ORIGINAL ARTICLE

Evaluation and comparison of impedance and amplitude changes in lesion index-guided pulmonary vein isolation

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Abstract

Background: The lesion index (LSI) has been used to estimate lesion formation after radiofrequency catheter ablation. However, the impedance drop and decrease in bipolar amplitude of intracardiac electrograms, which are parameters that are traditionally used to predict effective ablation lesions, are not used to calculate LSI. Therefore, we aimed to investigate the association between LSI and traditional parameters.

Methods: We retrospectively investigated 1355 ablation points from 31 patients who underwent LSI-guided pulmonary vein isolation (PVI) using TactiCath. All points were classified into 3 groups based on the impedance drop: (i) $<10\,\Omega$ ($n=67$), (ii) $10–20\,\Omega$ ($n=909$), and (iii) $>20\,\Omega$ ($n=379$). The LSI targets were 4.5 for the posterior left atrium and 5.2 for the anterior left atrium. After excluding 583 points at which it was difficult to measure the amplitude, 772 ablation points during sinus rhythm were included in the analysis of bipolar amplitude.

Results: The target LSI was achieved at 1177 points (86.9%). The median total impedance drop and amplitude just after ablation were 16.0 [13.0–20.0] Ω and 0.21 [0.14–0.30] mV, respectively. There were significant differences among the 3 groups in the impedance and amplitude before ablation, power, target LSI, final LSI, contact force, and interlesion distance. An impedance drop of $>10\,\Omega$ or an amplitude reduction of $>50\%$ was achieved at 95% and 82% of the study points, respectively. There were no major complications at any of the ablation points.

Conclusion: LSI-guided PVI seemed to be useful for making sufficient ablation lesions, as assessed by the conventional parameters of impedance and amplitude change.

KEYWORDS
ablation, atrial fibrillation, impedance drop, lesion index, pulmonary vein isolation

1 | INTRODUCTION

Ipsilateral extensive pulmonary vein isolation (PVI) using a radiofrequency (RF) catheter is a basic procedure for controlling the rhythm of atrial fibrillation (AF). In this procedure, it is important to create durable tissue degeneration because insufficient ablation can result in the recurrence of AF because of reconduction between the PV and the left atrium.[1]

Conventionally, impedance drop and amplitude reduction have been used to evaluate lesion formation caused by RF ablation.[2–6] The impedance drop because of RF ablation is a real-time marker of tissue heating.[7] When tissue degeneration occurs because of thermal coagulation, the local electrogram amplitude decreases. Although the change in amplitude as a definite endpoint has not been determined, the reduction in amplitude is often used as an indicator of effective ablation.

Since the commercial launch of the contact force sensing catheter, contact force can be monitored during the application of RF energy. Maintaining an appropriate contact force is needed to avoid poor tissue degeneration, collateral damage, and cardiac tamponade. In particular, it has been shown that low contact force during the procedure is associated with the recurrence of AF.[8] Recently, the lesion index (LSI), which was calculated from the power of RF application, contact force, and ablation time, has been available to estimate tissue degeneration. LSI-guided PVI shows good results in some studies.[9,10] The LSI is useful in reducing the recurrence of AF and ensuring procedural safety. However, LSI does not include conventional indicators, such as impedance drop and amplitude reduction,[11] and the relationship between the value of LSI and conventional indicators has not been evaluated.

The purpose of this study is to verify whether sufficient ablation lesion formation was obtained at each point with the LSI-guided PVI when assessed by traditional parameters that are the impedance drop and the amplitude decrease.

2 | METHODS

2.1 | Study design

Consecutive patients with paroxysmal or persistent AF who underwent catheter ablation in our hospital between February 2019 and October 2019 were retrospectively evaluated. Patients with prior ablation of AF were excluded from this study. The indications for catheter ablation of AF followed the guidelines of the Japanese Circulation Society/Japanese Heart Rhythm Society.[12] This was a single-center study and was approved by our institutional review board (approval number #20-347). The requirement of written informed consent was waived because of the retrospective nature of this study.

