Ablation Index-guided high-power ablation for superior vena cava isolation in patients with atrial fibrillation

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Abstract

Introduction: The ablation index (AI)-guided high-power ablation for pulmonary vein isolation (PVI) appears to be a novel strategy in treating atrial fibrillation (AF). This study aimed to evaluate the feasibility and safety of superior vena cava isolation (SVCI) by using an AI-guided high-power ablation strategy among patients with AF after PVI. **Methods and Results:** Data from 53 patients with AF were collected. Mapping and ablation of SVC were performed after PVI. The ablation power was set to 45 W and the ablation procedure was guided by AI. The SVC was divided into six segments in a cranial view. Applications and locations of radiofrequency (RF) were recorded. The RF applications and AI values in different SVC walls were compared and analyzed. SVCI was performed in 46 patients and electrical SVCIs were successfully achieved in all patients with a mean of 7.6 ± 2.9 RF applications. The mean time of the SVCI procedure was 9.5±4.5 min. The RF applications were located on different walls (anteroseptal anterior wall, 20/46 sites [43.5%]; posteroseptal wall, 38/46 sites [82.6%]; posterior wall, 40/46 sites [87.0%]; anterior walls, 37/46 sites [80.4%]; anterolateral wall, 27/46 sites [58.7%]; posterolateral wall, 23/46 sites [50%]). The mean AI value in septal, posterior, and anterior walls was higher than that of the lateral wall (392±28 vs 371±37, P < 0.001). There was no complication in any cases. **Conclusion:** AI-guided high-power ablation is a feasible and safe strategy for performing SVCI. The RF applications and AI value in different SVC walls varied.

Introduction

The high-power ablation strategy has received a growing interest in recent years[1-6]. Ablation index (AI), incorporating contact force, radiofrequency time, and applied power in a weighted formula, has been proved to help create durable ablation lesions[7-9]. There are several studies, which applied AI-guided high-power ablation strategy in atrial fibrillation (AF) ablation and had been validated to improve clinical outcomes after ablation[10-13].

The superior vena cava (SVC) plays an important role in nonpulmonary veins (PVs) foci to trigger atrial fibrillation (AF), and SVC isolation (SVCI) has been demonstrated to reduce AF recurrence in the several reports[14-18]. However, because of potential risks, including sinus node injury, phrenic nerve injury, and SVC stenosis, there have been no optimal ablation strategies for SVCI in previous reports. This study was undertaken to evaluate the AI-guided high-power ablation strategy for SVCI.

Methods

Study population

We retrospectively analyzed a total of 53 patients with AF who underwent the first ablation procedure in our center from September 2020 to August 2021. All patients performed PV isolation (PVI), after which an electrophysiological examination was performed. SVCI was undergone when there are trigger foci Inducing tachycardia or active superior vena cava potentials. All patients received cardiac contrast-enhanced Computed tomography or transesophageal echocardiography to exclude left atrial thrombosis. All patients took warfarin or new oral anticoagulants (noacs) for at least 4 weeks and stopped all antiarrhythmic drugs for at least 5 half-lives. The study was approved by the institutional ethics committee and complied with the Declaration of Helsinki. All patients underwent their written informed consent before the procedures.

Mapping and ablation protocol

After puncturing jugular and femoral veins, a decapolar catheter was placed into the coronary sinus, and a single transseptal puncture, using a Swartz sheath (St. Jude Medical), was performed under X-ray or intracardiac echocardiographic guidance. After the transseptal puncture, A 100U/kg body weight dose of heparin was administered, and repeated doses of heparin were given to maintain an activated clotting time between 300 and 350 seconds.

Under the guidance of a three-dimensional (3D) mapping system (Biosense Webster), mapping and ablation were performed by experienced electrophysiological doctors, using a Pentaray mapping catheter (Biosense Webster) and Thermocool Smart touch SF catheter (Biosense Webster). Ablation points were marked automatically according to VisiTag (Biosense Webster) settings (the lesion-tag size was set at 2.5mm, minimum time 3 s). Radiofrequency (RF) power was set at 45 W and irrigation flow was 15ml/min throughout the procedure.

