Research Square

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Efficacy and Safety of Low-Power (20 W) Catheter Ablation for Typical Atrioventricular Nodal Reentrant Tachycardia: A Prospective Multicenter Study

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Abstract

Background

Atrioventricular nodal reentrant tachycardia (AVNRT) is the most common supraventricular tachycardia. Although catheter ablation is the definitive treatment, atrioventricular (AV) block requiring permanent pacemaker implantation remains a major safety concern.

Objective

To evaluate the efficacy and safety of a low-power (20 W) slow pathway ablation strategy for typical AVNRT.

Methods

In this prospective multicenter study, 203 consecutive patients (mean age 54.4 ± 17.3 years; 59.6% women) underwent slow pathway ablation initiated at 20 W, with power escalation as needed. Variables associated with requiring higher power were analyzed using univariate logistic regression.

Results

Initial success at 20 W was achieved in 170 patients (83.7%); 33 patients (16.3%) required higher power. Compared with patients who achieved success at 20 W, those requiring higher power were younger and had higher pre-ablation heart rates. On univariate analysis, younger age (odds ratio [OR] 0.66 per 10-year increase, 95% confidence interval [CI] 0.54–0.83; $p < 0.001$) and higher pre-ablation heart rate (OR 1.88 per 10-bpm increase, 95% CI 1.30–2.73; $p < 0.001$) were associated with the need for higher power. Transient AV block occurred in 1.9% of patients, and no cases of permanent AV block or pacemaker implantation were observed. During 18.3 ± 4.1 months of follow-up, recurrence occurred in two patients (0.9%).

Conclusion

An initial 20 W ablation strategy provides high efficacy with excellent safety and no permanent AV block. Younger age and a higher baseline heart rate predicted the need for power escalation, supporting a stepwise low-to-high power approach for AVNRT ablation.

Introduction

Slow pathway modification using radiofrequency (RF) energy is the gold standard for treating atrioventricular nodal reentrant tachycardia (AVNRT) due to its high success rates.[1] The primary complication of AVNRT ablation is complete atrioventricular (AV) block, with reported incidences ranging from 0.1% to 0.8%.[2–4] Additionally, the late AV block requiring permanent pacemaker implantation (> 1 month after ablation) has been reported at 0.4% of patients.[5] Despite the clinically meaningful risk of acute and late AV block, data remain limited regarding optimal RF power settings for AVNRT ablation.

Slow pathway modification is generally performed by identifying the anatomical target site, confirming electrogram characteristics, and initiating ablation. Although this approach is widely practiced, no standardized protocol exists for optimal energy delivery or endpoint definitions, resulting in substantial procedural variability among operators. Prior studies have reported a broad range of power settings, from 20W to 50W, with some adopting stepwise power-escalation strategies.[6–8]

Notably, Bortone et al. reported that slow-accelerated junctional rhythm occurred at a mean power of 18.5 W during slow pathway modification. Furthermore, a recent study by Kawaji et al., using a near-field detection algorithm–guided approach, suggested that the slow pathway is relatively superficial, supporting the feasibility of effective ablation using lower energy levels.[9] However, evidence for low-energy ablation remains limited, with most studies conducted in single center settings and involving small, highly selected patient cohorts.[8, 10]

The present study evaluates slow pathway ablation using low-power RF energy (20 W) and demonstrated favorable clinical outcomes with a low risk of procedure-related permanent AV block.

Methods

Study patients

We conducted a prospective multicenter trial at three tertiary referral hospitals between May 2017 and February 2022. A total of 203 patients undergoing slow pathway ablation for typical AVNRT with 20 W energy were enrolled. All patients provided informed consent before the electrophysiology study and catheter ablation procedure. The study protocol was reviewed and approved by the institutional review board of Chungnam National University Sejong Hospital (CNUH201906005006-HE002).

