



Ablation Index-Guided High-Power Radiofrequency Application Shortens the Procedure Time With Similar Outcomes to Conventional Power Application in Atrial Fibrillation Ablation

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Background: The impact of high-power radiofrequency (RF) application in ablation index (AI)-guided atrial fibrillation (AF) ablation has not been elucidated.

Methods and Results: We investigated 1,333 patients undergoing first AF ablation (median age 68 years; interquartile range [IQR] 61–73 years). The first 301 patients underwent AI-guided conventional power RF application (CP group), whereas the following 1,032 patients underwent high-power RF application (HP group). The minimum AI target values were 400, 360, and 260 at the left atrial anterior wall, posterior wall, and esophagus, respectively. RF power in the CP group was 30–40, 20–25, and 20 W at the anterior wall, posterior wall, and esophagus, respectively, compared with 50, 40, and 25, respectively, in the HP group. Procedure time was shorter in the HP than CP group (median 153 [IQR 129–190] vs. 180 [IQR 152–229] min; $P < 0.0001$). The percentage of first-pass pulmonary vein isolation (69% vs. 73%; $P = 0.07$) and all procedure-related complications (2.0% vs. 3.4%; $P = 0.19$) was similar. Kaplan-Meier analysis showed similar recurrence-free survival (RFS) for all AF types. Respective 1-year RFS in the CP and HP groups was 82% and 87% in paroxysmal AF, 78% and 82% in persistent AF, and 59% and 58% in long-standing persistent AF.

Conclusions: In AI-guided AF ablation, high-power RF application shortens the procedure time without increasing complications and with similar outcomes.

Key Words: Atrial fibrillation; Ablation index; Catheter ablation; High-power radiofrequency application; Pulmonary vein isolation

The creation of durable lesions is essential to achieve permanent isolation of pulmonary vein (PV) in catheter ablation for atrial fibrillation (AF). In radiofrequency (RF) catheter ablation, several parameters, including RF application time, RF power, catheter contact force (CF), and catheter stability, affect lesion size and lesion durability. The automated ablation lesion tagging module based on catheter stability (VISITAG module; Biosense Webster, Diamond Bar, CA, USA) was developed to visualize RF application points passing the predefined stability criteria on the 3-dimensional (3D) mapping system (CARTO3 System; Biosense Webster). For each VISITAG point, integrated lesion size markers were calculated by CARTO mapping system. The force-time integral (FTI) is an integral parameter of CF and RF application time and has been reported as being useful in AF ablation.^{1,2}

However, the FTI formula does not include RF power, which substantially affect ablation lesion volume.³ The ablation index (AI) was developed as a similar quantitative ablation lesion marker, that considers CF, RF application time, and RF power in a weighted formula. AI was reported to minimize AF recurrence after ablation.^{4–6}

Recent studies have shown that high-power RF application can be used for AF ablation with short procedure times.^{7–11} However, the use of high-power RF may increase complications related to the application of RF (e.g., steam pops, pericardial effusion, and gastrointestinal complaints).⁸ Theoretically, using AI-guided high-power RF can create similar RF lesions in a short time of time without excessive RF application. We previously reported that, in AI-guided PV isolation (PVI), using high-power RF resulted in AF ablation with a shorter procedure time than conventional

Received July 18, 2021; accepted July 18, 2021; J-STAGE Advance Publication released online September 2, 2021 Time for primary review: 1 day

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ISSN-2434-0790



Table 1. RF Application Power

	RF application power (W)	
	CP	HP
LA anterior wall	30–40	50
LA posterior wall	20–25	40
LA wall on esophagus	20	25

CP, conventional power radiofrequency (RF) application; HP, high-power RF application; LA, left atrium.

power RF with the same AI target value.¹² However, the safety and long-term outcomes of AI-guided AF ablation using high-power RF were not fully elucidated in that study. In the present study, we retrospectively studied a large number of AF patients undergoing ablation procedures at Saiseikai Kumamoto Hospital to evaluate the advantage of AI-guided AF ablation using high-power RF over conventional RF AF ablation.

Methods

Study Population

AI-guided ablation was introduced at Saiseikai Kumamoto Hospital in April 2017, and AI-guided ablation using high-power RF was introduced in November 2018. At the beginning of AI-guided ablation at Saiseikai Kumamoto Hospital, AI-guided RF was only used by highly experienced operators. In January 2018, all operators at Saiseikai Kumamoto Hospital started using AI-guided RF. Thus, patients undergoing their first RF catheter ablation for AF after January 2018 were included in the present study. Patients who participated in our previous prospective study were excluded.¹² Consequently, we investigated 1,333 patients, consisting of the 301 patients undergoing AI-guided AF ablation with conventional RF power between January 2018 and October 2018 (CP group) and the following 1,032 patients undergoing AI-guided AF ablation with high-power RF between November 2018 and October 2020 (HP group).

This study was approved by the Ethics Committee of Saiseikai Kumamoto Hospital (Approval no. 776), and written informed consent was obtained from all patients before the RF ablation procedure.

Before the RF ablation procedure, transesophageal echocardiography was performed in patients with a CHADS₂ score ≥ 2 , persistent AF, a history of cerebral infarction, or systemic thromboembolism to rule out left atrial (LA) thrombus. All patients were administered an anticoagulant for >4 weeks before the study. There was no interruption to the use of warfarin before and after the procedure. In patients taking direct oral anticoagulants, the drugs were continued before the procedure, were stopped on the morning of the day of the ablation, and were resumed 4 h after the procedure unless major bleeding events occurred. Patients taking rivaroxaban or edoxaban in the evening continued this evening dose during the periprocedural period. Anticoagulants were continued for at least 3 months after the ablation.

Cardiac Catheterization

After confirming the anatomic position of the esophagus by asking patients to swallow contrast medium, all patients underwent the catheter ablation procedure in the fasting

state under local anesthesia and conscious sedation with dexmedetomidine and thiamylal. Respiratory management devices, such as a nasal airway device and adaptive servo ventilation, were used at the operator's discretion. A 6-Fr, double-decapolar, steerable catheter (BeeAT; Japan Lifeline, Tokyo, Japan) was inserted into the coronary sinus via the right internal jugular vein. An 8-Fr SoundStar ultrasound catheter (Biosense Webster) was inserted into the right atrium (RA) via the right femoral vein and the anatomy of the LA was mapped using the CartoSound module in the CARTO3 system. After transseptal puncture under intracardiac echocardiography, 2 8.5-Fr long sheaths (SL0; St. Jude Medical, St. Paul, MN, USA) were inserted into the LA. In patients with persistent AF, an 8.5-Fr deflectable sheath (Agilis; St. Jude Medical) was used at the operator's discretion. Patients were injected with 3,000 units heparin before the transseptal puncture, with an addition 5,000 units heparin immediately after the transseptal puncture, followed by repetitive injection of 1,000–2,000 units heparin to maintain an activated clotting time >300 s during the procedure.

