The optimal Ablation Index Values for Electrical Isolation of the Superior Vena Cava

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Abstract

Background The ablation index (AI) has been reported to be useful for a durable pulmonary vein isolation (PVI) to treat atrial fibrillation (AF). No study has reported the optimal AI value for the SVC isolation (SVCI). In this study, we aimed to investigate the optimal AI for the SVCI. Methods Thirty-six AF patients who underwent an initial SVCI were enrolled. Ablation was performed at a total of 549 points. The sites where dormant conduction was induced or additional ablation was needed were defined as touch-up sites (n=36). We compared the energy deliver time, power, CF, Force-Time Integral (FTI), and AI between the touch up sites and control sites (n=513). Results The median RF delivery time, power, CF, and FTI were all significantly lower at the touch up sites (touch up sites vs. control sites; energy delivery time, sec, 20.3[12.3-21.7] vs. 21.6[19.8-25.2], p=0.0003; power, W, 23.5[15-24] vs. 24[20-25], p<0.0001; CF, g, 7[6-10.8] vs. 11[9-15], p<0.0001; FTI, 126.5[99.3-208.8] vs. 244[183.5-340.5], p<0.0001). The AI also was significantly lower at the Touch up sites (touch up sites vs. control sites; AI, 350.1±43.6 vs. 277.2±21.8, p<0.0001). The median value of the AI at the control sites was 350 and no reconnections were seen where the minimum AI value was more than 308. Conclusion The AI value at the touch up sites was significantly lower than that at the control sites. The optimal AI value for the SVCI should be 350, and at least 308 would be needed.

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Methods

Thirty-six AF patients who underwent an initial SVCI were enrolled. Ablation was performed at a total of 549 points. The sites where dormant conduction was induced or additional ablation was needed were defined as touch-up sites (n=36). We compared the energy deliver time, power, CF, Force-Time Integral (FTI), and AI between the touch up sites and control sites (n=513).

Results

The median RF delivery time, power, CF, and FTI were all significantly lower at the touch up sites (touch up sites vs. control sites; energy delivery time, sec, 20.3[12.3-21.7] vs. 21.6[19.8-25.2], p=0.0003; power, W, 23.5[15-24] vs. 24[20-25], p<0.0001; CF, g, 7[6-10.8] vs. 11[9-15], p<0.0001; FTI, 126.5[99.3-208.8] vs. 244[183.5-340.5], p<0.0001). The AI also was significantly lower at the Touch up sites (touch up sites vs. control sites; AI, 350.1±43.6 vs. 277.2±21.8, p<0.0001). The median value of the AI at the control sites was 350 and no reconnections were seen where the minimum AI value was more than 308.

Conclusion

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Background

Radiofrequency (RF) catheter ablation is a well-developed treatment of atrial fibrillation (AF) (1,2). AF frequently originates from atrial muscular sleeves that extend into the thoracic veins such as the pulmonary veins (PV) and superior vena cava (SVC) (1,3,4) and the electrical isolation between the left atrium and these thoracic veins is the cornerstone strategy of AF ablation (3). An insufficient lesion-creation and conduction recurrence lead to the recurrence of arrhythmias (5~7). Therefore, a durable lesion-formation is a key factor for RF ablation. Lesion-formation depends on several factors such as the catheter contact force (CF), RF delivery time, and power (8). The ablation index (AI), a novel marker for incorporating the CF, RF delivery time, and power in a weighted formula, has been reported to be useful for a durable PVI (9~11). Several studies have reported the optimal value of the AI for PV isolation (PVI) and cavotricuspid isthmus line (CTI) ablation (12~14). However, no study has reported the optimal value of the AI for the SVC isolation (SVCI). In this study, we aimed to investigate the optimal AI for the SVCI.

Methods

Study population

We retrospectively analyzed 286 patients who underwent AF ablation in our hospital from January 2016 to June 2018. Among the 286 patients, we included 36 patients in this study. In those patients, a Force-Time Integral (FTI) guided SVCI was performed for patients whose length of the SVC sleeve was more than 3cm, and who revealed premature atrial contraction from the SVC. The patient characteristics are shown in Table 1. The study protocol was approved by the hospital's institutional review board(02-007).

Mapping and Ablation protocol

All antiarrhythmic drugs were discontinued for at least 5 half-lives prior to ablation. All patients took direct oral anticoagulants (DOAC) or warfarin for at least 1 month prior to the procedure. Computed tomography was performed to evaluate the cardiac anatomy.

During the procedure, the surface electrogram and intracardiac electrograms were continuously monitored and stored on a computer-based digital recording system. All ablation procedures were performed under deep sedation with dexmedetomidine hydrochloride, propofol, and pentazocine. A 100U/kg body weight dose of heparin was administered after securing the venous line, and the activated clotting time was maintained at 300 to 350 seconds.