Definition

Typical AVNRT was defined by an atrial-His/His-atrial ratio > 1 and a His-atrial interval ≤ 70 msec.[11] The echo window was defined as the interval during programmed stimulation with 10 msec decrements, in which a single echo was observed after ablation. Transient AV block was defined as second-degree AV block (Mobitz type I or II) or third-degree AV block that resolved completely during the procedure. Recurrence was defined as documented supraventricular tachycardia on a 12-lead ECG, 24-hour Holter monitoring, portable ECG devices, or repeat electrophysiology study.

Electrophysiology study and ablation

RF energy was delivered in pulses of up to 60 s at optimal sites, with a maximum temperature of 60°C.[12] Electrophysiology studies were performed in the fasting state. All patients discontinued antiarrhythmic medications for at least 5 half-lives. Conscious sedation with midazolam, propofol, and fentanyl was administered. Venous access was obtained through both groins, and multipolar catheters were placed in standard positions: the high right atrium, coronary sinus, right ventricular apex, and His bundle. Sustained typical AVNRT was induced in all patients using programmed atrial and ventricular stimulation at different cycle lengths, with isoproterenol administered when necessary.

Slow pathway ablation followed standard technique using three types of conventional 4-mm ablation catheters (Blazer®, Boston Scientific, Natick, MA, USA; EZ Steer®, Biosense Webster Inc. Irvine, CA, USA; Safire®, St. Jude Medical, Minnetonka, MN, USA). The ablation catheter was positioned in the posterior part of the atrial septum, between the tricuspid annulus and the coronary sinus ostium, until the atrial-to-ventricular electrogram ratio ranged from approximately 1:10 to 1:3, with a delay in the atrial electrogram relative to the His bundle recording. When multicomponent or low-amplitude high frequent potentials were identified, RF energy was applied for up to 20 seconds until a junctional rhythm with 1:1 retrograde ventriculoatrial (VA) conduction was observed.[13, 14] Slow-accelerated junctional rhythm—defined as ≥ 5 junctional beats with a mean cycle length > 350 msec[15]—was considered indicative of effective modification, after which RF energy was continued for up to 60 seconds. If fast-accelerated junctional rhythm (≥ 5 junctional beats with a mean cycle length ≤ 350 msec[15]) or VA block occurred,[16] RF delivery was immediately discontinued, and the catheter was repositioned. Acute success was defined as the non-inducibility of typical AVNRT, regardless of the presence of an AH jump or less than two echo beats, with or without isoproterenol administration. If slow-accelerated junctional rhythm was absent or AVNRT remained inducible after adequate 20 W ablation, power escalation to ≥ 25 W was performed. Failed ablation was defined as termination of the procedure with persistent inducible AVNRT.

The successful slow pathway ablation sites were categorized into three anatomical regions. The posterior region included sites along the tricuspid septal annulus extending to the inferoposterior interatrial septum near the coronary sinus ostium. The anterior region was near the His-bundle catheter along the tricuspid septal annulus. The mid-region was located between the posterior and anterior regions.

Study outcome

The primary efficacy endpoints were to assess the acute procedural success and post-ablation recurrence. The primary safety endpoint was the incidence of serious adverse events, particularly AV block, occurring during the procedure or follow-up. An independent clinical events committee adjudicated procedure-related serious adverse events.

Follow-up

Routine follow-up visits were scheduled at 1, 6, 12, 18, and 24 months post-procedure. Patients were also instructed to contact the study team if they experienced symptoms of tachycardia or bradycardia.

Statistical analysis

Continuous variables are presented as mean ± standard deviation and categorical variables as frequencies. Group differences were performed using the χ^2 test for categorical variables and Student's t-test for continuous variables. Univariate logistic regression was used to identify predictors of requiring power escalation above 20 W. Odds ratio (OR) with 95% confidence interval (CI) were calculated per 10-year increase for age, per 10-bpm increase for heart rate, and per 1°C increase for temperature. A p value < 0.05 was considered statistically significant. Statistical analysis was performed using commercially available software (SPSS 21 for Windows; SPSS Inc., Chicago, IL, USA).