AF Ablation Procedure

Circumferential PVI (CPVI) was performed in all patients by RF application to the ipsilateral PV antrum and intervenous carina in the integrated 3D image. We used an 8-Fr irrigation catheter with a 3.5-mm distal electrode, real-time CF monitoring, and a 56-hole porous tip for surround-flow irrigation (ThermoCool SmartTouch Surround Flow Catheter; Biosense Webster) with a point-to-point RF application technique. We set the AI target value at ≥ 400 at the anterior LA wall, ≥ 360 at the posterior LA wall, and ≥ 260 on the esophagus, as reported previously.¹¹ We set RF power at 30–40 W in the anterior LA wall, 20–25 W in the posterior LA wall, and 20 W on the esophagus in the CP group, and to 50, 40, and 25 W, respectively, in the HP group (Table 1). We attempted to keep the CF between 10 and 20 g during RF application. The VISITAG settings were as follows: maximum distance change 2.5 mm; minimum period 3 s; and contact force 3 g for $>25\%$ of the time. We did not monitor esophageal temperature during the procedure. We reapplied RF to any areas where the AI value did not achieve the target AI value.

After circular RF application to the PV antrum and intervenous carina, electrocardioversion was performed if AF persisted after RF application. An LA and PV electro-anatomical map was then created during RA pacing using a multielectrode catheter (PentaRay Nav Catheter; Biosense Webster) to confirm the disappearance of the PV and PV antrum potentials with a bipolar voltage >0.1 mV. We attempted to ablate any residual conduction gaps to complete CPVI. PV-to-LA conduction block was confirmed by pacing at an output of 10 mA with a pulse width of 1 ms from 10 pairs of the PentaRay Nav Catheter placed at the ostium of the PV. We defined first-pass isolation as creating a bidirectional block between the LA and PV after the initial circumferential ablation. Extra-PV ablation procedures, including LA roof linear ablation, LA posterior wall box isolation, ablation for a low-voltage zone, isolation of the superior vena cava (SVC), complex fractionated atrial electrogram (CFAE) ablation, and ablation of the cavotricuspid isthmus, were performed at the operator's discretion. After completing CPVI, a bolus of 10–20 μ g isoproterenol was administered intravenously to induce non-PV triggers; if they were present, we attempted to ablate them.

Table 2. Patient and Procedural Characteristics

	All patients (n=1,333)	Paroxysmal AF (n=755)	Persistent AF (n=383)	Long-standing persistent AF (n=195)	P value	CP (n=301)	HP (n=1,032)	P value
Patient characteristics								
Age (years)	68 [61–74]	69 [62–74]	67 [61–73]	66 [60–71]	0.0005	67 [61–73]	68 [61–74]	0.34
Female sex	407 (31)	277 (37)	97 (25)	33 (17)	<0.0001	91 (30)	316 (31)	0.90
BMI (kg/m ²)	24 [22–26]	24 [22–26]	25 [23–27]	25 [23–26]	<0.0001	24 [22–26]	24 [22–26]	0.37
AF type								0.62
Paroxysmal AF	755 (57)					172 (57)	583 (56)	
Persistent AF	383 (29)					90 (30)	293 (28)	
Long-standing persistent AF	195 (15)					39 (13)	156 (15)	
Prior stroke or TIA	114 (9)	57 (8)	30 (8)	27 (14)	0.03	21 (7)	93 (9)	0.26
CHF	177 (13)	58 (8)	83 (22)	36 (18)	<0.0001	39 (13)	138 (13)	0.85
Diabetes	189 (14)	99 (13)	61 (16)	29 (15)	0.42	41 (14)	148 (14)	0.75
Hypertension	666 (50)	374 (59)	208 (54)	84 (43)	0.04	146 (49)	520 (52)	0.57
CHADS ₂ score	1 [0–2]	1 [0–2]	1 [1–2]	1 [0–2]	0.004	1 [0–2]	1 [0–2]	0.49
CHA ₂ SDS ₂ -VASc score	2 [1–3]	2 [1–3]	2 [1–3]	2 [1–3]	0.03	2 [1–3]	2 [1–3]	0.97
LVEF (%)	62 [58–67]	64 [60–68]	60 [55–65]	60 [55–63]	<0.0001	62 [58–68]	62 [58–66]	0.36
LA diameter (mm)	41 [37–46]	39 [35–43]	44 [40–48]	46 [42–49]	<0.0001	41 [37–46]	41 [37–46]	0.82
Procedural characteristics								
CPVI	1,333 (100)	755 (100)	383 (100)	195 (100)	NA	301 (100)	1,032 (100)	NA
Cavotricuspid isthmus ablation	192 (15)	167 (22)	45 (12)	14 (7)	<0.0001	56 (19)	170 (16)	0.39
Low-voltage zone ablation	78 (6)	730 (4)	28 (7)	20 (10)	0.002	23 (8)	55 (5)	0.14
LA roof linear ablation	440 (33)	100 (13)	198 (52)	142 (73)	<0.0001	98 (33)	342 (33)	0.85
LA posterior wall box isolation	372 (28)	50 (7)	185 (48)	137 (70)	<0.0001	87 (29)	285 (28)	0.66
LA anterior linear ablation	20 (2)	9 (1)	5 (1)	6 (3)	0.21	4 (1)	16 (2)	0.78
Mitral isthmus linear ablation	5 (0.4)	4 (1)	1 (0.2)	0 (0)	0.36	2 (1)	3 (0.3)	0.38
SVC isolation	824 (62)	463 (61)	242 (63)	119 (61)	0.80	150 (50)	674 (65)	<0.0001
Non-PV foci ablation	145 (11)	75 (10)	47 (12)	23 (12)	0.45	31 (10)	114 (11)	0.71
CFAE ablation	116 (9)	18 (2)	38 (10)	60 (31)	<0.0001	69 (23)	47 (5)	<0.0001

Unless indicated otherwise, data are given as the median [interquartile range] or n (%). AF, atrial fibrillation; BMI, body mass index; CFAE, complex fractionated atrial electrogram; CHF, congestive heart failure; CP, conventional power radiofrequency application; CPVI, circumferential pulmonary vein isolation; HP, high-power radiofrequency application; LA, left atrium; LVEF, left ventricular ejection fraction; NA, not applicable; PV, pulmonary vein; SVC, superior vena cava; TIA, transient ischemic attack.