2.2 | Ablation procedure

In all cases, antiarrhythmic agents were uninterrupted. Warfarin and dabigatran were also uninterrupted. However, apixaban, rivaroxaban, and edoxaban were skipped in the morning on the procedure day if patients took them in the morning. ECG-gated cardiac computed tomography was performed before the ablation procedure unless patients had severe renal impairment, bronchial asthma, or a history of contrast agent allergy. The whole procedure was performed under deep sedation using midazolam and dexmedetomidine hydrochloride. An adaptive servo ventilator was used in all patients, and a nasal airway was introduced if needed. The activated clotting time was kept at 300–400 s with intravenous heparin administration. A steerable 6F 20-polar catheter (BeeAT; Japan Lifeline, Tokyo, Japan) was placed in the coronary sinus via the right jugular or femoral vein and served as a reference for the 3D electroanatomical mapping system (EnSite Precision; Abbott, St Paul, MN). Single transseptal puncture with navigation by intracardiac ultrasound (ViewFlex; Abbott) was used to deliver the ablation and mapping catheter to the left atrium (LA) (one puncture, two sheaths). A TactiCath irrigation catheter (Abbott) was delivered via an 8.5-F steerable sheath (Agilis; Abbott). Detailed left atrial and pulmonary vein geometry and electrical maps were collected with a multispline (HD grid; Abbott) or circular (Optima; Abbott) mapping catheter via an 8.5-F long sheath (SL-0; Abbott).

The irrigated RF current was delivered in power-controlled mode. We set the target LSI as 4.5 at the posterior of the PV antrum and 5.2 at the anterior. The interlesion distance (ILD) was set to <5 mm at the points targeting an LSI of 4.5 and <6 mm targeting an LSI of 5.2. The energy was set to 25–35 W at the posterior and 35–45 W at the anterior. Ablation was completed after achieving the target LSI or a duration of up to 30 s. The goal of ablation was to enclose the pulmonary veins with contiguous and optimized RF lesions indicated by LSI. A bidirectional conduction block between the PV and LA was confirmed after PVI.

2.3 | Detailed ablation data

Whole procedural data, including impedance, power, LSI, ablation time and contact force, were recorded every 0.1 s in the EnSite system, and these data were extracted after the operation. Ablation points of initial PVI lines only included in the analysis. Additional ablation strategies, such as LA-PV gap ablation and ablations beyond PVI strategies (linear ablation of the LA roof or LA bottom and RF application targeting the low voltage area), and unstable ablation points were excluded. The impedance drop was calculated as follows: (impedance just before RF application) – (minimum impedance during RF application). The study points were classified into 3 groups: (1) impedance drop of <10 Ω, (2) 10–20 Ω, and (3) >20 Ω. Since the measurement of bipolar amplitude was difficult during AF, the points where ablation was performed during sinus rhythm were included in the analysis of bipolar amplitude. The bipolar amplitude obtained from the ablation catheter was measured just before and just after ablation. The ILD was measured as the distance between the centers of the tags between the closer of the two points of contact. A trend of impedance dropping rapidly in the first few seconds followed by a slow decrease was observed at almost all points. The rapid drop and the gradual decrease were defined before and after the point where the slope changed, respectively, and the numerical value change in each phase was also analyzed. The amplitude at that inflection point was also recorded. A >50% reduction in bipolar

amplitude was considered to indicate the creation of a sufficient lesion.[13]

2.4 | Statistical analysis

All statistical analyses were performed using R v3.6.3 (The R Foundation for Statistical Computing, Vienna, Austria). Continuous variables are presented as the mean ± standard deviation or median and interquartile range [IQR] if not normally distributed and were compared using the unpaired *t*-test or Mann–Whitney *U* test. For continuous variables, differences among 3 groups were determined by an analysis of variance or the Kruskal–Wallis test, according to the normality of data distribution, and post hoc analyses were performed with the Bonferroni test. All categorical variables are expressed as raw numbers and percentages and were analyzed using Fisher's exact test. The correlation between changes in impedance/amplitude and other parameters was evaluated by the Spearman rank correlation coefficient. *p* values of <.05 were considered to indicate statistical significance in all analyses.

3 | RESULTS

3.1 | Baseline clinical characteristics

We retrospectively enrolled 31 consecutive patients (age, 71.0 [IQR 66.0–76.5] years; male, *n* = 24) with AF who underwent LSI-guided PVI at our hospital from February 2019 to October 2019. Paroxysmal AF was observed in 61% of the study subjects. The median CHADS2 score was 1 [1–3], and the LA volume calculated by cardiac computed tomography was 121.1 [94.5–144.8] mL (Table 1). No serious complications, including cardiac tamponade, major esophageal injury, and phrenic nerve injury, were observed in this study.

3.2 | Impedance drop analysis

The total number of ablation points was 1881 in 31 patients who underwent PVI. A total of 319 points of additional ablation strategies and 207 points where the catheter was displaced during ablation were excluded from this study (Figure 1). Finally, 1355 points were included in the impedance drop analysis. All ablation point data are shown in Table 2. The median impedance drop was 16 [13–20] Ω. An impedance drop of >10 Ω was achieved at 1288 (95%) points. The median power, ablation time, contact force, and ILD were 35 [30–40] W, 15 [11–22] s, 15 [11–19] g, and 4 [3–6] mm, respectively. The target LSI was achieved at 1177 points (86.9%). In addition, the impedance drop was correlated with the preprocedural impedance (RS = 0.58, *p* < .001, Figure 2A). Final LSI showed a weak correlation with impedance drop (RS = 0.22, *p* < .001, Figure S1).

