A Randomized Comparison of the Right- and Left-Sided Approaches to Ablation of the Atrioventricular Junction

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Radiofrequency ablation of the atrioventricular (AV) junction may be performed using either a right- or left-sided approach. This study prospectively compared the left-sided approach with persistent attempts from the right side in patients in whom initial radiofrequency applications on the right side were unsuccessful. Twenty-one of 54 patients did not have complete AV block induced after 3 right-sided radiofrequency applications. These 21 patients were randomly assigned to undergo either the left-sided approach (n = 10) or to undergo additional attempts from the right side (n = 11). The right-sided approach was performed by positioning the ablation catheter to record the largest possible atrial and His bundle electrograms. The left-sided approach was performed by positioning the ablation catheter along the left ventricular septum, where a His bundle potential was recorded. If either approach was not successful after an additional 17 radiofrequency applications, the alternative approach was then used. The AV junction was successfully ablated in all 10 patients randomized to the left-sided approach, but in only 6 of 11 patients randomized to persistent right-sided attempts (p <0.05). The 5 patients in whom the AV junction was not successfully ablated using the right-sided approach underwent the left-sided approach and had a successful outcome after a mean of 1.2 ± 0.4 radiofrequency applications. The left-sided approach required significantly fewer radiofrequency applications after randomization than the right-sided approach (3 ± 3.4 vs 11 ± 7.6, p <0.01). In patients in whom initial attempts at ablation of the AV junction using a right-sided approach are unsuccessful, the left-sided approach is more effective and efficient than persistent attempts using the right-sided approach.

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Although the conventional right-sided approach for radiofrequency ablation of the atrioventricular (AV) junction has a high success rate, some patients require multiple applications of radiofrequency energy to achieve a successful outcome.[1–6] In contrast, in most patients who have undergone ablation of the AV junction from the left ventricle, complete AV block has been induced by <5 applications of radiofrequency energy.[5–7] Therefore, the efficiency of AV junction ablation could be improved by using the left-sided approach if initial attempts with the conventional right-sided approach are unsuccessful. However, no previous studies have prospectively compared these 2 techniques. Therefore, the present study was designed to compare, in a prospective, randomized fashion, the right- and left-sided approaches to ablation of the AV junction in patients in whom an initial 3 radiofrequency energy applications using the right-sided approach are ineffective.

METHODS

Study design: Fifty-four consecutive patients with symptomatic, drug-refractory, supraventricular tachycardia underwent an attempt at radiofrequency catheter ablation of the AV junction using the conventional right-sided approach at the University of Michigan; in 33 of these patients (61%), complete AV block was induced by 1 to 3 applications of radiofrequency energy. The subjects of this study were the 21 patients in whom 3 applications of radiofrequency energy using the right-sided approach were unsuccessful in ablating AV conduction. Ten patients were randomly assigned to undergo the left-sided approach and 11 were randomly assigned to undergo additional attempts using the right-sided approach. If complete AV block was not achieved after 17 applications of radiofrequency energy using the technique to which the patient was randomly assigned, the alternate technique was then used.

Characteristics of subjects: The characteristics of the patients assigned to undergo the right- and left-sided approaches are described in Table I. All of the patients had severe symptoms caused by either atrial fibrillation or atrial tachycardia with an uncontrolled ventricular rate. The only difference in the clinical characteristics between the 2 groups was that the indication for AV junction ablation was paroxysmal atrial fibrillation more often in the patients assigned to the left-sided approach (p = 0.04, Table I).

Study protocol: The study protocol was approved by the Human Research Committee at the University of

Michigan, and informed, written consent was obtained from all patients. A 6 or 7Fr electrode catheter was inserted into a femoral vein and positioned in the right ventricular apex for use as a temporary pacemaker. The catheter used for ablation was a 7Fr bipolar or quadripolar electrode catheter with a 4 mm distal electrode, 2 to 5 mm interelectrode spacing, and a deflectable tip (Mansfield Scientific, Boston, Massachusetts). Bipolar recordings from the distal pair of electrodes of the ablation catheter were filtered at 50 to 500 Hz and recorded at a gain of 80 mm/mV. The intracardiac electrograms and leads V_1, I, II and III were displayed on an oscilloscope and recorded on a Siemens-Elema Mingograph-7 recorder at a paper speed of 25 to 100 mm/s. All patients received 3,000 U of intravenous heparin at the start of the procedure.