We compared procedure characteristics, including procedure time, the percentage of first-pass isolations and complications, and long-term outcomes after the ablation procedure, between the CP and HP groups.

Follow-up

All patients were followed-up in the outpatient clinic of Saiseikai Kumamoto Hospital. At 1, 3, 6, 9, and 12 months after ablation, all patients were asked about their symptoms and underwent both a 12-lead electrocardiogram (ECG) and 24-h Holter ECG monitoring. A mobile ECG recorder was used at the discretion of the physician. AF recurrence was defined as any atrial tachyarrhythmias lasting >30s that occurred after a 3-month blanking period. Redo procedures were performed for patients with recurrence of atrial tachyarrhythmia after a 3-month blanking period. PV potentials were evaluated in these redo procedures by creating an LA and PV electroanatomical map,

and the percentage of PVs with reconnection were compared between the CP and HP groups.

Statistical Analysis

The normality of data distribution was tested using the Shapiro-Wilk test. Continuous variables with a normal distribution are expressed as the mean \pm SD and were compared using Student's t-test or analysis of variance. Continuous variables that were not normally distributed are expressed as the median and interquartile range (IQR) and were compared using the Wilcoxon test or Kruskal-Wallis test. Categorical variables are expressed as numbers and percentages and were compared using the Chi-squared test.

We analyzed the effect of the AF type (i.e., paroxysmal AF, persistent AF, and long-standing persistent AF) on the PV reconnection detected in the redo procedures using Cochran-Armitage trend tests. According to the Kaplan-Meier method, we plotted atrial tachyarrhythmia recurrence-

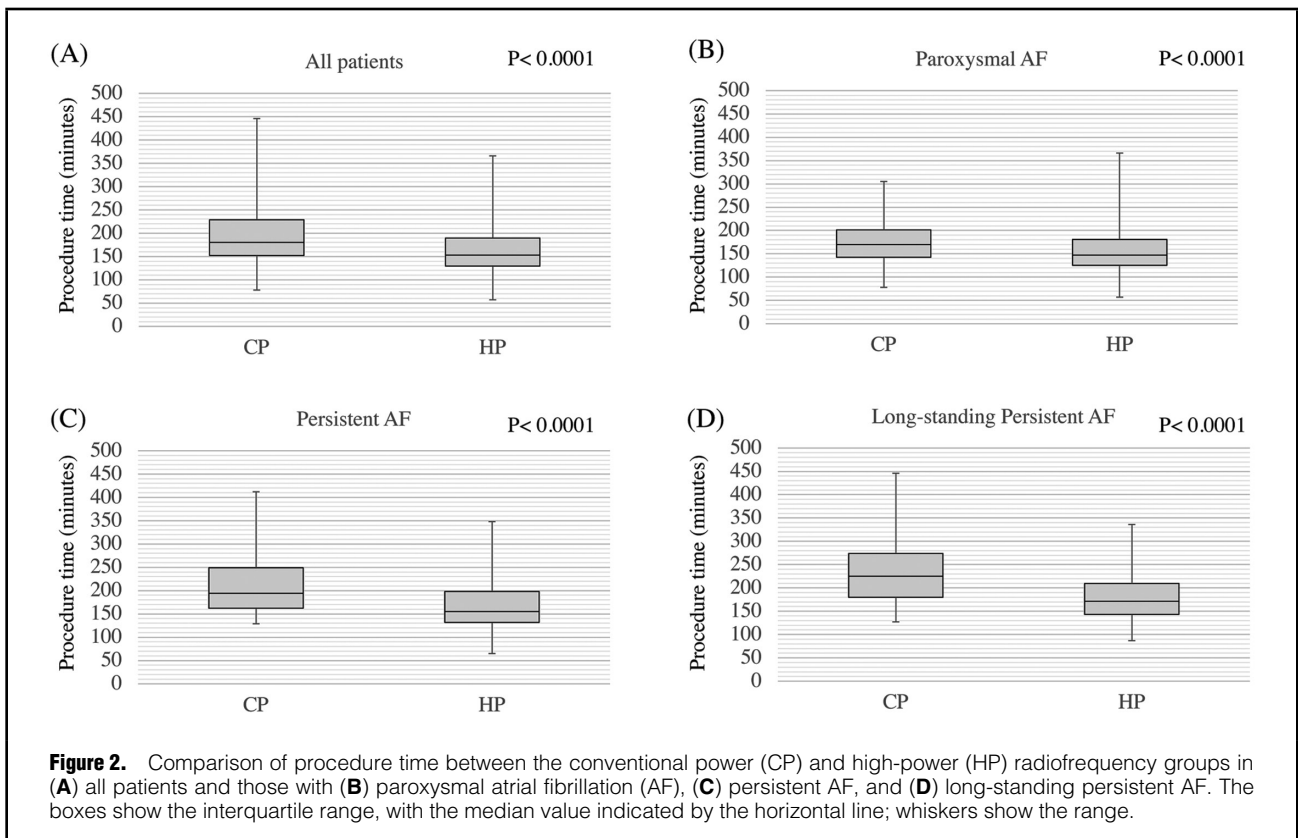
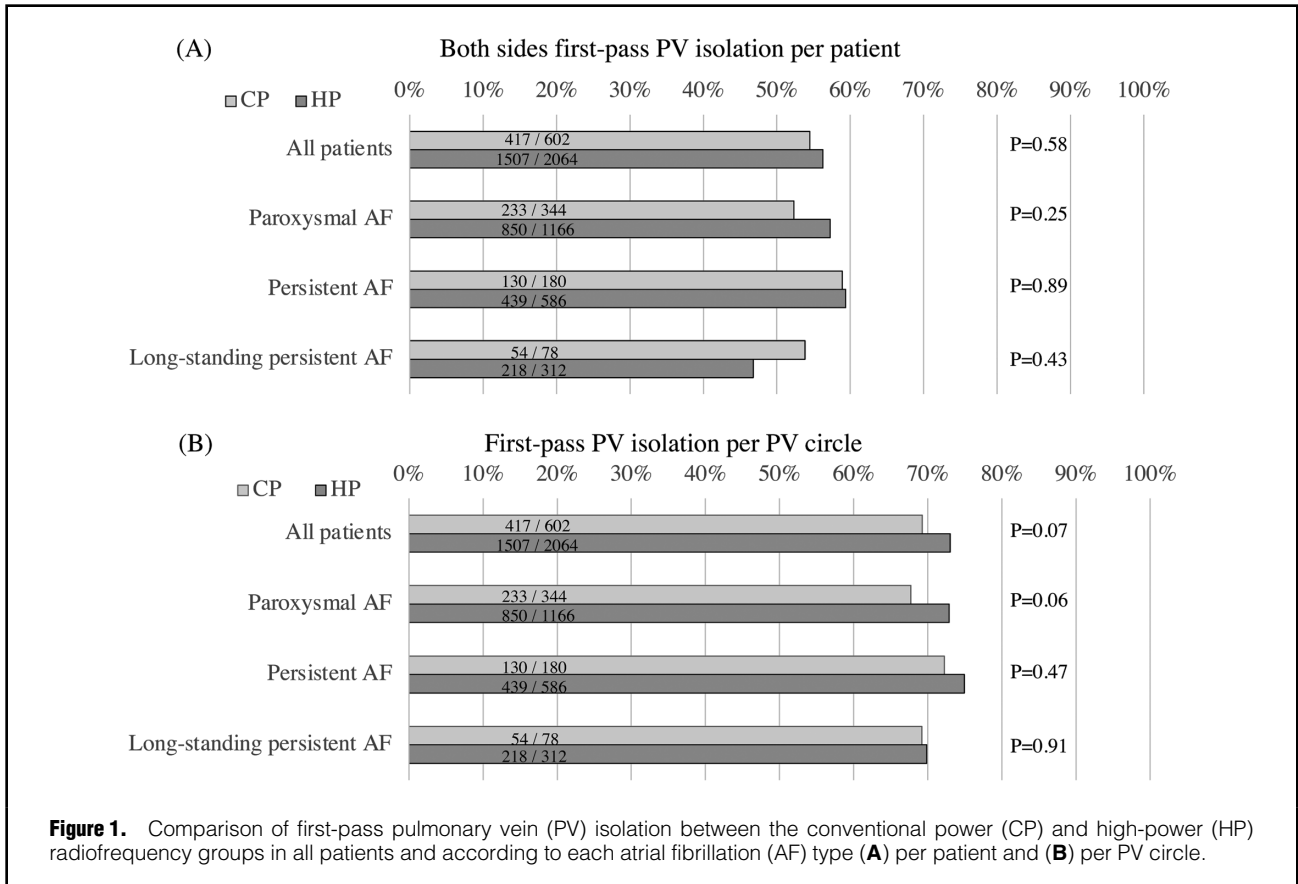