The protocol of SVC isolation

After finishing PVI, operators used a PentaRay catheter to create Electroanatomical maps of the right atrium (RA) and SVC during sinus rhythm. Besides, an electrophysiological examination was performed at the same time. The SVC was divided into six segments in a cranial view: anterior, anterolateral, posterolateral, posterior, posteroseptal, and anteroseptal portions. Before RF delivery, High output pacing (10mA) was performed at sites on the lateral wall to identify a phrenic nerve position, which was marked on the Electroanatomical SVC map. Diaphragmatic movement was observed on fluoroscopy during the RF delivery at the phrenic nerve capture site. Once PNI was suspected, the delivery was immediately discontinued. If local SVC potentials were recorded from the ablation catheter, SVCI was performed at the roofline level of right PVI,10mm above the RA-SVC junction generally, in the order of the anteroseptal, posteroseptal, posterior, anterior, anterolateral, and then posterolateral segments. The endpoint of each RF ablation lesion was the disappearance of local potential. If the potential was restored, RF energy delivery was performed repeatedly. The endpoint of the SVCI was the elimination of all SVC potentials and no potential restoration until the end of the procedure.

Diaphragmatic movement and electrocardiograph (ECG) recordings were monitored before, during, and after the ablation procedure. A chest X-ray was undertaken before and on the next day after the procedure in all patients. Phrenic nerve injury was defined as the elevation of the ipsilateral diaphragm under X-ray fluoroscopy and abnormal movement of the diaphragm during inspiratory movement. Sinus node injury was defined as ECG showing an average heart rate of < 45 beats/min or sinus arrest > 3S.

Statistical analysis

All statistical analyses were performed using the SPSS 25.0 software (SPSS Inc.). Continuous variables are expressed as the mean $\pm$ standard deviation (SD) for normally distributed variables and were compared using a Student's t-test. The measurement data of skew distribution are expressed in M (Q1, Q3), and the Mann Whitney U test is used for comparison between groups. Categorical variables were tested by the chi-square test or Fisher's exact test. All tests were 2-tailed, and a p-value < 0.05 was defined as a statistical significance.

Results

Patient characteristics

There were 46 patients with paroxysmal AF in whom SVCI, following the PVI, was performed. SVCI wasn't performed due to the lack of SVC potential in the remaining 7 patients. The patient characteristics were shown in Table 1. the mean age was 62.3 ± 11.0 years, and 19 (35.8%) patients were female; the median duration was 3.0 (2.0, 7.0) years; the CHA2DS2-VASc score was 2.0 (1.0, 3.0); the mean left atrial diameter (LAD) was 40.0 ± 4.9 mm; the mean left ventricular ejection fraction (LVEF) was 63.9 ± 4.7 %.

Superior vena cava isolation

For the regional analysis, the ablation area was classified into 8 SVC segments circumferentially as shown in Figure 1. SVCI was performed in 46 of the 53 patients. All ablation lesions were performed exclusively with a power of 45W. The procedure time for the SVCI was 9.5±4.5 min. SVCIs were successfully achieved in all patients with a mean of 7.6 ± 2.9 RF applications. A first pass isolation was obtained in 38 patients (82.6%), and additional ablation was needed in 8 patients (17.4%). The total number of RF applications until SVC isolation was 353 points.

The endpoint of the SVCI could be achieved by segment ablation in most cases. The ablation was performed at the different SVC walls. The detailed locations of RF applications are shown in Figure 1. RF applications were located on the anteroseptal wall in 20 patients (43.5%), posteroseptal wall in 38 patients (82.6%), posterior wall in 40 patients (87.0%), anterior wall in 37 patients (80.4%), anterolateral wall in 27 patients (58.7%), and posterolateral wall in 23 patients (50.0%).