Results

Baseline characteristics

The baseline clinical characteristics of the study patients are summarized in Table 1. The mean age of the 203 patients was 54.4 ± 17.3 years, with 82 men and 121 women. Hypertension was present in 68 patients (33.5%), and diabetes in 31 patients (15.3%).

Table 1
Clinical Characteristics of the Study Patients

Number of patients	**203**
Age (years)	54.4 ± 17.3
Female, n (%)	121 (59.6%)
Hypertension	68 (33.5%)
Diabetes	31 (15.3%)
Coronary artery disease	12 (5.9%)
Valvular heart disease	0
Chronic lung disease	0
Stroke	4 (2.0%)
Values are expressed as the mean ± standard deviation or n (%).	

Ablation procedures

Procedural data are summarized in Table 2. Slow pathway ablation using 20 W was acutely successful in 170 of 203 patients (83.7%). Successful ablation sites were located in the posterior region in 83 cases, the mid-region in 72 cases, and the anterior region of the triangle of Koch (ToK) in 15 cases. The mean number of RF applications required to achieve slow-accelerated junctional rhythm was 6.1 ± 4.8 in patients with initial success at 20 W and 16.8 ± 14.9 in those requiring higher power.

Table 3
Comparison between the Group with Initial Success at 20W and the Group Requiring Higher Power

Clinical Characteristics	**Initial Success at 20 W (N = 170)**	**Requiring Higher Power (N = 33)**	***P* Value**
Age	56.4 ± 16.5	43.8 ± 17.1	< 0.001
Sex	67 (36.4%)	15 (45.5%)	0.517
Hypertension	58 (34.1%)	10 (30.3%)	0.671
Diabetes	31 (18.2%)	0	0.008
Valvular heart disease	0	0	N/A
Coronary artery disease	9 (5.3%)	3 (9.1%)	0.397
Chronic lung disease	0	0	N/A
Stroke	4 (2.4%)	0	0.373
Procedural characteristics			
Ablation site			0.060
Ablation at the posterior region of the ToK, n (%)	83 (48.8%)	9 (27.3%)	
Ablation at the mid-region of the ToK, n (%)	72 (42.4%)	18 (54.5%)	
Ablation at the anterior region of ToK, n (%)	15 (8.8%)	6 (18.2%)	
Mean RF applications	6.1 ± 4.8	16.8 ± 14.9	< 0.001
Session with obtained slow-accelerated junctional rhythm	4.9 ± 4.6	8.4 ± 6.4	0.002
Procedure duration (min)	82.2 ± 22.0	112.4 ± 30.1	< 0.001
Fluoroscopic time (min)	13.2 ± 8.2	21.5 ± 11.2	< 0.001
Heart rate before ablation	77.3 ± 10.8	84.8 ± 11.8	< 0.001
RF application duration (sec)	81.7 ± 53.5	85.4 ± 17.3	< 0.001
Number of RF applications	6.1 ± 4.8	16.8 ± 14.9	< 0.001
Total RF delivery time (sec)	221.3 ± 140.8	496 ± 442.3	0.001

Values are expressed as the mean ± standard deviation or n (%).

AV, atrioventricular; RF, radiofrequency; ToK, triangle of Koch; RF, Radiofrequency.

Clinical Characteristics	Initial Success at 20 W (N = 170)	Requiring Higher Power (N = 33)	*P* Value
ECG characteristics	159.8 ± 26.2	151.0 ± 27.8	0.039
Pre-PR interval(ms)	160.5 ± 27.2	156.0 ± 23.3	0.325
Post-PR interval(ms)			
Values are expressed as the mean ± standard deviation or n (%).			
AV, atrioventricular; RF, radiofrequency; ToK, triangle of Koch; RF, Radiofrequency.			