Ablation protocol: The right-sided approach to ablation of the AV junction was performed by inserting the ablation catheter in the right femoral vein and positioning it at the anterior/superior aspect of the tricuspid annulus. Radiofrequency energy was applied at sites where the largest possible atrial and His bundle deflections were recorded.

The technique used to ablate the AV junction from the left ventricle has been described previously.[7] The ablation catheter was inserted into a femoral artery and positioned in the left ventricle along the anterior septum. Radiofrequency energy was applied at sites at which the largest possible His bundle deflection was recorded, irrespective of the size of the atrial electrogram. Radiofrequency energy was delivered as an unmodulated sine wave at a frequency of 500 kHz (EP Technologies, Inc, Mountainview, California) between the distal electrode of the ablation catheter and a large skin electrode (Valleylab, Boulder, Colorado) positioned on the posterior chest. All applications of radiofrequency energy were at an output of 35 W and were 30 seconds in duration.

The procedure duration and the duration of fluoroscopy from the point of randomization, including the time required for arterial cannulation in patients randomized to the left-sided approach, and the number of radiofrequency energy applications required after randomization were recorded in each case. The time at which complete AV block was induced was taken as the end of the ablation procedure.

The intrinsic escape rhythm 15 minutes after ablation was recorded in each patient by adjusting the temporary pacemaker to a rate of 30 beats/min for up to 2 minutes. If an escape rhythm emerged, its cycle length was measured.

Postablation protocol: Patients were observed for 15 to 30 minutes after ablation of the AV junction. If complete AV block persisted, a rate-responsive ventricular pacemaker was implanted. To avoid postablation ventricular tachycardia, pacing was performed at a rate of 80 to 90 beats/min for 24 to 48 hours after the procedure. Patients underwent continuous, telemetric electrocardiographic monitoring for 2 to 3 days and were then discharged from the hospital. They were seen at follow-up 1 to 2 weeks and 3 months after ablation to evaluate the efficacy of the procedure and to determine the rate of the intrinsic escape rhythm. All patients were instructed to contact one of the authors in the event of a recurrence of arrhythmia-related symptoms.

TABLE I Characteristics of Patients Randomly Assigned to Undergo Right- and Left-Sided Ablation of the Atrioventricular Junction

	Right-Sided (n = 11)	Left-Sided (n = 10)
Age (years, mean ± SD)	64 ± 10	63 ± 9
Women:men	5:6	6:4
Heart disease present	4 (36%)	4 (40%)
Heart disease type		
Coronary artery disease	3	2
Hypertensive	1	2
LVEF (mean ± SD)	0.51 ± 0.09	0.50 ± 0.13
Symptom duration (years)	7 ± 4	9 ± 5
Indication for ablation		
Paroxysmal AF	4	9
Chronic AF	5	1
Atrial tachycardia	2	0
Rhythm during ablation		
Sinus rhythm	5	7
Atrial fibrillation	6	3
Number of prior medications	4.5 ± 3	4.4 ± 2.1

AF = atrial fibrillation; LVEF = left ventricular ejection fraction.

Statistical analysis: Values are expressed as mean ± 1 SD. Continuous variables were analyzed using Student's unpaired *t* test. Categorical variables were analyzed by Fishers exact test or contingency table analysis. A p value <0.05 was considered significant.

RESULTS

Efficacy of ablation attempts (Table II): Each of the 10 patients randomly assigned to the left-sided approach had a successful outcome, compared with 6 of the 11 patients (54%) randomly assigned to continue with the right-sided approach ($p < 0.05$). Based on an intention-to-treat analysis, the 10 patients randomized to undergo the left-sided approach required significantly fewer radiofrequency applications after randomization than did the 11 patients randomized to the right-sided approach (3 ± 3.4 vs 11 ± 7.6, $p < 0.01$).