Table 3. Complications			
	CP (n=301)	HP (n=1,032)	P value
Overall complications	6 (2.0)	35 (3.4)	0.19
Death	0 (0)	0 (0)	
Perforation/tamponade	1 (0.3)	5 (0.5)	
Steam pop	0 (0)	0 (0)	
Atrioesophageal fistula	0 (0)	0 (0)	
Endoscopic esophageal lesion	0 (0)	0 (0)	
PV stenosis	0 (0)	0 (0)	
Phrenic nerve injury	1 (0.3)	5 (0.5)	
Gastric hypomotility	1 (0.3)	8 (0.8)	
Stroke/thromboembolic events	0 (0)	1 (0.1)	
Puncture site hematoma/vascular injury	2 (0.7)	3 (0.3)	
Heart failure	0 (0)	5 (0.5)	
Pericarditis	0 (0)	6 (0.6)	
Nasal bleeding related to nasal airway device	1 (0.3)	2 (0.2)	

Unless indicated otherwise, data are given as n (%). CP, conventional power radiofrequency application; HP, high-power radiofrequency application; PV, pulmonary vein.

free survival rate curves for all patients with a follow-up period of >90 days. Because AF type was a strong predictor of recurrence after the AF ablation procedure, we compared survival curves among AF types using the log-rank test. Patients who died >90 days after the procedure without AF recurrence were treated as censored patients.

All tests were 2-tailed, and $P < 0.05$ was considered significant. Statistical analyses were performed using JMP version 9.0 (SAS Institute, Cary, NC, USA).

Results

Patient and Procedure Characteristics

Table 2 shows patient and procedure characteristics. Many of the patient characteristics differed significantly among AF types, with LA diameter being greater in patients with persistent and long-standing persistent AF. However, the baseline characteristics were similar between the CP and HP groups. All patients underwent CPVI. Ablation was performed for the cavotricuspid isthmus more frequently in paroxysmal AF, whereas LA roof linear ablation, posterior wall box isolation, and CFAE ablation were more frequent in cases of persistent AF and long-standing persistent AF. The percentage of RF application for extra-PVs was similar between the CP and HP groups, except for SVC isolation and CFAE ablation; SVC isolation was performed more frequently in the HP group ($P < 0.0001$) and CFAE ablation was performed more frequently in the CP group ($P < 0.0001$).

Figure 1 shows the percentage of first-pass isolations, which was similar between the CP and HP groups. **Figure 1A** shows the percentage of both sides first-pass PVI per patient and **Figure 1B** shows first-pass PVI per PV circle. The median procedure time was significantly shorter in the HP than CP group (**Figure 2**) across all patients (153 [IQR 129–190] vs. 180 [IQR 152–229] min, respectively; $P < 0.0001$), as well as in paroxysmal AF (147 [IQR 125–181] vs. 170 [IQR 142–210] min, respectively; $P < 0.0001$), in persistent AF (155 [IQR 132–199] vs. 195 [IQR 162–249] min, respectively; $P < 0.0001$), and in long-standing persistent AF (171 [IQR 143–210] vs. 225 [IQR 180–274] min, respectively; $P < 0.0001$).