The number of RF applications at each segment is shown in Figure 2. RF applications were needed at 38 (10.8%) points in the anteroseptal segment, 74 (21.0%) in the posteroseptal segment, 81 (22.9%) in the posterior segment, 72 (20.4%) in the anterior segment, 45 (12.7%) in the anterolateral segment, and 43 (12.2%) in the posterolateral segment.

The average AI per lesion to eliminate SVC potential was different on different walls. The distribution of the mean AI value in different walls was shown in Figure 3. It was demonstrated that the mean AI value in septal, posterior, and anterior walls was similar, which was higher than that of the lateral wall (392±28 vs 371±37, $P < 0.001$).

There were no complications in any patients, including sinus node injury and phrenic nerve injury, which were related to the procedure of SVCI.

Discussion

To the best of our knowledge, our study is the first study to introduce the AI-guided high-power ablation strategy for SVCI. The main finding of the present study is that AI-guided high-power ablation for SVCI appears effective and safe. An electrical SVCI was achieved without any compromise on complications in all patients. SVCI was performed by segment ablation in most cases. More RF applications were needed in septal, posterior, and anterior walls. Besides, the AI value in septal, posterior, and anterior walls was higher than that in lateral walls.

Superior vena cava isolation

In the past two decades, catheter ablation has been well-developed and is the mainstream method for the treatment of AF. Because atrial fibrillation is most commonly triggered by ectopic beats inside the PVs, PVI has become the cornerstone of AF ablation[19]. However, the outcome of a PVI alone is unsatisfactory. Therefore, it is necessary to search for new ablation strategies in addition to PVI for improving the outcome of AF ablation. It was reported that AF was also triggered and maintained by non-PV ectopic beats, which might be from SVC, crista terminalis, coronary sinus ostium, and so on[14-16]. Mapping and ablation of non-PV AF triggers were also vital for the freedom of AF after the first ablation procedure.

SVC was reported to be the most common non-PVs foci to trigger AF, the incidence of which was 5.3% to 12.0% [14-18]. Therefore, it was expected that SVCI in addition to the PVI was beneficial to improve the clinical outcomes of AF ablation. However, there weren't all studies in support of this[20]. We consider that performing SVCI has limited effect and is controversial for the reason that the creation of a durable lesion around the SVC is challenging due to the proximity of the sinus node and phrenic nerve[21-22].

AI-guided high-power ablation

The quality of RF lesions was recognized as a major determinant of arrhythmias recurrence. When performing ablation, the goal of that is to create transmural lesions while avoiding collateral damage to vital structures. A high-power ablation strategy for PVI has been demonstrated to create contiguous and durable RF lesions without compromise on complications in several studies[1-6]. The energy delivered creates lesions by two heating phases, namely resistive and conductive heating. The former causes local, immediate tissue injury while the latter conduct heating to deeper tissue[23]. A high-power ablation strategy allows an equivalent amount of energy to be delivered over a shorter ablation time, which increases local resistive heating to achieve transmural lesions and reduces conductive heating to limit collateral damages[24].

However, the atrial myocardium extending into the SVC is thinner than that of the junction between the left atrium and PVs[25]. Besides, the right phrenic nerve runs close to the lateral wall of the SVC and the ablation sites are near the sinus node[21-22]. Considering the above reasons, an optimal setting of RF energy delivered was needed to ensure the efficacy and safety of SVCI. AI as an ideal parameter for PVI showed a high single procedure success in several clinical studies[7-9]. In a recent paper, Kawano et al. for the first time examining the target AI value for the SVCI reported that a target AI value for SVCI may be 350, and this information could be helpful to the safety and efficacy of SVCI[26]. In our study, the AI value is bigger and the reasons may be the followings. Firstly, the applied power was higher in our study. Secondly, the level of the ablation line and endpoint of each lesion were different.