The 5 patients in whom the right-sided approach was ineffective in creating AV block underwent the left-sided approach and had a successful outcome after a mean of 1.2 ± 0.4 radiofrequency applications. Among the patients randomly assigned to the right-sided approach, there were no significant differences between those in whom the right-sided approach was successful and those who crossed over to the left ventricular approach with respect to age, gender, underlying heart disease, left ventricular ejection fraction, or rhythm at the time of the ablation procedure.

Duration of procedures: Based on an intention-to-treat analysis, there were no significant differences between the patients randomly assigned to undergo the left-sided approach and those randomly assigned to the right-sided approach with respect to the time required to achieve complete AV block (18.2 ± 12.4 vs 26.8 ± 16.8 minutes, $p = 0.2$) or the duration of fluoroscopy (8 ± 8.3 vs 16.8 ± 13.5 minutes, $p = 0.1$) after randomization.

Electrogram characteristics at ablation sites: Because only 6 successful right-sided target sites were

TABLE II Results and Long-Term Complications of the Right-Sided and Left Ventricular Approaches for Ablation of the Atrioventricular Junction

Patient	Heart Disease	LVEF	Initial Approach	Number of RF Applications	Outcome	Number of RF Appl. After Crossover	Outcome After Crossover	Follow-Up (mos)	Long-Term Comp.
1	SH	0.55	Left	12	3° AVB	—	—	17	0
2	0	0.55	Left	1	3° AVB	—	—	16	0
3	SH	0.50	Left	1	3° AVB	—	—	16	0
4	0	0.50	Left	1	3° AVB	—	—	15	0
5	0	0.59	Left	3	3° AVB	—	—	12	0
6	CAD	0.54	Left	1	3° AVB	—	—	12	0
7	0	0.52	Left	4	3° AVB	—	—	9	0
8	0	0.55	Left	1	3° AVB	—	—	8	0
9	CAD	0.15	Left	4	3° AVB	—	—	3	SD
10	0	0.50	Left	2	3° AVB	—	—	7	0
11	0	0.65	Right	17	No AVB	1	3° AVB	16	0
12	CAD	0.35	Right	17	No AVB	2	3° AVB	1	SD
13	SH	0.45	Right	17	No AVB	1	3° AVB	7	0
14	0	0.55	Right	17	No AVB	1	3° AVB	7	0
15	CAD	0.42	Right	17	No AVB	1	3° AVB	14	0
16	CAD	0.45	Right	2	3° AVB	—	—	7	0
17	0	0.50	Right	14	3° AVB	—	—	14	0
18	0	0.55	Right	12	3° AVB	—	—	10	0
19	0	0.57	Right	1	3° AVB	—	—	14	0
20	0	0.53	Right	1	3° AVB	—	—	9	0
21	0	0.60	Right	6	3° AVB	—	—	8	0

Appl. = applications; AVB = atrioventricular block; CAD = coronary artery disease; Comp. = complications; SH = systemic hypertension; LVEF = left ventricular ejection fraction; RF = radiofrequency energy; SD = sudden death.

TABLE III Characteristics of Successful and Unsuccessful Target Sites for Ablation of Atrioventricular Junction

	Right-Sided Sites		Left-Sided Sites	
	Successful (n = 39)	Unsuccessful (n = 202)	Successful (n = 15)	Unsuccessful (n = 21)
Atrial amplitude (mv)	0.43 ± 0.38‡	0.19 ± 0.25	0.13 ± 0.16	0.22 ± 0.14
His amplitude (mv)	0.14 ± 0.08*	0.07 ± 0.08	0.13 ± 0.09†	0.07 ± 0.08
Ventricular amplitude (mv)	0.73 ± 0.35*	0.59 ± 0.32	0.83 ± 0.27	0.86 ± 0.27
Atrial/ventricular ratio	0.83 ± 1.14‡	0.56 ± 1.23	0.18 ± 0.20	0.29 ± 0.21
His/ventricular ratio	0.24 ± 0.23*	0.13 ± 0.16	0.19 ± 0.19†	0.08 ± 07

