Superior vena cava isolation with 50 W high power, short duration ablation strategy

Shigeki Kusa MD1 | Hitoshi Hachiya MD1 | Yoshikazu Sato MD1 | Satoshi Hara MD1 | Hiroaki Ohya MD1 | Naoyuki Miwa MD1 | Kazuya Yamao MD1 | Yoshito Iesaka MD1 | Tetsuo Sasano MD2

1Cardiovascular Center, Tsuchiura Kyodo Hospital, Tsuchiura, Ibaraki, Japan
2Department of Cardiovascular Medicine, Tokyo Medical and Dental University, Tokyo, Japan

Correspondence
Shigeki Kusa, MD, Cardiovascular Center, Tsuchiura Kyodo Hospital, 4-1-1 Ootsuno, Tsuchiura, Ibaraki 3000028, Japan. Email: shigeki.kusa@gmail.com

Disclosures: None.

Abstract
Introduction: The optimal ablation strategy is unknown regarding a superior vena cava isolation (SVCI). This study aimed to examine the feasibility and safety and to analyze the lesion characteristics of the SVCI using high-power, short-duration (HPSD) ablation.

Methods and Results: A total of 100 patients underwent an index SVCI using HPSD (n = 50, HPSD group) or conventional lower-power and longer-duration (n = 50, LPLD group) ablation, using the Thermocool Smarttouch SF. In the HPSD group, ablation was performed with a power of 50 W for 7 s, and was limited to 4 s at the lateral segment close to the right phrenic nerve. The ablation setting used in the LPLD group was 20–25 W for 20–30 s and was limited to 10–20 W for 15–30 s at the lateral segment when diaphragmatic capture was seen. An electrical SVCI was achieved in all patients. The HPSD group required a significantly shorter procedure time (10.8 ± 3.2 vs. 14.8 ± 6.4 min; p < .01), shorter radiofrequency duration (49 ± 16 vs. 282 ± 124 s; p < .01), fewer lesions (8.3 ± 2.5 vs. 10.4 ± 4.4; p < .01), and lower ablation index (316 ± 38 vs. 356 ± 62; p < .001) than the LPLD group. The incidence of a postprocedural asymptomatic mild diaphragmatic elevation was comparable (2% in the HPSD group vs. 6% in the LPLD group; p = .61).

Conclusion: The 50-W HPSD ablation strategy allowed for a successful, fast, and safe SVCI with the fewer ablation lesions and the lower ablation index.

KEYWORDS
ablation, ablation index, atrial fibrillation, high power, short duration, superior vena cava

1 | INTRODUCTION

The superior vena cava (SVC) has been shown to be the most frequent location among nonpulmonary vein (PV) foci of atrial fibrillation (AF),1,2 and the efficacy of the electrical isolation of the SVC has been demonstrated in the several reports.3–7 However, the optimal ablation strategies have not been clearly defined.

Although recent studies have shown the usefulness of a PV isolation (PVI) using a high-power short-duration (HPSD) ablation strategy,8–10 there has been no reports describing this method adapted to an SVC...
ablation. This study was undertaken to evaluate the electrical SVC isolation (SVCI) using the HPSD ablation strategy.

2 | METHODS

2.1 | Study population

A total of 100 patients (64 ± 9 years, 84 males, 43 paroxysmal AF) undergoing a first-ever SVCI following their index PVI of AF were enrolled. Fifty patients underwent the SVCI using the HPSD ablation (HPSD group) protocol between December 2019 and August 2020. Another 50 patients receiving the SVCI using a lower-power and longer-duration ablation with the conventional settings (LPLD group) between January 2017 and August 2018 were included in the analysis for a comparison. The type of AF was classified according to the latest consensus statement. All patients gave their written informed consent. The study protocol was approved by the institutional ethics committee. The study complied with the Declaration of Helsinki.

2.2 | Ablation protocol

The electrical SVCI was empirically performed if the signals were recorded by a circular mapping catheter (Lasso, Biosense Webster), using a 3.5-mm externally irrigated tip catheter with contact force (CF) sensing (Thermocool Smarttouch SF, Biosense Webster). The SVC was divided into eight segments: anterior, anterolateral, lateral, posterolateral, posterior, posteroseptal, septal, and anteroseptal portions. Subsequently, the regions including the three lateral portions were defined as the lateral segment, which was comprised of the anterolateral, lateral, and posterolateral portions. The remaining region was defined as the non-lateral segment.