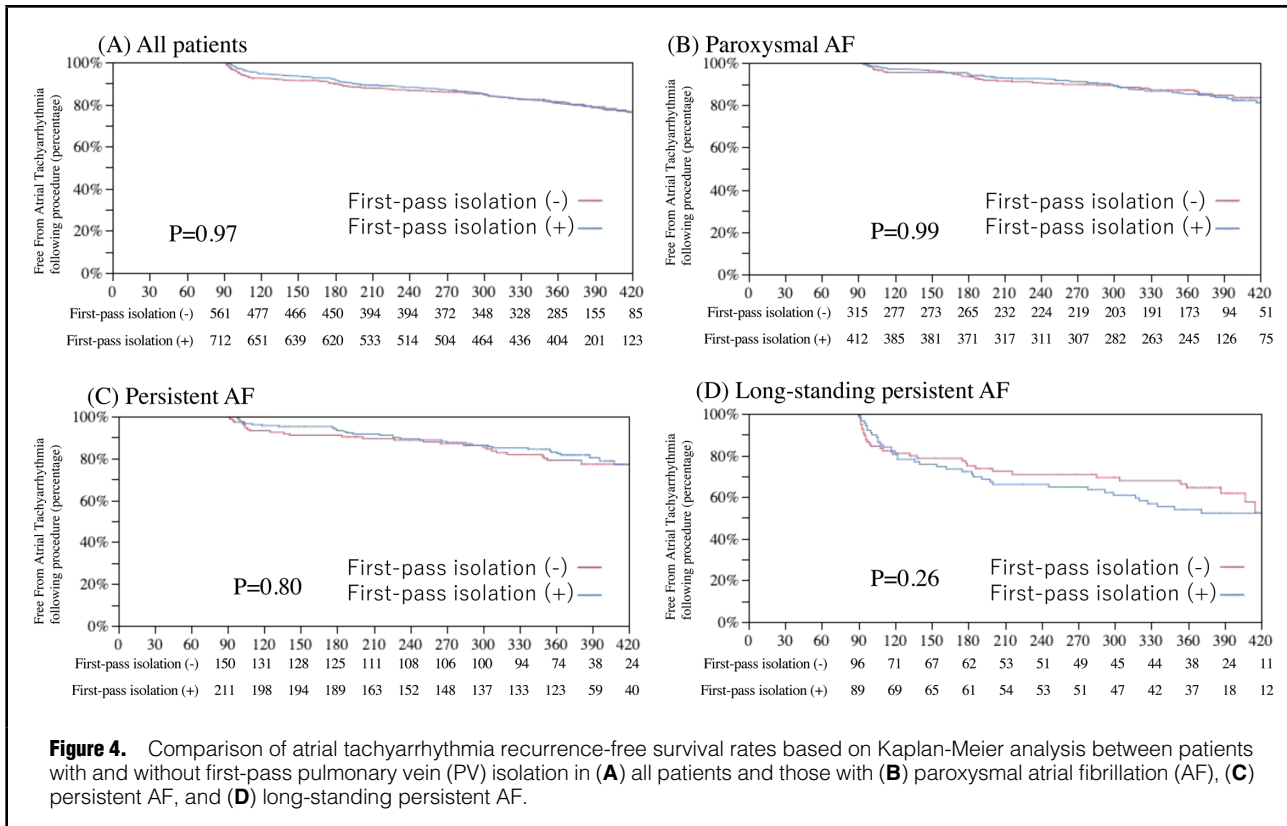
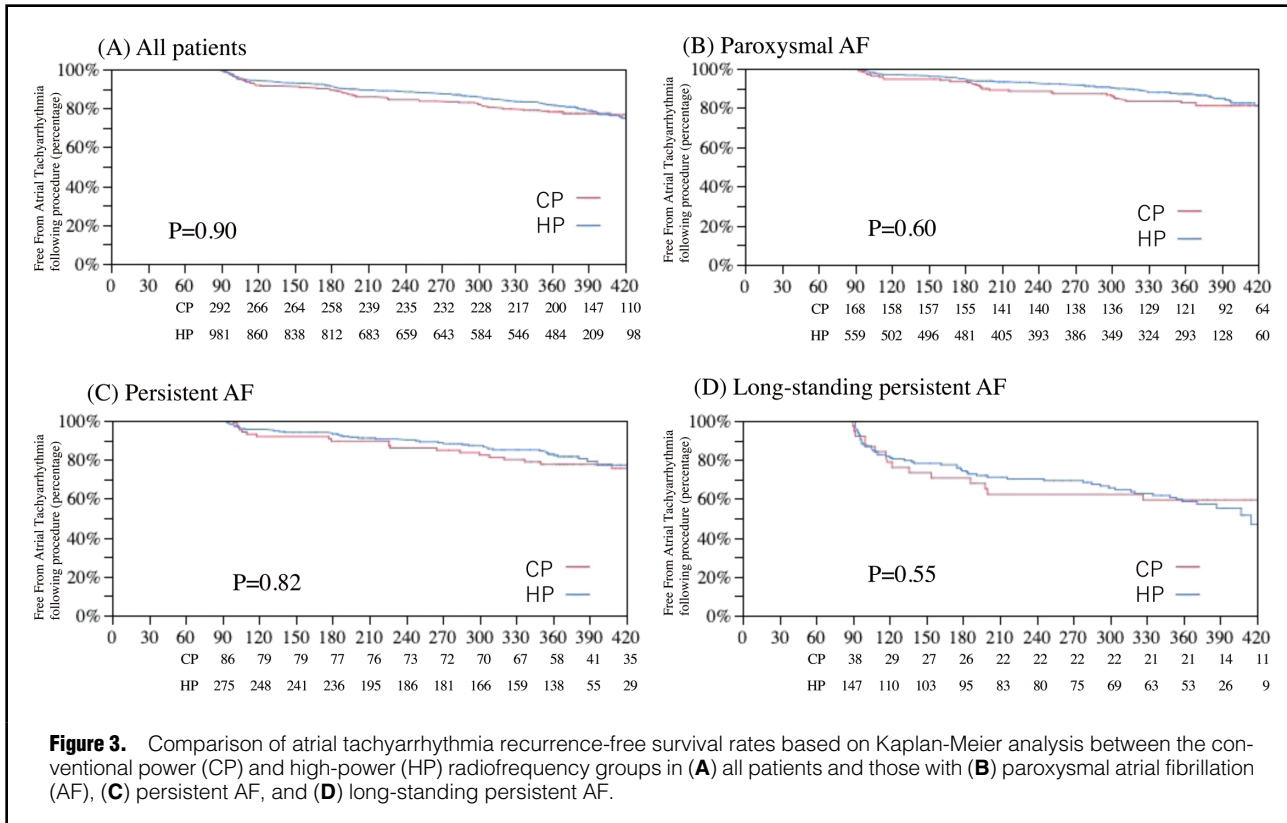
Procedure-Related Complications