We divided each ablation point into 3 groups according to impedance drop (Table 2). The lower impedance drop group (67 points,

TABLE 1 Baseline clinical characteristics.

Age (years) [IQR]	71.0 [66.0–76.5]
Gender, *n* (male %)	24 (77.4)
BMI [IQR]	25.2 [22.5–26.7]
Comorbid disease, *n* (%)	
CHF	12 (38.7)
Hypertension	13 (41.9)
DM	11 (35.5)
CKD	14 (45.2)
Paf, *n* (%)	19 (61.3)
CHADS2 score [IQR]	1 [1–3]
AAD, *n* (%)	
I	13 (41.9)
II	23 (74.2)
III	4 (12.9)
IV	8 (25.8)
VKA, *n* (%)	4 (12.9)
DOAC, *n* (%)	27 (87.1)
LVEF (%) [IQR]	61.9 [53.3–66.8]
LVDd (mm) [IQR]	49.6 [44.3–53.0]
LVDs (mm) [IQR]	32.1 [29.0–37.0]
LA volume (mL) [IQR]	121.1 [94.5–144.8]

Note: Data are presented as the median [IQR], or *n* (%).

Abbreviations: AAD, antiarrhythmic drug; BMI, body mass index; CKD, chronic kidney disease; CHF, chronic heart failure; DM, diabetes mellitus; DOAC, direct oral anticoagulant; IQR, interquartile range; Paf, paroxysmal atrial fibrillation; LA, left atrium; LVDd, left ventricular end-diastolic diameter; LVDs, left ventricular end-systolic diameter; LVEF, left ventricular ejection fraction; VKA, vitamin K antagonist.

4.9%) showed significantly lower preprocedural impedance, ablation power, contact force, final LSI, and prevalence of achievement of the target LSI and a shorter ILD in comparison to the other two groups. When the points were divided into four segments (anterior, posterior, roof and bottom), the lower impedance drop points were more common at posterior wall (8 points 1.5% at anterior, 46 points 9.1% at posterior, 5 points 2.6% at roof and 8 points 5.7% at bottom). When analyzed separately by the target LSI (4.5 or 5.2), there was no significant difference between contact force, final LSI, achievement of LSI and ILD in the group of target LSI 4.5 (Tables S1A and S1B). Impedance drop of >10 Ω was observed in 637 (98%) and 651 (92%) points in LSI 5.2 and 4.5 group, respectively (*p* < .001).

3.3 | Amplitude reduction analysis

Out of 1355 points, 483 ablation points that were ablated during AF; 100 points where amplitude values were difficult to measure were excluded (Figure 1). A total of 772 points were included in the amplitude change analysis (Table 2). The preprocedural and postprocedural amplitude were 0.77 [0.44–1.39] mV and 0.21

[0.14–0.30] mV, respectively. The median amplitude reduction was 0.47 [0.21–0.94] mV. A bipolar voltage of <0.5 mV or <0.3 mV after ablation or an amplitude reduction of >50% was achieved at 729 (94%), 565 (73%), and 629 (82%) points, respectively. The bipolar

amplitude just before ablation was well correlated with the amplitude reduction (RS = 0.97, $p < .001$, Figure 2B). Final LSI showed a low correlation with amplitude reduction (RS = −0.14; $p < .001$, Figure S2).
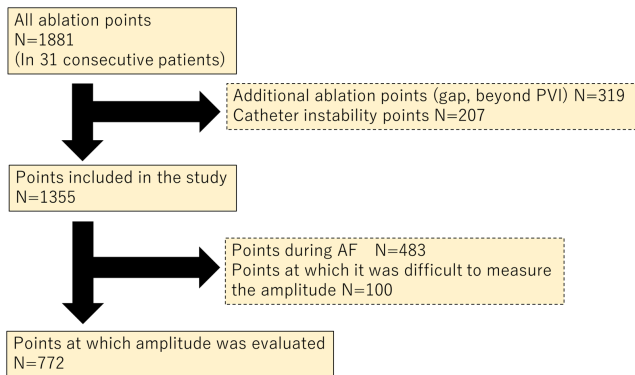
We divided 772 points into 3 groups according to impedance drop (Table 2). The higher impedance drop group showed a significantly higher preprocedural amplitude and amplitude reduction. On the other hand, there was no significant difference in postprocedural amplitude or the prevalence of achievement of >50% amplitude reduction among the 3 groups.