Among 33 patients who required higher power escalation beyond 20 W, 17 (8.4%) achieved success with 25 W, and 16 (7.9%) required > 25 W. In all cases, ablation was performed in the posterior or mid-region of the ToK. Three patients (1.5%) ultimately had unsuccessful slow pathway ablation. Compared with those who achieved initial success at 20 W, patients requiring higher power were significantly younger (43.8 ± 17.1 vs 56.4 ± 16.5 years, $P < 0.001$) and had higher pre-ablation heart rates (84.8 ± 11.8 vs 77.3 ± 10.8 bpm, $P < 0.001$). Univariate logistic regression showed an inverse association between age and the need for power escalation (OR 0.66 per 10-year increase, 95% CI 0.54–0.83; $p < 0.001$), and positive associations with pre-ablation heart rate (OR 1.88 per 10-bpm increase, 95% CI 1.30–2.73; $p < 0.001$) and maximum temperature (OR 1.11 per 1°C increase, 95% CI 1.02–1.20; p = 0.015). Several comorbidities were absent or rare in the > 20 W group, limiting reliable estimation of their effects. (Table 4, Fig. 1)

Table 4
Univariate Predictors of Requiring Higher Power (above 20 W)

Variable	Requiring Higher Power (N = 33)	Initial Success at 20 W (N = 170)	OR (95% CI)	*P* Value
Female sex	18/33 (54.5%)	103/170 (60.6%)	0.78 (0.37–1.65)	0.518
Age (per 10 years)	43.8 ± 17.1	56.4 ± 16.5	0.66 (0.54–0.83)	< 0.001
Hypertension	10/33 (30.3%)	58/170 (34.1%)	0.84 (0.37–1.88)	0.671
Diabetes mellitus	0/33 (0.0%)	31/170 (18.2%)	NE	0.003
Valvular disease	0/33 (0.0%)	0/170 (0.0%)	NA	
Coronary artery disease	3/33 (9.1%)	9/170 (5.3%)	1.79 (0.46–6.99)	0.403
Chronic lung disease	0/33 (0.0%)	0/170 (0.0%)	NA	
Chronic kidney disease	0/33 (0.0%)	1/170 (0.6%)	NE	1.000
Prior stroke	0/33 (0.0%)	4/170 (2.4%)	NE	1.000
Heart rate before ablation (per 10 bpm)	84.8 ± 11.8	77.3 ± 10.8	1.88 (1.30–2.73)	< 0.001

Notes: Categorical variables are presented as n/N (%), and continuous variables as mean ± SD. Odds ratios (ORs) and *p* values were estimated using univariate logistic regression. For variables with complete separation (zero cell counts), ORs are not estimable (NE) and *p* values are from Fisher's exact test. Variables with no variability in the cohort are marked as not applicable (NA). Max temperature had 1 missing value in the success group and was analyzed using complete cases.

VA block during junctional ectopy occurred in 48 patients (23.6%) during RF application. Transient anterograde AV block was observed in 4 patients (1.9%), including three cases of second-degree Mobitz type I blocks and one case of third-degree AV block. All transient AV blocks occurred either after the acceleration of slow-accelerated junctional rhythm or during VA block assessment, prompting immediate cessation of RF application. All events were resolved completely before the end of the procedure. No patient developed permanent AV block requiring pacemaker implantation.

Follow-up observation

Patients were followed for an average of 18.3 ± 4.1 months. Among those who experienced transient AV block during the procedure, no recurrence of AV block was observed, and none required permanent pacemaker implantation. AVNRT recurred in two patients (0.9%), both of whom underwent repeat ablation with 30 W. No adverse events were reported during follow-up.

Discussion

The findings of this study demonstrate that low-power RF application for slow pathway modification is both effective and safe in patients with typical AVNRT. In this study, 83.7% of patients achieved successful ablation with an initial power of 20 W. Younger age and higher pre-ablation heart rate were associated with the need for

higher power. Over a mean follow-up of 18.3 ± 4.1 months, no patients developed permanent AV block requiring pacemaker implantation, and the recurrence rate following low-power ablation was 0.9%. These results indicate that initiating ablation with low-energy (20 W), followed by escalation when necessary, is a safe and effective strategy.