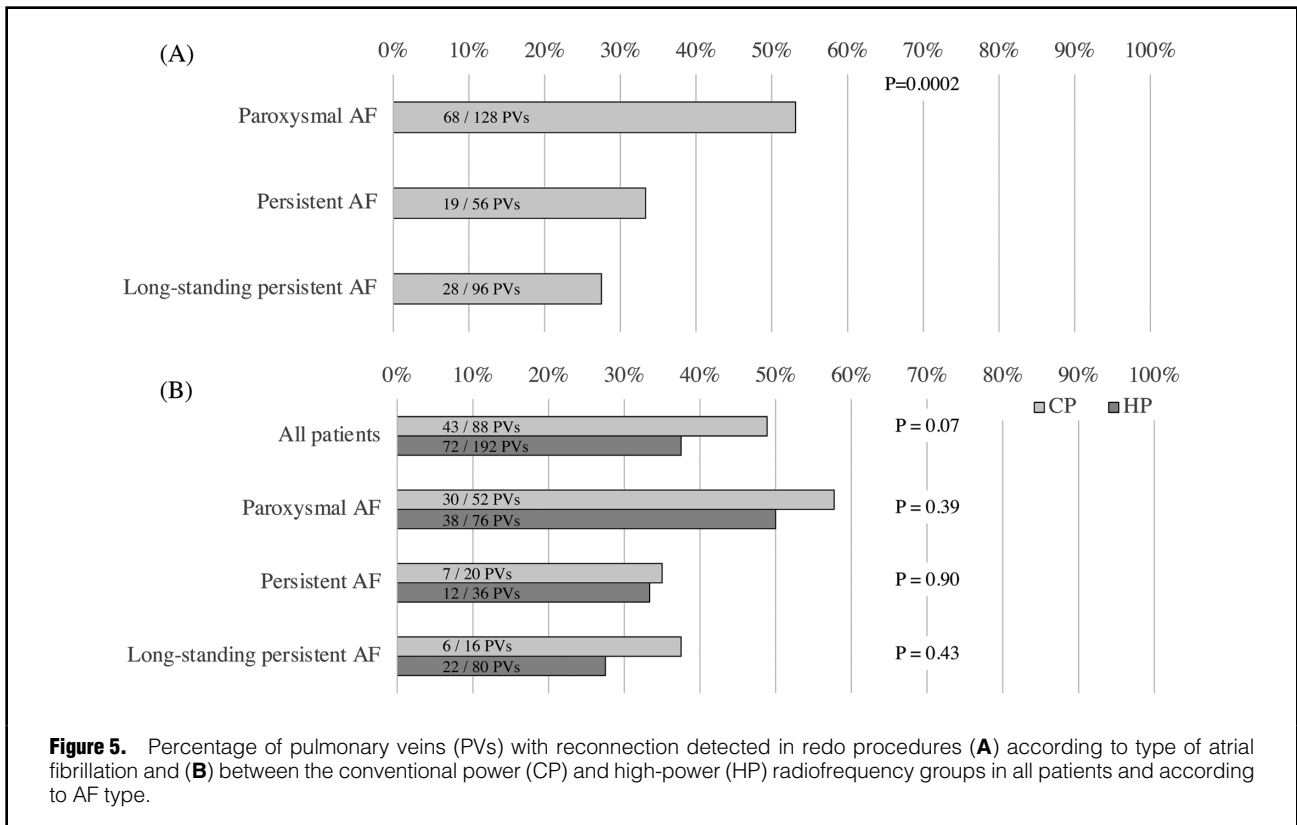
Table 3 summarizes procedure-related complications. The percentage of all procedure-related complications was similar between the CP and HP groups (2.0% vs. 3.4%, respectively; $P = 0.19$). One phrenic nerve injury occurred in the CP group, compared with 5 in the HP group. All phrenic nerve injuries occurred during SVC isolation. All patients except for 1 were asymptomatic, and spontaneous recurrence occurred in all patients a median of 1 day (IQR 36–282 days) after the ablation procedure. The power setting of SVC isolation was the same in the CP and HP groups (20–25 W). Gastric hypomotility occurred in 1 patient in the CP group and in 8 patients in the HP group. All patients experienced nausea and loss of appetite, with spontaneous recurrence occurring a median of 14 days (IQR 9–22 days) after the procedure. There were 5 cases of heart failure deterioration in the HP group. All these patients had organic heart disease: 2 had ischemic cardiomyopathy, 1 had hypertrophic cardiomyopathy, 1 had cardiac amyloidosis, and 1 had sick sinus syndrome. In 2 patients (1 ischemic cardiomyopathy, 1 hypertrophic cardiomyopathy), heart failure deteriorated before the procedure due to persistent atrial fibrillation and symptoms were not relieved by medical rate control and standard heart failure therapy. These symptoms became temporarily serious after the procedure. In 2 patients (1 cardiac amyloidosis, 1 sick sinus syndrome), sinus bradycardia after the procedure led to the deterioration in heart failure. In 1 patient with ischemic cardiomyopathy, saline infusion during the procedure worsened the symptoms of heart failure.

Follow-up

In all, 1,273 patients were analyzed over a follow-up period of >90 days. The median follow-up period was significantly shorter in the HP than CP group (358 [IQR 190–384] vs. 392 [IQR 322–444] days, respectively; $P < 0.0001$) for all patients.

Figure 3 shows atrial tachyarrhythmia recurrence-free survival curves. For all patients, there was no difference between the CP and HP groups (**Figure 3A**; $P = 0.90$, log-rank test). There were also no differences between the CP





and HP groups for patients with paroxysmal AF (Figure 3B; $P=0.60$), persistent AF (Figure 3C; $P=0.80$), or long-standing persistent AF (Figure 3D; $P=0.55$). The respective 1-year atrial tachyarrhythmia recurrence-free survival rates in the CP and HP groups were 82% and 87% for patients with paroxysmal AF, 78% and 82% for patients with persistent AF, and 59% and 58% for patients with long-standing persistent AF. We also analyzed atrial tachyarrhythmia recurrence-free survival curves following successful first-pass isolation (Figure 4). There were no differences in the recurrence-free survival rates for all patients, as well as patients with paroxysmal AF, persistent AF, or long-standing persistent AF.