Furthermore, we divided 772 points into 2 groups according to the presence or absence of a 50% reduction in amplitude (Table 3). There were no significant differences between the two groups in power, ablation time, contact force, prevalence of achievement of target LSI, or the impedance data. The bipolar amplitude just before the ablation was higher, that just after the ablation was lower, and the ILD was larger in patients with >50% amplitude reduction. The analysis was performed on ablation sites divided into four segments, but there were no significant differences. When analyzed separately

FIGURE 1 Flowchart of the ablation points and subjects evaluated in this study.

TABLE 2 Procedural characteristics among the 3 groups classified by impedance drop.

		Total impedance drop			
	Total (N = 1355)	<10 Ω (N = 67, 4.9%)	10–20 Ω (N = 909, 67.1%)	≥20 Ω (N = 379, 28.0%)	*p* value
Impedance drop (Ω)	16 [13, 20]	9 [7, 9]	15 [12, 17]*	23 [21, 26]*†	<.001
Pre impedance (Ω)	117 [110, 124]	107 [102, 110]	114 [109, 120]*	125 [119, 132]*†	<.001
Minimum impedance (Ω)	100 [95, 105]	99 [95, 103]	100 [94, 105]	102 [96, 106]*†	<.001
Power (W)	35 [30, 40]	30 [30, 30]	30 [30, 40]*	35 [30, 40]*†	<.001
Ablation time (s)	15 [11, 22]	16 [11, 21]	15 [10, 22]	16 [12, 22]†	.003
Contact force (g)	15 [11, 19]	13 [9, 19]	14, [11, 19]	15 [11, 21]*†	.008
<5 g (%)	34 (2.5)	4 (6.0)	23 (2.5)	7 (1.8)	.124
Target LSI of 5.2, *n* (%)	650 (48.0)	13 (19.4)	416 (45.8)*	221 (58.3)*†	<.001
Final LSI	4.8 [4.6, 5.4]	4.7 [4.6, 4.9]	4.8 [4.6, 5.4]*	5.3 [4.7, 5.4]*†	<.001
Achievement of LSI (%)	1177 (86.9)	54 (80.6)	781 (85.9)*	342 (90.2)*†	.033
Inter lesion distance (mm)	4 [3, 6]	4 [3, 6]	4 [3, 5]	4 [3, 6]†	.005
ILD ≥ 5 mm, *n* (%)	508 (37.5)	23 (37.7)	317 (38.0)	168 (49.9)*†	<.001
Results of the analysis of the 772 points for which subject data were available					
	Total (N = 772)	<10 Ω (N = 42, 5.4%)	10–20 Ω (N = 510, 66.1%)	≥20 Ω (N = 220, 28.5%)	*p* value
Pre amplitude (mV)	0.77 [0.44, 1.39]	0.77 [0.48, 1.06]	0.73 [0.42, 1.31]	0.89 [0.47, 1.60] †	.023
Post amplitude (mV)	0.21 [0.14, 0.30]	0.22 [0.13, 0.31]	0.21 [0.14, 0.30]	0.20 [0.14, 0.30]	.976
<0.1 mV (%)	74 (9.6)	1 (2.4)	52 (10.2)	21 (9.5)	.255
<0.3 mV	565 (73.2)	29 (69.0)	380 (74.5)	156 (70.9)	.496
<0.5 mV	729 (94.4)	39 (92.9)	483 (94.7)	207 (94.1)	.852
Amplitude reduction (mV)	0.47 [0.21, 0.94]	0.33 [0.17, 0.60]	0.45 [0.17, 0.88]	0.65 [0.30, 1.24]†	.011
>50% (%)	629 (81.5)	33 (78.6)	410 (80.4)	186 (84.5)	.367

Note: Data are presented as the median [IQR] or % unless otherwise indicated.

Abbreviations: ILD, inter lesion distance; IQR, interquartile range; LSI, lesion index.

*$p < .05$ versus <10 Ω;