*p < 0.05 versus unsuccessful right-sided sites.
†p < 0.05 versus unsuccessful left-sided sites.
‡p < 0.05 versus successful left-sided sites.

available for analysis among the 11 patients randomly assigned to the right-sided approach, the target sites among the 33 patients who had a successful outcome with initial attempts using the right-sided approach and who did not qualify for randomization were also analyzed. The electrogram characteristics of the successful and unsuccessful right- and left-sided target sites are described in Table III. Successful right-sided sites had atrial, His bundle and ventricular electrograms that were significantly larger in amplitude than the corresponding electrograms at unsuccessful right-sided sites. In comparing the successful and unsuccessful left-sided target sites, only the amplitude of the His bundle electrogram was significantly larger at successful sites than at unsuccessful sites. In comparing the successful right- and left-sided sites, the atrial electrogram amplitude and the atrial:ventricular electrogram ratio were significantly larger on the right side.

Intrinsic escape rhythms: Fifteen minutes after ablation of AV conduction, 9 of 15 patients (60%) who had a successful outcome with the left-sided approach had an intrinsic escape rate <30 beats/min, compared with 4 of 6 patients (67%) who had a successful outcome with the right-sided approach (p = 0.8). Among patients in whom an escape rhythm was present 15 minutes after ablation, the mean cycle lengths of the escape rhythms in the patients who underwent the left- and right-sided approaches did not differ significantly (1,737 ± 431 vs 1,500 ± 354 ms, p = 0.5).

Three months after the ablation procedure, 3 of 15 patients (20%) who had a successful outcome with the left-sided approach had an intrinsic escape rate <30 beats/min, compared with 2 of 6 patients (33%) who had a successful outcome with the right-sided approach (p = 0.8). Among patients in whom an escape rhythm was present 3 months after ablation, the mean cycle lengths of the escape rhythms in the patients who underwent the left- and right-sided approaches did not differ significantly (1,436 ± 189 vs 1,560 ± 81 ms, p = 0.3).

Long-term follow-up (Table II): During a mean of 10.6 ± 4.5 months of follow-up, all patients continued to have complete AV block. Two patients died sudden-

ly during follow-up (Table II). One patient who was assigned to the left-sided approach had an ischemic cardiomyopathy and a left ventricular ejection fraction of 0.15 and died in his sleep approximately 3 months after the ablation procedure. A second patient, who was assigned to the right-sided approach but crossed over to the left-sided approach and had coronary artery disease, a history of an anterior wall myocardial infarction, and a left ventricular ejection fraction of 0.35, had a fatal out-of-hospital cardiac arrest with documented ventricular fibrillation 1 month after the ablation procedure. A postmortem examination was not performed in either patient.

DISCUSSION

Main findings: The results of this study demonstrate that when AV block is not easily achieved with ≤3 applications of radiofrequency energy using the conventional right-sided approach for catheter ablation of the AV junction, it may be preferable to then use the left-sided approach instead of persisting with right-sided attempts. The left-sided approach was uniformly effective in creating complete AV block, whereas persistent right-sided attempts eventually were successful in only 54% of the patients assigned to this approach. A noteworthy indication of the value of the left-sided approach is that complete AV block was achieved by only 1 or 2 radiofrequency applications in the left ventricle, after a total of 20 applications had been ineffective in 5 patients who had been assigned to the right-sided approach.

Another indication of the superiority of the left-sided approach over continued use of the right-sided approach is that based on an intention-to-treat analysis, a mean of 11 radiofrequency applications was required to achieve success in patients randomized to the right-sided approach, compared with a mean of only 3 applications with the left-sided approach. Therefore, when radiofrequency ablation of the AV junction is not effective after 3 applications of radiofrequency energy at the tricuspid annulus, switching to the left-sided approach is more efficacious and efficient than continuing to attempt ablation from the right side.