The risk of permanent AV block extends beyond the immediate post-procedural period and may manifest months or even years after ablation. Previous studies have reported cases of very late-onset second- or third-degree AV block following AVNRT ablation.[17, 18] Transient retrograde VA block during junctional rhythm or the development of fast-accelerated junctional rhythm have been identified as predictors of AV block during slow pathway ablation. Accordingly, prompt recognition of these signs and immediate discontinuation of RF delivery are essential to prevent irreversible injury. In this study, 48 patients (23.6%) experienced transient VA block; however, immediate cessation of energy delivery prevented progression to permanent AV block.

Several strategies have been proposed to reduce the risk of AV block, including temporarily interrupting RF delivery at the onset of junctional rhythm and performing multiple short applications lasting ≤ 30 seconds.[19] Liberman et al.,[20] suggested rapid atrial pacing during ablation to confirm preserved anterograde AV conduction. However, if junctional rhythm is slightly faster than the pacing cycle length, it may be difficult to recognize, potentially delaying energy cessation. Low-power ablation has also been investigated as a strategy to reduce AV block risk.[8, 10, 21, 22] Table 5 summarizes previous findings alongside the results of the present study. Dechering & Schleberger et al. reported similar acute success between high-power (50 W) and moderate-power (30 W) ablation, with a slightly higher recurrence in the 30 W group.[21] Langberg et al. demonstrated the efficacy of a stepwise escalation strategy beginning at 10 W and increasing to 30 W, effectively eliminating the slow pathway while avoiding unnecessary high-power applications.[10] Bortone et al. also supported a gradual power titration starting from low-energy.[8] In the present study, we validated an initial low-power ablation strategy (20 W) with selective stepwise escalation. Previous studies indicated that junctional rhythm tends to be unstable at power settings below 20 W, suggesting that 20 W represents the minimum effective threshold[8, 10]. Based on these findings, we selected 20 W as the initial power setting. This approach yielded a high acute success rate (98.5%) and a low recurrence rate (0.9%), with no cases of permanent AV block.

Table 5
Comparison of Studies Evaluating Energy Power for Slow Pathway Ablation

Study type	Jung & Kwon et al.	Dechering & Schleberger et al.[21]	Langberg et al.[10]	Bortone et al.[8]	Wasmer et al.[4]	Katritsis et al.[22]
	Prospective	Randomized (50 W vs. 30 W)	Randomized (Anterior vs. Posterior)	Retrospective	Retrospective	Prospective
Number	203 (170 in 20 W, 33 in above 20 W)	634 (342 in 50 W vs. 292 in 30 W)	50 (28 vs. 22)	468	2,101	1,087
Energy power (Watt)	20 W (Above 20 W: 16.3%)	50 W vs. 30 W	10 W to 30 W	From 5 W, Mean 31.7 ± 3.0	N/A	20 W to 40 W
Mean number of RF applications	6.1 ± 4.8 vs. 16.8 ± 14.9	5.9 ± 6.6 vs. 7.6 ± 8.5	9 ± 5 vs. 7 ± 5	3.2 ± 1.1	5 ± 7	N/A
Mean duration of RF delivery (seconds)	81.7 ± 53.5 vs. 85.4 ± 17.3	137 ± 191 vs. 218 ± 241	N/A	N/A	222 ± 264	432 ± 384 (typical) vs. 318 ± 180 (atypical)
Acute success (%)	98.5	98.8 vs. 97.7	96	98.7	98	N/A
FU duration (months)	18.3 ± 4.1	39 ± 7.5 vs. 31 ± 11.4	N/A	28.1 ± 14.1	62 ± 43	3
Redo ablation or recurrence (%)	0.9	4.6 vs. 6.8	N/A	3.6		2.2
Transient AV block (%)	1.9	2.6 vs. 1.7	N/A	1.9	2	0.1
Permanent AV block (%)	0	0 vs. 0	2	0.2	0.2	0.1