† $p < .05$ versus 10–20 Ω.
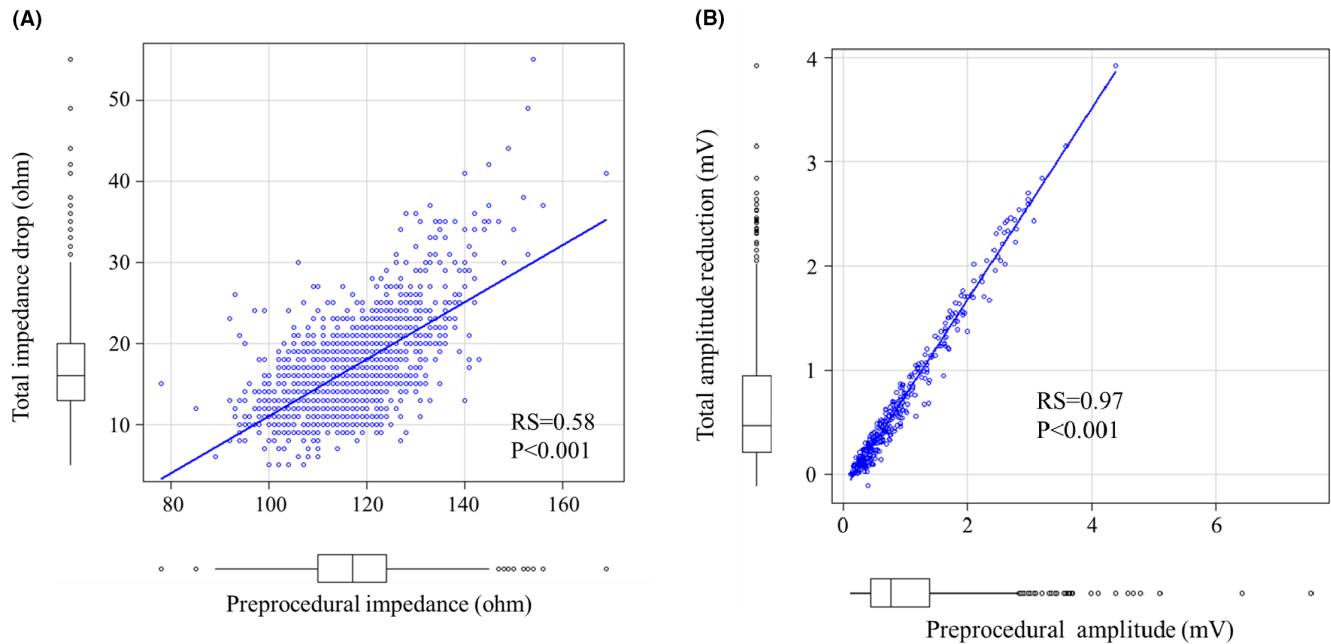
(A)

(B)

FIGURE 2 (A) Correlation between the preprocedural impedance and total impedance drop (RS=0.58; $p<.001$). (B) Correlation between the total amplitude decrease and the preprocedural amplitude (RS=0.97, $p<.001$).

TABLE 3 Comparison of cases with and without a 50% reduction in amplitude.

		Total amplitude reduction		
	Total (N=772)	<50% (N=143, 18.5%)	≥50% (N=629, 81.5%)	p value
Amplitude reduction (mV)	0.47 [0.21, 0.94]	0.11 [0.07, 0.15]	0.64 [0.38, 1.20]	<.001
Pre amplitude (mV)	0.77 [0.44, 1.39]	0.36 [0.27, 0.49]	0.92 [0.56, 1.54]	<.001
Post amplitude (mV)	0.21 [0.14, 0.30]	0.25 [0.19, 0.32]	0.20 [0.13, 0.29]	<.001
Power (W)	30 [30, 40]	35 [30, 40]	30 [30, 40]	.371
Ablation time (s)	17 [12, 23]	16 [12, 23]	17 [12, 23]	.764
Contact force (g)	14 [11, 19]	14 [10, 19]	14 [11, 19]	.635
Achievement of target LSI (%)	662 (85.8)	127 (88.8)	535 (85.1)	.29
Pre impedance (Ω)	118 [111, 125]	116 [110, 124]	119 [111, 125]	.078
Minimum impedance (Ω)	102 [96, 106]	100 [95, 106]	102 [97, 106]	.29
Impedance drop (Ω)	16 [13, 20]	16 [13, 19]	16 [13, 20]	.101
Inter lesion distance (mm)	4 [3, 5]	4 [3, 5]	4 [3, 6]	.017

Note: Data are presented as the median [IQR] or % unless otherwise indicated.

Abbreviations: IQR, interquartile range; LSI, lesion index.

by target LSI, the achievement rates of amplitude decrease were 79% and 84% when the target LSI was 5.2 and 4.5, respectively ($p=.115$).