In the LPLD group, who underwent ablation with a conventional power setting, radiofrequency (RF) energy was limited to settings of 10–20 W for up to 30 s at the lateral segment where diaphragmatic stimulation was seen during the pacing at 10 V with a 2 ms pulse width, and was delivered with a power of 20–25 W for 20–30 s at the non-lateral segment. The CF was adjusted to 10–20 g as per the optimal settings based on the past studies analyzed for the PVI. Each Visitag appeared when satisfying the following parameters: minimum CF of 3 g, force over time of 25%, and minimum time of 3 s. The AI is a composite of the power, CF, and time, which is the value introduced to improve the lesion formation. The AI was not referred to for modifying the targeted parameters associated with each RF application regardless of whether the AI was displayed online during the RF delivery. In the cases performed before April 2018, the AI was retrospectively analyzed using the same software as that used for the cases performed after May 2018 when the AI was introduced in our institution.

2.3 | Analysis of the SVC ablation lesion

The ablation procedures were analyzed offline. The following parameters of each ablation tag (VISITAG, Biosense Webster) were compared between the two groups: power (W), RF duration (sec), average CF (g), and ablation index (AI, arbitrary unit [AU]). Each Visitag appeared when satisfying the following parameters: minimum CF of 3 g, force over time of 25%, and minimum time of 3 s. The AI is a composite of the power, CF, and time, which is the value introduced to improve the lesion formation.

2.4 | Statistical analysis

All statistical analyses were performed using SPSS 19.0 software (SPSS Inc.). Continuous variables are presented as the mean ± SD, and they were compared using a Student’s t test. Categorical variables were tested by a χ² test or Fisher’s exact test. A probability value of p < .05 was defined as a statistical significance.

3 | RESULTS

3.1 | Clinical characteristics

No significant statistical difference was seen in the patient clinical characteristics between the two groups except that the HPSD group was 3 years younger (63 ± 10 years vs. 66 ± 9 years, p = .04).
3.2 Superior vena cava isolation

The results of the SVC ablation are shown in Table 1. An acute electrical SVC I was achieved and the SVC I was maintained until the end of the procedure in all patients. The HPSD group required a significantly shorter procedure time for the SVC I than the LPLD group. The RF time was significantly shorter and number of RF applications fewer in the HPSD group than LPLD group, both when compared between the total value and when individually analyzed in the lateral and the non-lateral segment. The ablation was performed at the lateral segment in 47 (94%) and 46 (92%) patients in the HPSD and LPLD groups, respectively (p = .50).

3.3 SVC ablation lesions

The characteristics of the SVC ablation lesions are given in Table 2. The number of RF applications at the lateral segment accounted for 33% and 34% of the total number applied in the SVC ablation in the HPSD and LPLD groups, respectively.

All ablation lesions were deployed exclusively with a power of 50 W in the HPSD group. In the LPLD group, the power varied within a range of 10 to 30 W according to the physician’s discretion. However, settings of 10, 15, or 20 W (94%, 164 lesions)
and 20 or 25 W (97%, 334 lesions) were predominantly used at the lateral and non-lateral segments, respectively.

The RF duration per lesion was significantly shorter in the HPSD group than LPLD group (Table 2). In the HPSD group, the duration of the RF applications was 3–4 s at 115 (86%) lesions within the lateral segment and 6–7 s at 255 (92%) lesions within the non-lateral segment. The ablation was performed for a duration within 15–34 s at 471 (91%) of the lesions in the LPLD group.

### 3.4 | Ablation index

The average AI per lesion was statistically lower in the HPSD group than LPLD group at both the lateral and non-lateral segments (Table 2). Additionally, the distribution of the AI classified according to the settings of the RF power and duration, is given in Figure 1 to reveal the level of the AI given by the 50-W HPSD ablation among the specific settings in the LPLD group.

**FIGURE 1** Results of AI at the lateral segment (A) and the non-lateral segment (B) were shown according to the classification based on the representative settings of radiofrequency applications. Values of AI were given above each bar as mean [SD]. A total of 62 lesions were excluded because of the unavailability of AI, inappropriate radiofrequency duration (≤14 or ≥35 s in the LPLD group), and so on. See text for further discussion. AI, ablation index.
At the lateral segment, it was demonstrated that the AI of the lesions created by the RF applications with 50 W for 3-to-4 s in the HPSD group showed a value between that with the 10 and 15 W ablation for 25–34 s in the LPLD group (Figure 1A). The AI at the non-lateral segment for the ablation lesions at 50 W for 6–7 s in the HPSD group was similar to that at 20 W for 15–24 s, and lower than that at 25 W for ≥15 s in the LPLD group (Figure 1B).