Mapping and ablation were performed under the guidance of a three-dimensional (3D) mapping system (CARTO3(r); Biosense Webster, Irvine, CA, USA). A duodecapolar catheter (Map-iT^{TM}, ACCESS POINT, Rogers, MN, USA) was placed into the coronary sinus (CS). A duodecapolar catheter with five branches (Pentaray(r); Biosense Webster, Irvine, CA, USA) was used to construct a 3D map of the SVC. An open-irrigated 3.5 mm tip electrode catheter (Thermocool SMARTTOUCH(r); Biosense Webster, Irvine, CA, USA) was utilized for the ablation.

The protocol of SVC isolation

Firstly, electroanatomical SVC maps were created using a Pentaray catheter during sinus rhythm. The local SVC potentials were recorded from the ablation catheter. To determine the site of the phrenic nerve, high output pacing (10V) was performed. The sites where phrenic nerve stimulation was observed, were marked as a phrenic nerve position on the SVC map. The AI was blinded to the operator, and the circumferential SVC isolation was performed 1 cm above the earliest activation sites during sinus rhythm. The RF energy was set at 20W-25W and was decreased to 15W-20W in the phrenic nerve area or area close to the sinus node. Ablation was discontinued immediately when a decrease in the diaphragmatic movement was observed on the fluoroscopic image. The endpoint of the SVCI was the disappearance of all SVC potentials, and bidirectional block was confirmed by pacing from the ablation catheter in the SVC. We also confirmed dormant conduction after an intravenous injection of isoproterenol and adenosine triphosphate.

Study design

Ablation was performed at a total of 549 points in 36 patients. The sites where dormant conduction was induced or additional ablation was needed due to residual SVC potentials after the circumferential ablation, were defined as touch-up sites (n=36). The SVC was divided into four segments (Figure 1) and the location of the touch up sites was analyzed. The value of the AI was also retrospectively calculated at every ablation site. We compared the energy deliver time, power, CF, FTI, and AI between the touch up sites and control sites (n=513). The local potentials at the ablation site were obtained from the ablation catheter and compared among the 4 SVC segments.

Statistical analysis

The statistical analyses were performed using JMP software (versionPro14, SAS institute, Cary, North Carolina). Continuous data are expressed as the mean+-SD for parametric data or median (interquartile range [IQR]) for non-parametric data. A comparison of the means between the groups was performed using an independent samples T-test for normally distributed data and Mann-Whitney U-test for non-uniformly distributed data. A value of $p<0.05$ was considered statistically significance.

Results

The location of the touch up sites

A first pass isolation was obtained in 27 patients and additional ablation was needed in 9 patients. The detailed location of the touch up sites are shown in Figure 1. A touch up ablation was needed at 20 points in the anterior area, 10 in the lateral area, and 6 in the septum area. Touch up ablation was not needed in the posterior area. No one had any transient or prolonged phrenic nerve injury or sinus node injury.

Comparison of the ablation parameters between two groups

Figure 2 shows the comparison of the ablation parameters between the touch up sites and control sites. All parameters at the touch up sites were significantly lower than those at the control sites (touch up site vs. control sites; energy delivery time, sec, 20.3 [12.3-21.7] vs. 21.6 [19.8-25.2], p=0.0003; power, W, 23.5 [15-24] vs. 24 [20-25], p<0.0001; CF, g, 7 [6-10.8] vs.11 [9-15],p<0.0001; FTI, 126.5 [99.3-208.8] vs. 244 [183.5-340.5],p<0.0001; AI, 277.2+-21.8 vs. 350.2+-42.8 , p<0.0001). The median value of the AI at the control sites was 350 and the maximum value of the AI at touch up sites was 308.

Comparison of the local potentials among the 4 segments of the SVC

Figure 3 shows the comparison of the local potentials among the 4 segments of the SVC. The median amplitude of the local potentials at each segment was as follows: anterior area, 0.36mV (0.20-0.76); septal area, 0.35mV (0.20-0.73); posterior area, 0.23mV (0.14-0.50); and lateral area, 0.23mV (0.12-0.50). The local potential was highest at the anterior area and lowest at the posterior and lateral areas.

Discussion

To the best of our knowledge, this is the first study to examine the optimal AI value for the SVCI. The major findings in our study were as follows: 1) Touch up ablation was frequently needed in the area close to the phrenic nerve or sinus node. 2) The optimal AI value for the SVCI was 350, and at least 308 would be needed. 3) The amplitude of the SVC was asymmetric and was higher in the anterior area and septal areas than lateral and posterior areas.

The location of the touch up sites in the SVCI

Miyazaki et al. reported that conduction gaps were located on the anterolateral wall of the SVCI in the majority of cases (15). Our study also revealed that touch up ablation was needed in the anterior and lateral areas. The median value of the AI in the anterior and lateral areas was relatively lower than that in the posterior and septal areas. The ablation of the anterior or lateral area had a potential risk of sinus node or phrenic nerve complications. As a result of the fact that the operators worried about these complications, the AI value may have been lower than that of the other areas. The lower AI value in the anterior and lateral areas resulted in a higher incidence of touch up ablation in those areas.