3.4 | Two phases of impedance drops

Figure 3 shows a representative image of the impedance and amplitude change during ablation. Impedance dropped rapidly in the first 1–2 s (early phase) and then decreased gradually (delayed phase). These two phases are almost always observed at any other point. We

named them the "rapid drop phase" and "gradual decrease phase," respectively. Changes in impedance and amplitude between the rapid drop and gradual decrease phases are summarized in Table 4. The mean duration of the rapid drop was 1.5 ± 0.8 s, and the gradual decrease lasted 15.8 ± 7.9 s. The impedance drop was greater in the rapid drop phase, and the amplitude reduction was greater in the gradual decrease phase. The impedance drop during the rapid drop phase was well correlated with the total impedance drop (RS=0.80; $p<.001$, Figure 4A). On the other hand, the impedance drop during the gradual decrease phase was weakly correlated with the total impedance drop (RS=0.61; $p<.001$, Figure 4B).
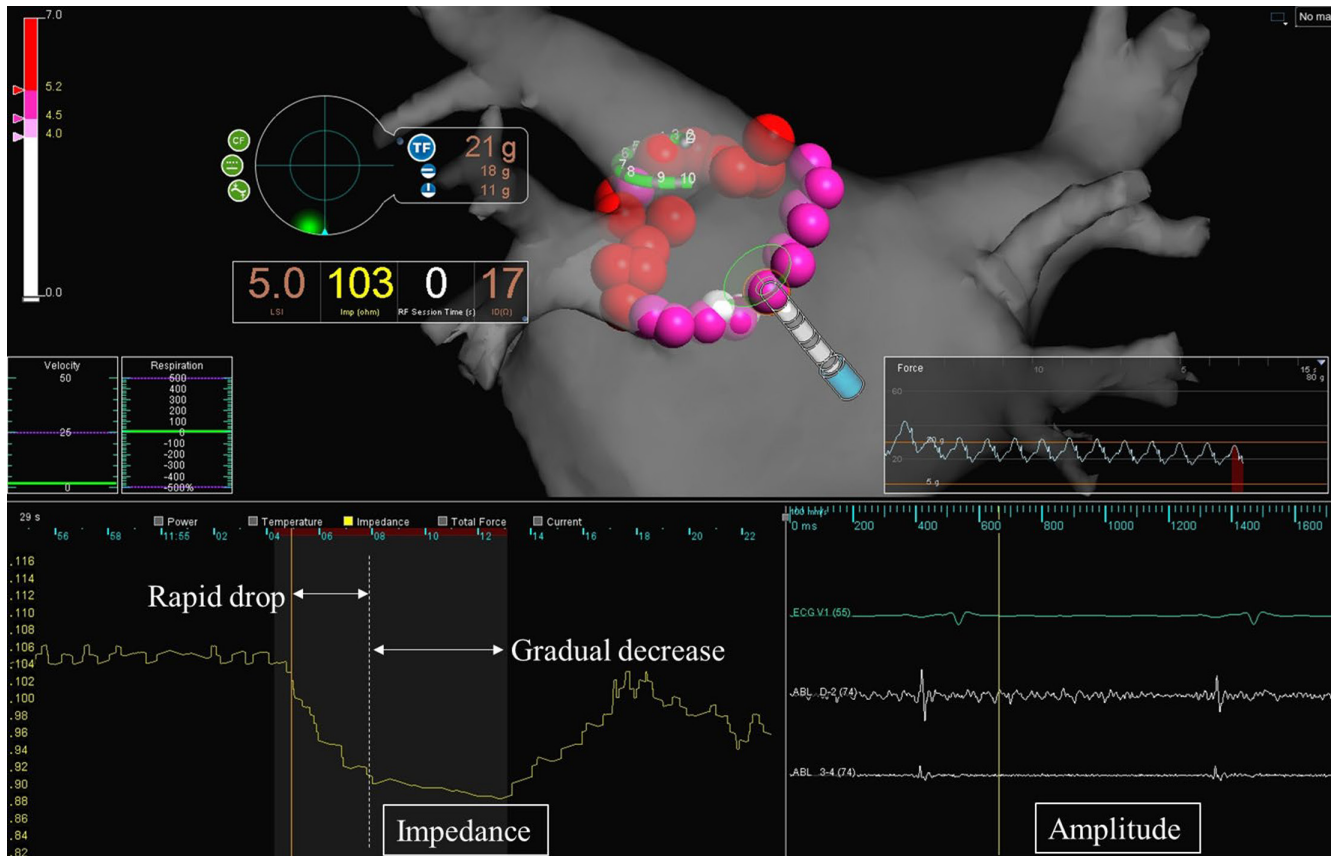
FIGURE 3 Representative 3D mapping data during ablation. The yellow line graph at the lower left shows the change in impedance. At the timing of the dotted line, the speed of the impedance drop changes; these changes are referred to as "rapid drop" and "gradual decrease," respectively. The local amplitude, as determined by an ablation catheter, is shown on the lower right of this figure.

TABLE 4 Changes in impedance and amplitude between the rapid drop and gradual decrease phases.