3.5 | Complications

Right PNI was observed in 1 (2%) and 3 (6%) patients in the HPSD and LPLD groups, respectively ($p = .61$). The PNI was recognized during the procedure in one patient whereas it was not in the remaining 3 patients who were diagnosed by the chest X-ray performed on the day after the procedure. The degree of the right diaphragmatic elevation was mild, which was half of the height of one vertebra, and no symptoms associated with PNI were observed in all four patients. No other complications related to the SVC ablation, including sinus node injury or steam pops, were observed in any patients.

3.6 | Follow-up

During the follow-up (216 ± 110 days in the HPSD group and 764 ± 397 days in the LPLD group), freedom from recurrent atrial tachyarrhythmias beyond the 3-months blanking period after a single ablation procedure was greater achieved in the HPSD group than LPLD group (92% vs. 72%, $p < .01$). Repeated procedures were performed in 2 (4%) and 10 (20%) of the patients in the HPSD group and LPLD group, respectively. Of those, electrical reconnections between the right atrium and SVC were seen in 1 (50%) and 6 (60%) patient(s) in the HPSD group and LPLD group, respectively. In the present study, a spontaneous AF initiation was observed from the SVC in one patient in the HPSD group.

4 | DISCUSSION

4.1 | Major findings

To the best of our knowledge, this is the first study to investigate the outcomes of the SVC ablation using an HPSD ablation strategy. The major findings were as follows: (1) An electrical SVCI was successfully achieved in all patients. (2) The procedure time and RF duration for the SVCI were significantly shorter in the HPSD group. (3) The HPSD group required fewer lesions despite the CF per lesion being lower than that in the LPLD group. (4) The average AI was lower in the HPSD group. (5) The incidence of right PNI in the HPSD group was comparable to that in the LPLD group.

4.2 | Rationale for the empiric SVCI

The SVC has been described as one of the most frequent sites among non-PV triggers of AF. It has been reported that arrhythmogenicity of the SVC was found in 5.2% of a total of 1425 patients undergoing AF ablation one to three times. Additionally, the prevalence of AF originating from the SVC was 37.3% when examined among the patients receiving their second ablation procedures for recurrent tachyarrhythmias occurring after the PVI for paroxysmal AF, which was the most frequent among the non-PV foci. Another report including patients with persistent AF also revealed that the SVC was the most frequent site among the non-PV foci seen both in the index and redo ablation procedures.

Considering these observations, an empirical SVCI in addition to the PVI could be expected to improve the outcomes of the AF-free survival after ablation. However, no consistent data for or against has been demonstrated in terms of the SVCI despite several studies having evaluated the efficacy. A meta-analysis comparing the types of lesion sets demonstrated that performing an SVCI in all studied patients in addition to the PVI was associated with the largest improvement in the success rates of ablation in the paroxysmal AF. However, the efficacy of an empirical SVCI has been shown in one randomized study solely in patients with paroxysmal AF, and not in those with persistent AF. Another randomized controlled trial and meta-analysis did not show any statistically significant advantage of an empirical SVCI.

We think that it is difficult to conclude whether an empirical SVCI is beneficial or not for the following reasons: (1) it is deemed unlikely that the incremental benefit of an empirical SVCI in addition to the index PVI could contribute to statistically significant results given that the prevalence of the AF source is relatively lower in the SVC than PVs, and (2) it is expected that the additional value of the empirical SVCI would not reach a statistical significance in patients with persistent AF as a previous study has shown, partly because of the presence of other atrial foci with a greater prevalence than in those with paroxysmal AF.

Recently, it was found that the strategy of the empirical SVCI during a second ablation procedure for paroxysmal AF reduced the rate of recurrent atrial tachyarrhythmias as compared to that of the conventional SVCI in which an additional SVCI was performed only when a trigger of AF or rapid activity was seen within the SVC with or without a provocative test. Those results suggest that a procedure to confirm the spontaneous initiation of SVC-triggered AF could not fully guide the need for an SVCI.

In our study, therefore, an SVCI was empirically performed during the index ablation procedure when electrical signals were present within the SVC.

4.3 | Rationale of the HPSD ablation strategy for the SVCI

A biophysical analysis demonstrated that thermal injury during RF ablation consists of two consecutive phases: (1) the resistive phase,
which results in the immediate heating of the superficial tissue layer, and (2) the conductive phase, which is time-dependent, passive heating into the deeper tissue layers. Based on these considerations, the concept of an HPSD ablation has been proposed as a novel ablation strategy for “thin” atrial tissue to balance the procedural efficacy and safety, by increasing the resistive heating to achieve transmural lesions whereas reducing the conductive heating to limit collateral damages. In fact, the animal experiment showed that the HPSD ablation with 50 W for 5 s successfully provided atrial transmural lesions without any complications.