Redo procedures were performed in 140 patients (44 in the CP group, 96 in the HP group) with atrial tachyarrhythmia recurrence occurring a median of 354 days (IQR 241–478 days) after the first procedure. According to AF type, the percentage of patients undergoing redo procedures was significantly higher among those with long-standing persistent AF (25%) compared with those with paroxysmal AF (8%) and persistent AF (7%; $P<0.0001$). In addition, the percentage of patients undergoing redo procedures was significantly higher in the CP than HP group due to the longer follow-up period in the former (15% vs. 9%; $P=0.01$). Figure 5 shows the percentage of PV reconnections detected in the redo procedure. PV reconnection was detected less in persistent AF and long-standing AF than in paroxysmal AF (34% and 29% vs. 53%, respectively; $P=0.0002$, Cochran-Armitage trend test; Figure 5A) but there was no significant difference between the CP and HP groups (43/88 PVs [49%] vs. 72/192 PVs [38%], respectively; Figure 5B). Similarly, the percentage of patients

with at least 1 PV reconnection was significantly lower in the persistent and long-standing persistent AF groups than in the paroxysmal AF group (61% and 46% vs. 70%, respectively; $P=0.009$, Cochran-Armitage trend test), but there was no significant difference between the CP and HP groups (68% vs. 56%, respectively; $P=0.18$).

Twelve patients died during the follow-up period after AF ablation. Two patients in the CP group died (urinary tract infection at 502 days; unknown reason 615 days after the procedure). Ten patients were died in the HP group: 3 due to sudden death at 25, 295, and 364 days; 2 due to aggravation of heart failure at 53 and 106 days; 2 due to infection (pneumonia at 38 days and infective endocarditis at 49 days); 1 due to cerebral hemorrhage at 106 days; 1 due to interstitial pneumonia at 152 days; and 1 due to malignant lymphoma at 232 days after the procedure.

Discussion

This study compared the procedural and long-term outcome data of AI-guided AF ablation between conventional-power and high-power RF groups. The main findings were that high-power RF, compared with conventional power RF, reduced procedure time and achieved AF ablation without increasing procedure-related complications, and that the rate of first-pass PV isolations, atrial tachyarrhythmia recurrence-free survival after the procedure, and the percentage of PV reconnections detected in redo procedures in patients with AF recurrence were similar between the CP and HP groups. The percentage of PV reconnections detected in redo procedures was significantly lower in patients with persistent AF and long-standing

persistent AF compared with paroxysmal AF.

Conventional vs. High-Power Ablation

In the present study, AI-guided AF ablation with high-power RF decreased procedure time. Previously, the FAFA AI High Power Study reported that the procedure time of AI-guided 50-W ablation for PVI was short (55.6 ± 6.6 min).¹³ Using AI-guided RF application with higher RF power can achieve the AI target value and create a similar RF lesion with a shorter RF application time.¹⁴ We previously reported that AI-guided RF application using 30, 40, and 50 W RF could achieve the AI target value of 400 in 18, 12, and 10s.¹² These results indicate that using high-power RF can reach the AI target value within 10s in many ablation points and efficiently create similar RF lesions.

Our previous study suggested that AF ablation with high-power RF application may not necessarily improve long-term outcomes.¹² However, in that previous study we could not make any conclusions regarding the impact of high-power RF due to the small number of patients in the study ($n=60$) and the short follow-up periods (~ 6 months).¹² Recently, several studies showed the impact of 50-W RF application on the outcome of the AF ablation procedure. For example, Chen et al showed that 50-W RF application targeting AI values of 550 for the anterior LA wall and 400 for the posterior LA wall could complete PVI with a high first-pass isolation rate (96.7%), short procedure time (55.8 min), and low atrial tachyarrhythmia recurrence (85.2%) after 15 months of follow-up.¹⁵ O'Brien et al reported a similar atrial tachyarrhythmia recurrence rate following AI-guided 50-W RF application compared with lower RF power application (35–40 W) after 12 months of follow-up.¹⁶ The POWER-AF study, a randomized study comparing AI-guided high-power (45 W) RF application with conventional (35 W) RF application, showed similar outcomes in both groups after 6 months of follow-up.¹⁷ However, these studies could not conclude the safety and outcome of AI-guided 50-W RF application in AF ablation due to the limited number of patients in the high-power RF application arms ($n=122$,¹⁵ 88,¹⁶ and 48 patients¹⁷).

In the present study we performed a retrospective analysis with a relatively larger number of patients who underwent AI-guided high-power RF ablation ($n=1,032$) and a longer follow-up period (~ 1 year), and showed that high-power RF application was not necessarily associated with improved outcomes in all AF types. This suggests that AI-guided RF application with the same target AI values creates similar RF lesions regardless of RF application power. Thus, the AI value per se seems to be the most important determinant for CPVI. Appropriate values must be set when AI-guided CPVI is attempted.

Safety of AI-Guided High-Power RF Application

In this study, the use of AI-guided high-power RF did not increase procedure-related complications compared with the use of conventional RF power. As mentioned above, AI-guided high-power application could reach AI target values with a relatively short period of RF application.¹⁴ This high-power, short-duration RF application was reported to create a relatively shallow lesion,¹⁴ which may minimize collateral damage. A previous study showed that the complication rate following AF ablation with high-power and short-duration RF (45–50 W for 2–15 s) was very low.¹⁸ A recent study reported that the incidence of endoscopically detected esophageal lesions after AI-guided PVI using

high-power (50 W, AI target 400) was low (2.5%).¹⁹ These results suggest that AI-guided high-power RF application could complete AF ablation with a low incidence of collateral organ damage.