	Rapid drop phase	Gradual decrease phase	_p_ value
Time (s)	1.5±0.8	15.8±7.8	<.001
Impedance (Ω)			
Pre [IQR]	117 [110, 124]	107 [102, 113]	
Post [IQR]	107 [102, 113]	100 [95, 105]	
Impedance drop [IQR]	9 [7, 12]	7 [5, 9]	<.001
Amplitude (mV)			
Pre [IQR]	0.77 [0.44, 1.39]	0.53 [0.32, 0.99]	
Post [IQR]	0.53 [0.32, 0.99]	0.21 [0.14, 0.30]	
Amplitude reduction [IQR]	0.15 [0.01, 0.39]	0.30 [0.12, 0.73]	<.001
% amplitude reduction [IQR]	0.22 [0.02, 0.43]	0.60 [0.39, 0.77]	<.001

Note: Data are presented as the mean±SD or median (IQR).

Abbreviation: IQR, interquartile range.

4 | DISCUSSION

The results of this study indicate that the median impedance drop and amplitude decrease during LSI-guided PVI were 16 [13–20] Ω and 0.47 [0.21–0.94] mV, respectively. An impedance drop of >10 Ω or an amplitude reduction of >50% was achieved at 95% and 82% of the study points, respectively. Therefore, LSI-guided PVI could achieve sufficient lesion formation in terms of traditional parameters, including impedance drop and bipolar amplitude decrease.
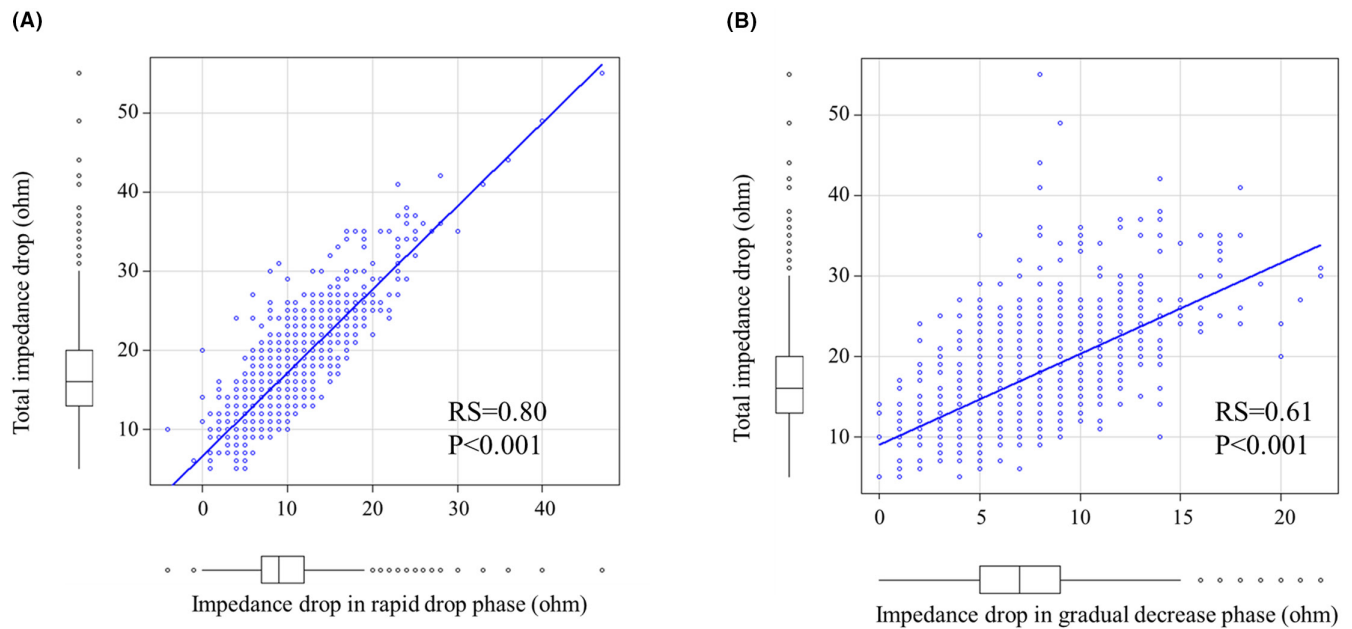
(A)

(B)

FIGURE 4 Correlation between total impedance drop and impedance drop in the rapid drop phase (A, RS=0.80, $p<.001$) and in the gradual decrease phase (B, RS=0.61, $p<.001$).