The atrial myocardium extending into the SVC has been reported to be thin, which is thinner than that of the junction between the LA and PVs. Phrenic nerve injury has been recognized as an important complication during the electrical SVC ablation as the right PN runs close to the lateral segment of the SVC. Examination of heart specimens in cadavers has shown that the minimal distance between the right PN and anterolateral wall of the SVC was 5.8 ± 1.1 mm at the SVC-right atrium junction. Considering the thin myocardial sleeve and proximity to the right PN, we sought to evaluate the efficacy and safety of the HPSD ablation strategy for the SVC with the anticipation of showing equivalent or better outcomes as compared to the conventional LPLD ablation strategy.

4.4 Ablation settings for the SVC ablation: Consideration based on pre-clinical studies

The optimal settings for the power and duration of the RF energy have not been determined for the SVC ablation. Conventionally, a power of 20–30 W has been frequently used, and the ablation has been limited to settings of 10–20 W for up to 20–30 s at sites close to the right PN. In the present study, we referred to the study of ablation lesion characteristics conducted with a variable power and duration to determine the RF delivery settings in the HPSD group. Borne et al. showed that in the ex vivo model, the average maximum depth of the ablation lesion for a CF of 10 g with 50 W for 15 s was two times that with 20 W for 30 s (1.8 ± 0.5 and 0.9 ± 0.2 mm). Therefore, the protocol for the RF delivery in the HPSD group was determined to be a power of 50 W for 7 s at the non-lateral segment, which was expected to yield a similar lesion depth as that with 20 W for 30 s. As for the lateral segment requiring a further limitation of the RF delivery, we referred to an in vivo study demonstrating the results of ablation with 50 W for 5 s, in which the lesion depth was 2.3 ± 0.5 mm with a CF of 10 g on the beating right atrial wall of sheep. Given the thin atrial myocardial sleeve extending into the SVC (1.2 ± 1.0 mm, maximum 4 mm) reported in human autopsied hearts, we decided that the RF delivery should be limited to 50 W for 4 s with a CF of ≤10 g within the lateral segment close to the right PN, while expecting a lesion depth of 1–2 mm.

The mean CF ranged between 10 and 20 g in the LPLD group whereas we aimed for a CF of ≤10 g in the HPSD group (Figure 1). We believe that the setting of the CF in the LPLD group was reasonable since it was deemed relevant to accommodate the CF to the conventional settings used for the PVI, which was before the AI and HPSD ablation had begun to be used widely. As for the HPHD group using a 50-W ablation, we thought that a CF of ≤10 g would be adequate for an effective lesion depth and safe for preventing excessive tissue heating and subsequent steam pops, based on the preclinical evaluation. Although the difference in the CF between the two groups was attributable to the study design, the undisputed evidence of our study was that the electrical SVC ablation was successfully achieved with a more “conservative” CF in the 50-W HPSD ablation.

4.5 HPSD ablation lesions for the SVC: Insights from the results of the AI

The AI value in the HPSD group in our study for the SVC consistently had a lower value ≤300 and ≤400 for the 50-W RF applications for 3–4 s at the lateral segment and 6–7 s at the non-lateral segment, respectively (Figure 1). These AI values in our study seemed adequate when considering the thinner muscular sleeve in the SVC than LA-PV junction, and the histological findings that the myocardial extensions into the SVC predominantly exhibit a discontinuous pattern and degenerative changes.

When comparing the two groups in the present study, the average AI value and CF were lower in the HPSD group. At the lateral segment, the HPSD ablation lesion with 50 W for 3–4 s had a value between that of the ablation with 10 and 15 W for 25–34 s, which were the most limited settings in the LPLD group (Figure 1A). The AI during the ablation with 50 W for 6–7 s at the non-lateral segment revealed a lower value than that with 20 W for 25–34 s, which was the most frequent setting in the LPLD group (Figure 1B). Recently, an ex vivo evaluation reported that an increment in the power and subsequent shortening of the RF duration under control using the AI results in a wider and shallower ablation lesion with a similar volume. When comparing these “conservative” results of the parameters associated with the HPSD ablation in our study, it seems that the lesion depth in the HPSD group was likely to be equal or less than that in the LPLD group. Furthermore, it is probable that the lesion diameter was larger in the HPSD group than in the LPLD group because the number of RF applications required for the SVC was fewer in the HPSD group. Therefore, we concluded that the HPSD ablation strategy in our study yielded wider and shallower lesions as compared to those using the strategy in the LPLD group.