A combined ablation technique, namely AI-guided high-power ablation strategy, incorporates ideal ablation parameters into high-power ablation, which makes the ablation procedure safer and more effective[10-13]. On one hand, it uses high power to achieve transmural lesions; on the other hand, limits the collateral damages. Moreover, the strategy may be an optimal ablation technique for SVCI.

In our studies, An electrical SVCI was achieved in all patients. What's more, the AI-guided high-power ablation for SVCI seemed not associated with additionally increased complications, including sinus node injury and phrenic nerve injury. The SVCI time was 9.5+-4.5 min, we performed an empiric SVCI during the waiting period for the observation of PV reconnections after the CPVI, which has been reported to be very important for achieving a durable PVI[27]. Therefore, the procedural time for the SVCI was not time-wasting or time-consuming.

It was reported that the myocardial sleeves, between the right atrium (RA) and SVC, were discontinuous in most cases. Besides, the RA-SVC myocardial connection varied in thickness and length[28]. In our study, more RF applications were located on septal, posterior, and anterior walls, and in which higher AI value was needed to achieve the electrical SVCI. The following reasons may account for this fact. Firstly, the myocardial sleeves in the septal, posterior, and anterior walls were thicker. Secondly, the lateral wall had a potential risk of sinus node injury or phrenic nerve injury, therefore, the performer used a lower AI value in this area.

Study Limitations

This was a single-center study with a small number of patients. Further studies are needed to clarify the safety and efficacy of SVCI. The long-term efficacy of the SVCI and SVC stenosis wasn't fully evaluated because of the short follow-up duration. The optimal AI value in the different walls needed to be explored further.

Conclusion

AI-guided high-power ablation strategy is effective and safe for SCVI. More RF applications and higher AI values were needed in septal, posterior, and anterior walls.

Declarations

Author's contribution: Luqian cui, Shujuan dong, and Yingjie chu designed the study. Luqian cui and Shujuan dong collected and analyzed the data statistically. All authors contributed to the writing of this manuscript.

Conflict of interest: The authors declare that they have no conflict of interest.

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Figure 1. The location of the Radiofrequency (RF) applications.

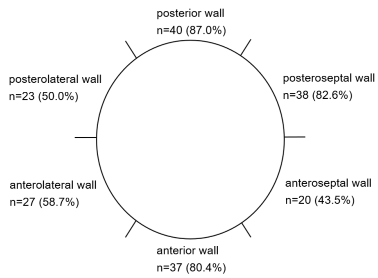


Figure 2. Radiofrequency Applications

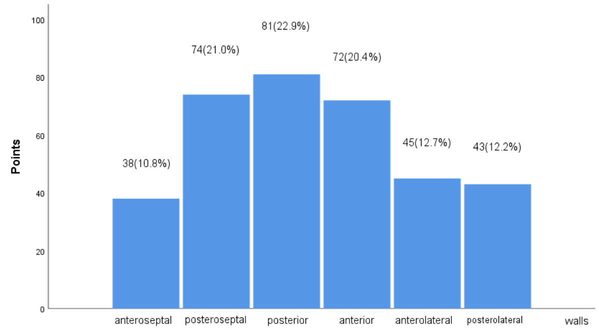
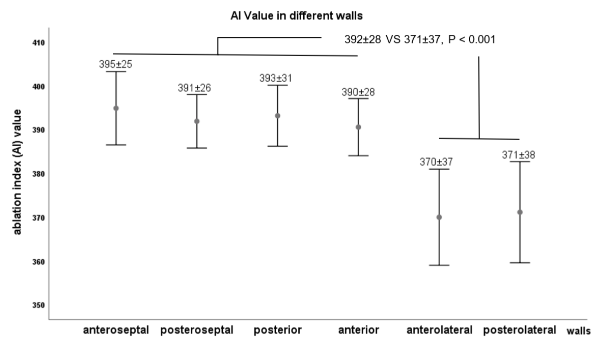


Figure 3. The Value of Ablation index in different walls



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