Transient anterograde AV block during ablation not only necessitates immediate interruption of RF delivery but may also result in fatal complications requiring pacemaker implantation. Higher ablation energy and target temperature levels are expected to increase the likelihood of AV block or VA block during junctional ectopy.[12] Therefore, it is reasonable to assume that fast-accelerated junctional rhythm and VA block assessment during 20 W RF delivery are less likely to cause irreversible AV nodal injury compared with higher power applications. In this study, transient AV block was rare (1.9%), consisting predominantly of second-degree AV block (Mobitz type I), all resolving within 30 seconds.

Among the 33 patients who required power above 20 W, several factors may explain the need for higher energy. First, increased blood flow associated with a higher heart rate may produce a cooling effect, limiting lesion formation. Second, rapid cardiac motion may diminish catheter stability and contact. Third, 20 W applications may be insufficient to generate adequately sized lesions in these patients.

From our clinical perspective, the overall acute success rate of 98.5% achieved with an initial low-power strategy appears acceptable, particularly given the absence of permanent AV block. Although Bortone et al. previously demonstrated the utility of a low-power strategy, their method—incrementing power by 5 W every 5 seconds up to 10 W above the threshold for junctional rhythm and maintaining energy delivery for 120 seconds—may be challenging to implement in routine practice[8, 21]. In contrast, our strategy is simple, reproducible, and requires no additional procedural steps beyond selecting a low initial power and considering the baseline heart rate before energy delivery.

Study limitations

This study has several limitations. First, it is a relatively small-scale, non-randomized prospective study. Although all consenting patients with typical AVNRT were enrolled during the study period, selection bias may still be present. Additionally, the small sample size may have limited statistical power to detect complications or recurrence. Given that the incidence of permanent AV block typically ranges from 0.1% to 0.8%, the sample size of 203 patients may be underpowered to definitively detect a difference in this rare outcome. Second, the optimal energy level may vary depending on catheter-tissue contact. In this study, all operators made efforts to ensure adequate catheter-tissue contact to achieve successful ablation with low-energy. However, since a contact force-sensing catheter was not used, variability among operators may exist. As a result, the required energy may differ depending on the degree of contact, and procedural outcomes may be influenced by the operator's experience and expertise. Third, a three-dimensional electroanatomical mapping system was not used in this study. This was because the study was limited to first-time AVNRT ablation cases, in which a three-dimensional mapping system —and consequently contact force–sensing catheters—is not reimbursed under the Korean National Health Insurance system. Therefore, all procedures in this study were performed using a conventional fluoroscopy-guided approach. As a result, precise measurement of the spatial distance between the ablation site and the His bundle was not feasible, which should be considered when interpreting the procedural findings. Fourth, because all ablation catheters used in this study were non-irrigated tip catheters, these findings may not be directly applicable to procedures performed with irrigated-tip catheters. Finally, the mean follow-up duration of 18.3 ± 4.1 months is sufficient to assess early outcomes but may be inadequate to capture very late recurrences of AVNRT. Moreover, the relatively short follow-up period limits the ability to detect late-onset AV block

Conclusion

We demonstrated that the low-power slow pathway ablation is both effective and exceptionally safe for the treatment of AVNRT. Initiating ablation at 20 W may reduce the risk of permanent AV block while maintaining high efficacy.

Abbreviations

AV
atrioventricular

AVNRT
atrioventricular nodal reentrant tachycardia
CI
confidence interval
OR
odds ratio
RF
radiofrequency
ToK
triangle of Koch
VA
ventriculoatrial

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Board of Chungnam National University Sejong Hospital (IRB No. CNUH201906005006-HE002). Written informed consent was obtained from all participants prior to enrollment.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author contributions

M.K. and C.H.K. conceived and designed the study. M.K. and L.-Y.J. acquired, analyzed, and interpreted the data and drafted the manuscript. M.K. critically revised the manuscript for important intellectual content and approved the final version. C.H.K., L.-Y.J., I.G.S., and J.H.L. contributed to data collection. All authors reviewed and approved the final manuscript and agreed to be accountable for all aspects of the work.