Duration of procedures: Although fewer applications of radiofrequency energy were required to achieve complete AV block with the left-sided than with the right-sided approach, this greater efficiency was not associated with a decrease in the total duration of the ablation procedure. When switching to the left ventricular approach, several minutes are required to cannulate the femoral artery and to position the ablation catheter in the left ventricle, and this may partially offset the advantage gained by achieving a successful outcome with fewer applications of radiofrequency energy.

Comparison with previous studies: In previous reports on the efficacy of the left-sided approach to ablation of the AV junction, patients were limited to those in whom multiple applications of radiofrequency energy along the tricuspid annulus had been ineffective.[5–7] In accord with the results of the present study, complete AV block was achieved with a small number of energy applications in the left ventricle after multiple energy applications on the right side had failed. The present study is the first to demonstrate an advantage of the left ventricular approach even in patients in whom only 3 applications of radiofrequency energy on the right side have failed.

Electrogram characteristics at ablation sites: The amplitude of the His bundle electrogram was associated with a successful outcome at both right- and left-sided target sites. However, the amplitude of the atrial electrogram was associated with successful ablation only on the right side. The mean amplitude of the atrial electrogram at effective target sites in the left ventricle was significantly smaller than at effective target sites on the right side, and no different from the mean amplitude of the atrial electrogram at ineffective left-sided sites. These results are in agreement with the results of prior studies and imply that the left ventricular approach results in ablation of a more distal portion of the AV junction.[1,2,6,7]

Intrinsic escape rhythms: No differences were noted either at 15 minutes or at 3 months after ablation between the right- and left-sided approaches in the proportion of patients having an escape rhythm of <30 beats/min, or in the mean rate of the escape rhythms faster than 30 beats/min. Therefore, with respect to intrinsic escape rhythms, there is no evidence of any advantage or disadvantage to the left-sided approach compared with persistent use of the right-sided approach when initial attempts with the right-sided approach are ineffective.

Complications of ablation: Two patients in this study died suddenly within 3 months after undergoing ablation of the AV junction. A successful outcome had been achieved using the left-sided approach in both patients, 1 after 3 unsuccessful right-sided radiofrequency applications, and the other after 20. Sudden death has been reported to occur in approximately 2% of patients who undergo direct-current ablation of the AV junction,[8] but has never been reported after radiofrequency ablation.[1–7,9] As was the case in most patients who died suddenly after direct-current ablation of the AV junction, the 2 patients in this study who died suddenly had severe preexisting left ventricular dysfunction. It is unclear whether their sudden deaths were related to the underlying heart disease, the ablation procedure, or a combination of both factors. However, the fact that no sudden deaths have been reported in a large number of patients who have undergone radiofrequency ablation of left- or right-sided accessory pathways or AV nodal reentrant tachycardia suggests that the sudden deaths in the present study are more likely to have been a complication of the underlying heart disease than the ablation procedure.[10–18]

Study limitations: A major limitation of the design of this study is that it does not allow a comparison of the complication rates of the right- and left-sided approaches to radiofrequency ablation of the AV junction. Each patient in this study in whom radiofrequency energy was delivered in the left ventricle already had received either 3 or 20 applications of radiofrequency energy on the right side. Therefore, although all of the complications that occurred in this study occurred in patients in whom AV block was achieved using the left ventricular approach, it cannot be known whether these

complications were attributable to the right-sided or left ventricular energy applications. A study design in which patients were randomly assigned to the right-sided and left ventricular approaches without any previous ablation attempt would have permitted a comparison of complication rates. However, because it is unlikely in clinical practice that the left ventricular approach ever would be used without first trying the right-sided approach, it was believed that this type of study design would not have been clinically relevant.

Conclusions: In patients who are appropriate candidates for radiofrequency ablation of the AV junction, complete AV block can be achieved easily and quickly in almost all patients using the conventional, right-sided approach to ablation. However, if AV conduction persists after 3 radiofrequency applications at the tricuspid annulus, it is more efficient to switch to the left-sided approach than to persist with the right-sided approach. In patients in whom left ventricular catheterization would be problematic, persistent attempts with the right-sided approach may be appropriate. These would include patients with aortic stenosis, a prosthetic aortic or mitral valve, and patients with occlusive arterial disease.

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