The optimal values of the AI in the SVCI

Several studies have reported the optimal value of the AI for the PVI and CTI. Although there were minor differences among the studies, the optimal values of the AI for the PVI is 400-500 for the left atrial (LA) anterior wall and 250-400 was for the LA posterior wall (12,13). For the CTI ablation, an AI target of 500 for two-thirds of the anterior segments and 400 for one-third of the posterior segments were needed (14). The optimal value of the AI differed among the ablation sites. In our study, the optimal AI value for the SVCI was 350, and at least 308 would be needed, which was lower than the optimal AI value reported for the PVI and CTI. The wall thickness of the LA differed according to the location and the minimum wall thickness of the LA was 2.2 6.5mm (16). The wall thick ness of the CTI was 2.7 4.1mm (17). However, the wall thickness of the SVC was 1.2+-1.0 mm (18). The wall thickness of the SVC was relatively thinner than that of the LA or CTI and that was related to the lower optimal value of the SVCI. Furthermore, pulmonary vein reconnections were frequently observed in higher voltage zones (19). That indicated that higher voltage zones needed higher AI values. Suraj et al. reported the mean bipolar voltage in the LA during sinus rhythm was 1.44+-1.27 mV(20). On the other hand, the median bipolar voltage of the SVC in the present study was 0.29 mV (0.16-0.65) and was lower than that of the LA. The the difference in the voltage amplitude between the SVC and PV may have led to the difference in the optimal AI value.

Asymmetric voltage amplitude of the SVC

A previous report revealed that the length of the SVC muscular sleeve was asymmetric and was longest in the anterior to septal regions (21). Our study revealed that the voltage amplitude of the SVC was also asymmetric and longer in the anterior and septal regions than lateral and posterior areas. The higher voltage amplitude in the anterior area also was related to the higher incidence of touch up ablation in the anterior area.

Clinical implications

Despite the frequency of the SVC having non-PV foci and the opportunity to perform an SVCI, few studies have considered the optimal AI values for the SVCI. This study showed that an AI value of 350 may be a new indicator of the need for an SVCI. We also showed that the amplitude of the anterior and septal walls was higher than that of the other segments. This information could be useful for a safe and effective SVCI.

Limitations

There were several limitations to our study. Firstly, there were no cases that underwent a 2nd session of ablation. The reconnections of the SVC have not been evaluated, and therefore, the medium- to long-term durability was unclear. Secondly, this study was a single-center retrospective study based on the FTI guided ablation with a relatively small sample of subjects. So further randomized controlled studies based on the AI guided ablation would be needed for its validation in a larger cohort. Finally, the SVCI could be the result of SVC stenosis. However, we did not perform computed tomography after the ablation. Hence the incidence of SVC stenosis was unknown.

Conclusion

The AI value at the touch up sites was significantly lower than that at the control sites. The optimal AI value for the SVCI should be 350, and at least 308 would be needed.

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Authors' contributions

HM and DK, study conception and design; MY, AK, MY, YG, and AS, data collection and data analysis; AH, KT, and IY, manuscript revision; HT and RK, study supervision

Disclosure

The authors have no conflicts of interest to disclose.

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【Figure Legend】

Figure 1. The location of the touch up sites.

The superior vena cava (SVC) was circumferentially divided into 4 segments. Touch up ablation was mostly needed on the anterolateral wall.

Figure 2. This shows the comparison of the ablation parameters between the touch up sites and control sites.

All parameters of the touch up sites were significantly lower than that of the control sites. The median value of the AI at the control sites was 350 and the maximum value of the AI at the touch up sites was 308.

Figure 3. The comparison of the local potentials and AI for each area of the SVC.

The continuous variables are shown as the median value or mean value. The local potentials were highest in the anterior area and lowest in the posterior and lateral area.

Abbreviation: Ant = anterior wall; Lat =lateral wall; Post =posterior wall; Sep = septal wall

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	n=36
Clinical Parameters	
Age	52.0±12.4
Gender, Male, n (%)	35 (97.2)
BMI, kg/m^2	24.6±4.3
CHADS2 score, n (%)	
0	25(69.4)
1	6(16.7)
2～3	4(11.1)
4～6	1(2.8)
Hypertension, n (%)	6(16.7)
Diabetes mellitus, n (%)	5(13.9)
Structural heart disease, n (%)	1(2.8)
Type of AF, n (%)	
Paroxysmal	19(52.8)
Chronic	17(47.2)
Laboratory Findings	
BNP, pg/ml	17.9 (6.3-53.7)
Cr, mg/dl	0.91±0.20
Echocardiographic finings	
LVEF, %	64.1±7.0
LAD, mm	39.4±5.6

Table 1. Baseline characteristics of the study patients

Continuous variables are shown as the mean (±SD) or median (first–third quartile) and categorical variables as the number (%).

Abbreviations: BMI, body mass index; AF, atrial fibrillation; BNP, brain natriuretic peptide; Cr, creatinine; LVEF, left ventricular ejection fraction; LAD, left atrial diameter