Disclosures

None

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Table 2

Table 2 is available in the Supplementary Files section.

Figures

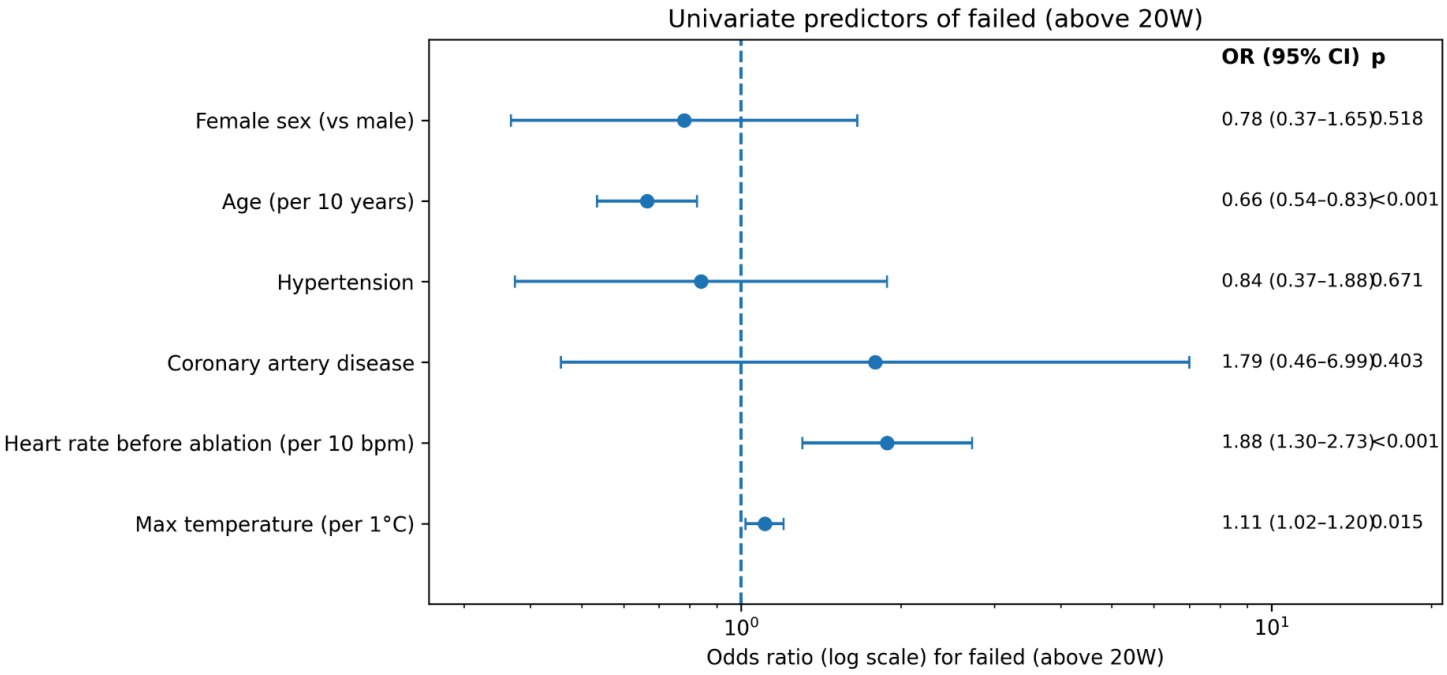

Figure 1

Forest Plot of Univariate Predictors of Requiring Higher Power (above 20 W)

The x-axis is on a log scale; the dashed vertical line indicates OR=1. Variables with complete separation or no variability were not plotted: diabetes mellitus (Fisher p=0.003), chronic kidney disease (Fisher p=1.000), prior stroke (Fisher p=1.000), valvular heart disease and chronic lung disease (no variability).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table2.docx