimal need for pacing, programming to minimize ventricular pacing is standard, including the use of algorithms that favor atrial pacing over atrioventricular sequential pacing. However, in patients

with advanced atrioventricular block, ventricular pacing is obligatory, and these patients may be subject to the same poor outcomes noted in the DAVID trial and in MOST.

Potential alternatives to deleterious right ventricular pacing in these patients may be alternative site-specific pacing, such as the right ventricular outflow tract or the His bundle. In short-term studies, however, outcomes with right ventricular outflow-tract pacing have not been superior to those with right ventricular apical pacing.⁸⁻¹¹ Although one small study showed a significant difference in left ventricular ejection fraction by 18 months in favor of right ventricular outflow-tract pacing,¹² further studies would be necessary to fully assess this strategy. Furthermore, no study has shown the optimal location for a septal or outflow-tract lead or a reliable method for ensuring that it is in an optimal location.¹³ His-bundle pacing is difficult to accomplish reliably, and it is not applicable to patients with native block in the His-Purkinje system.¹⁴

Given the established role of ICD therapy in the primary prevention of sudden cardiac death in patients with heart failure and abnormal systolic function, it was imperative that an ICD be implanted in patients who met the enrollment criteria for our study and who had an independent indication for ICD therapy for primary prevention of sudden cardiac death. The addition of ICD therapy to the use of a CRT device might have affected total mortality and potentially minimized the difference between the two treatment groups. Given that the hazard ratios and 95% credible intervals for the pacemaker and ICD groups were nearly identical, we conclude that the benefit of biventricular pacing in patients with atrioventricular block is similar with the two types of devices.

A limitation of this study is the relatively large number of patients who switched from right ventricular pacing to biventricular pacing. However, a substantial proportion of these crossovers happened after a primary outcome event had occurred in the patient. Furthermore, given the intention-to-treat design, this phenomenon would probably have skewed the data in favor of right ventricular pacing and weakened the overall findings of the study. There was also a fairly high number of missing echocardiograms at various time points, resulting in the censoring and ex-

clusion of some later events from the analysis of the primary outcome. However, the analysis of the composite outcome of death or an urgent care visit for heart failure, which did not require censoring because of missing data regarding the left ventricular end-systolic volume index, showed a similar relative benefit of biventricular pacing.

In conclusion, biventricular pacing provided a significant clinical benefit over right ventricular pacing in patients with left ventricular dysfunction and atrioventricular block who require ventricular pacing.

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Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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