Conventionally, changes in impedance and local amplitude have been used to evaluate tissue degeneration in RF ablation. The change in impedance is considered a real-time marker of the change in tissue temperature because of heating; as the tissue temperature increases during RF ablation, the impedance to current flow decreases as ions in the heated tissue show undergo greater movement.[4] It has also been shown that the diameter and depth of the ablation lesion are well correlated with the drop in impedance and have an even more direct relationship than temperature measurements.[7] The decrease in local amplitude is also considered to be a real-time marker of tissue degeneration because of ablation. Some studies suggest a 5–10 Ω decrease in resistance or a ≥50% decrease in the bipolar amplitude of local electrograms are evidence of lesion formation with perfused radiofrequency ablation catheters. On the other hand, the efficacy of RF ablation using LSI has been demonstrated in various reports[14] and has become the standard indicator. In our study, the amount of impedance drop and amplitude decrease were well correlated with the impedance and amplitude just before ablation when the target LSI was set to 4.5 on the posterior wall and 5.2 on the anterior wall. These findings indicated that the impedance just after ablation was approximately 100 Ω and that the amplitude was approximately 0.2 mV, regardless of the degree of impedance drop and amplitude decrease. In other words, the use of the LSI to guide ablation appears to be very reasonable.

The LSI consists of contact force, time, and power[11] and does not include changes in impedance or amplitude, which are conventional measures. A previous study showed that when acute pulmonary vein reconnection occurred, the lower minimum impedance at the same site was an independent risk factor for acute reconnection.[15] An excessive drop in impedance has also been reported

to lead to fatal complications such as steam pop and cardiac tamponade.[16] In our study using LSI-guided PVI, approximately 5% of the ablation points had an impedance drop of <10 Ω, and approximately 30% had an impedance drop of >20 Ω. In a previous study, it was reported that sufficient contact force leads to decreased impedance.[17] Our finding that contact force was higher in the higher impedance drop group is in line with a previous report. Moreover, the ILD was shorter and the preprocedural amplitude was lower in the lower impedance drop group. A previous study on LSI also reported the formation of ablation lesions of approximately 6 mm with an LSI of 4.5 and 7 mm with an LSI of 5.2.[11] Therefore, the reason why LSI-guided PVI resulted in a smaller impedance drop could be that the ablation points included areas that had already been ablated. Even in the lower impedance drop group, the impedance after ablation was approximately 100 Ω, and the amplitude was approximately 0.2 mV, suggesting that the ablation was sufficient. Although the correlation between LSI and impedance/amplitude changes was not strong, LSI-guided PVI appeared to be useful for adequate lesion formation. On the other hand, the ILD was larger, the impedance and bipolar amplitude just before ablation were larger, and the target and final LSI were higher in the higher impedance drop group. These findings may indicate that a large amount of myocardium was ablated when the ILD was sufficiently large or that the anterior wall of the PV antrum resulted in a huge impedance drop. And this may have been a factor in the large number of lower impedance drop groups below 10 Ω at the posterior wall. It also may can explained that the achievement rate of impedance drop (92% vs. 98%) was significantly lower in the group of target LSI 4.5 than in the group of target LSI 5.2. These results suggest that LSI-guided PVI is effective for adequate lesion formation. In terms of safety, an impedance drop of over 20 Ω was

shown at approximately 30%, but there were no major complications, including steam pop, at all ablation points in this study. LSI-guided PVI may also be useful for assuring safety. Group analysis with Target LSI showed no significant differences in contact force, final LSI, achievement of LSI and ILD in the group with Target LSI 4.5. This may be because the Target LSI 4.5 is for the posterior wall, which is easier to ensure stable catheter contact compared to other sites. In addition, the target ILD was 5 mm short, so it is thought that the difference in ILD was less likely to occur.

In the present study, we found that there are two phases of drop in impedance during ablation. We observed a rapid drop and gradual decrease at almost all ablation points. The impedance drop mainly occurred in the rapid drop phase, and the amplitude reduction in the gradual decrease phase was larger than that in the rapid drop phase. One possible explanation is that a rapid drop phase could reflect resistive heating and a gradual decrease phase could reflect conductive heating.

The present study was associated with some limitations. First, this was a retrospective single-center study and the study population was relatively small. Second, the clinical course of the ablation site, such as reconduction and the recurrence of AF, could not be evaluated. Therefore, further multicenter prospective studies with large sample sizes are needed to confirm and enhance our findings.

In conclusion, LSI-guided ablation could achieve efficient lesion formation based on conventional indicators.

CONFLICT OF INTEREST STATEMENT

Authors declare no conflict of interests for this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author or the first author upon reasonable request.

ETHICS STATEMENT

This study was approved by the institutional review board (approval number #20-347).

PATIENT CONSENT STATEMENT

The requirement of written informed consent was waived because of the retrospective nature of this study project.

PERMISSION TO REPRODUCE MATERIAL FROM OTHER SOURCES

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.