However, the results of some studies raise concerns about the safety of AI-guided high-power RF application. High-power RF application could reach the target AI value in a few seconds and sometimes exceed the target AI value before the real-time AI value is displayed, especially when the contact force of the RF catheter on the LA wall is high. This excessive AI value can cause serious collateral organ damage. O'Brien et al reported a higher rate of excessive ablation following the use of 50-W RF compared with 35–40 W RF.¹⁶ In the POWER-AF study, a patient who underwent AI-guided high-power (45 W) RF application developed ulcerative perforation of the esophagus that needed to be treated with a covered stent.¹⁷ During AI-guided high-power RF application to the esophagus, operators should pay attention that the contact force is kept relatively low (e.g., <10 g) and that the AI value does not exceed the target, which is often difficult because of the rapid increase in AI and the delayed display of real-time AI. We set the RF power to 25 W for the esophagus, and in a previous study showed that this low-power setting for the esophagus reached the target AI value in approximately 11s.¹² This low RF power setting for the esophagus provides sufficient time for the operator to confirm the real-time AI value and stop RF application before it becomes excessive. High-power RF application to the esophagus with a short RF application time and adjusted low contact force without AI guidance would be possible, but the safety of this procedure needs to be validated.

Appropriate AI Target Value

Previously, Taghji et al proposed the “CLOSE” protocol to complete AI-guided PVI efficiently and effectively.⁵ In that protocol, AI target values of ≥ 550 at the LA anterior wall and ≥ 400 at the posterior wall, including the esophagus, are used. The initial report of the CLOSE protocol in 130 paroxysmal AF patients using a 25- to 35-W RF power setting showed an excellent high percentage of first-pass PVI (98%) and 12-month recurrence-free survival (91.3%), with a low complication rate (only one patient experienced a transient ischemic attack).⁵ Many subsequent studies have evaluated the impact of AI-guided high-power RF application with the same AI target value as the CLOSE protocol.^{13,15,17} However, as mentioned above, safety concerns remain for AI-guided high-power RF application using this AI target value. For example, the FAFA AF High Power Study reported the safety of AI-guided 50-W ablation for PV isolation with the same AI target value (550 in the LA anterior wall, 400 in the LA posterior wall), but also showed an 8% incidence of steam pop in the study patients.¹³ In contrast, we used a lower AI target value (400 at the LA anterior wall, 360 at the posterior wall, and 260 at the esophagus) in the present study and there was no occurrence of steam pop.

The percentage of first-pass PVI in this study was lower than in studies of high-power RF application using the same AI target value as used in the CLOSE protocol. However, the rate of atrial tachyarrhythmia recurrence-free survival was similar. Osorio et al reported that first-pass isolation on at least one side was an independent predictor of atrial tachyarrhythmia recurrence-free survival after PVI.²⁰ However, Osorio et al also showed that first-pass

isolation on both sides, which was generally used as first-pass isolation, was not a predictor of atrial tachyarrhythmia recurrence-free survival.²⁰ In the present study, the recurrence-free survival rate was similar between patients with and without first-pass isolation on both sides. Wang et al estimated the impact of moderate AI targets (i.e., LA anterior wall 400–450, posterior wall 280–330, and roof/inferior wall 380–430) on the outcomes of PVI in 140 patients with paroxysmal AF and reported low rates of first-pass isolation (49.3%) and excellent recurrence-free survival at the 1-year follow-up (92.1%).²¹ These results suggest that the low rate of first-pass PVI in the present study may be due to the low AI target value, and that first-pass isolation on both sides may not be associated with an improved outcome after AF ablation. First-pass PVI may be aiming to simplify the operation and shorten the procedure time. An optimal AI target value that can achieve a high rate of first-pass PVI safely with high-power RF application may be needed. In Japan, standard target AI values still remain to be elucidated, and different target values are used in different institutions. The appropriate AI values for PVI in Japanese AF patients need to be determined.

Durability of PVI

Analysis of the 140 patients undergoing redo procedures for recurrent AF in the present study revealed that the percentage of PV reconnection was similar between the CP and HP groups (i.e., regardless of the RF power used in the first ablation procedure). This also indicates that AI-guided high-power RF application created a similar lesion to that created using conventional power RF application, as long as the same AI target values were used. However, the percentage of PV reconnections decreased substantially in patients with persistent and long-standing persistent AF compared with those with paroxysmal AF. Redo procedures were only performed in patients with recurrence of atrial tachyarrhythmia, and the percentage of patients undergoing redo procedures was significantly lower among those with paroxysmal AF and persistent AF than long-standing persistent AF. These results suggest that, in paroxysmal AF, PV reconnection was the main mechanism of the recurrence, as reported previously,^{22,23} rather than the non-PV arrhythmogenic substrate. As AF progresses from the paroxysmal to persistent form, the non-PV arrhythmogenic substrate, which induces AF recurrence even without PV reconnection, may play an important role in recurrence, especially in the case of long-standing persistent AF.

Study Limitations

This study has some limitations. First, this study was a single-center retrospective study. A multicenter prospective study enrolling many patients is needed to enable conclusions to be made regarding the advantage of using AI-guided high-power RF for AF ablation. Second, the number of patients differed significantly between the CP and HP groups: the number of patients in the HP group was 3-fold higher than in the CP group. This was because the AI-guided CP RF applications were performed over a relatively shorter period. Third, the percentage of extra-PV RF application, including SVC isolation and CFAE ablation, differed significantly between the CP and HP groups. This difference may have affected the procedure time and outcome of AF ablation. Fourth, we used the CP group as the historical control. An improvement in physicians' tech-

niques could have positively affected procedure time. Fifth, the number of study patients, especially in the CP group, may be too small to detect the rare complications. Sixth, the follow-up period was significantly shorter in the HP than CP group. However, the number of patients at risk at 1 year was larger in the HP group because of a larger number of patients. Seventh, we assessed the recurrence of atrial tachyarrhythmia based on symptoms and periodically repeated ECG and Holter ECG recording, but not based on an implantable loop recorder. Therefore, the recurrence of asymptomatic paroxysmal AF may have been underestimated. Finally, we performed redo procedures only for patients with atrial tachyarrhythmia recurrence, and so the true incidence of PV reconnection in the CP and HP groups could not be assessed precisely.

Conclusions

In AF ablation, AI-guided high-power application shortened the procedure time without increasing procedure-related complications. However, this procedure is not necessarily associated with an improved outcome in terms of the rate of atrial tachyarrhythmia recurrence-free survival after the procedure.

Sources of Funding

This study did not receive any specific funding.

Disclosures

K.O. has received honoraria from Johnson and Johnson and Medtronic. The remaining authors have no conflicts of interest to declare.

IRB Information

This study was approved by the Ethics Committee of Saiseikai Kumamoto Hospital (Approval no. 776).

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