4.6 Phrenic nerve injury

We evaluated the right PNI by monitoring the patients’ respirations during the procedure as well as by a comparison of the chest X-ray before and the day after the procedure, as per the protocol shown in the prior study. One might argue that a poor inspiratory effort might affect the findings of the chest X-ray acquired on the day after the procedure, and therefore using fluoroscopy during the procedure...
would provide a better measurement for confirming PNI. However, we also think that the following limitations should be considered regarding how PNI is recognized: (1) an impaired diaphragmatic movement is potentially underestimated during the procedure because the patients are under sedation, and (2) the magnitude of the procedure to monitor the diaphragmatic movements, which controls the respirations in the patients during the ablation, potentially is not uniform. Especially, it was deemed that the impairment in the diaphragmatic movement in our study patients was minimal since the degree of diaphragmatic elevation was mild on the chest X-ray on the day after the procedure. Furthermore, the patients’ recovery from the procedure in the present study was sufficient on the day after the ablation procedure since we did not use any general anesthesia but instead used conscious sedation. Therefore, the patients underwent post-procedural chest X-ray examination in a similar condition to that before the procedure, including the inspiratory effort. We think that not only checking the patients’ respiration on fluoroscopy and the post-procedural chest X-ray, but also comparing the chest X-ray between that acquired before and after the procedure would allow validating the diagnosis of PNI.

4.7 Clinical implications

The physiological and histological features in which the HPSD ablation provides wide and shallow lesions mainly by resistive heating rather than subsequent conductive heating, is deemed appropriate for ablation in the SVC, which harbors a thin myocardial sleeve and an extracardiac adjacent structure such as the right PN. Our new protocol of the 50-W HPSD ablation for the SVCI may be useful to achieve an electrical isolation efficiently with minimal ablation lesions, by creating a wide and transmural lesion with potentially decreasing the collateral injury, which can develop into a novel ablation strategy.

4.8 Limitations

This was a nonrandomized, single-center study with a relatively small number of patients. Right PNI occurred in the HPSD group. The ablation settings varied and were not uniform among the patients in the LPLD group.

The difference in the CF between the two groups was partly due to the study design. The settings of the CF in the HPSD group and LPLD group were determined from the results of the preclinical examination and conventional settings used for the PVI, respectively. However, the most important finding of the present study was that the electrical SVCI was successfully achieved even with a lower CF in the HPSD group.

The degree of the ablation lesion might differ between the types of generators even if the ablation parameters are the same. For example, the Ampere Cardiac Ablation Generator (Abbott) has a ramp-up time of at least 2 s to reach the power chosen whereas the interval to reach the power is shorter with the generator we used (Stockert J70 RF generator or SMARTABLATE, Biosense Webster), which potentially could affect the lesion size especially with a very short duration ablation.

The chronic efficacy of the index ablation procedure including the SVCI was not fully evaluated because of the short follow-up duration in the HPSD group. We think that establishing a strategy of ablating thin atrial tissue while minimizing the collateral damage would lead to the lesion durability of the SVCI given the distinctive anatomical characteristics, such as the thin myocardial tissue and close relationship with the right PN, however, follow-up data is necessary. Therefore, in the present study, we sought to concentrate on the outcomes of the acute electrical isolation. Although the freedom rate from recurrent tachyarrhythmias was not deemed to be determined solely by the quality of the lesions of the SVCI, we believed that it should be explored in a further study including a large number of patients with a long-term follow-up.

It is difficult to clarify whether the wide and shallow lesions produced by the HPSD ablation in the ex vivo model could be reproduced in our study. As the previous study indicated, the difference between the preclinical and clinical settings with regard to conditions such as the direction of the catheter tip, local impedance or fiber orientation should be considered when we discuss the lesion characteristics using the AI.

5 Conclusion

The 50-W HPSD ablation allowed for a successful acute electrical SVCI with a shorter procedure time, shorter RF duration, fewer ablation lesions, and lower AI, which was a potentially useful strategy for the SVCI as compared to the conventional LPLD ablation. Further investigation is necessary to confirm the effectiveness and safety.

Acknowledgements

The authors are solely responsible for all the other content of this study, which includes the design and conduct of the study, all study analyses, and the drafting and editing of the paper and its final contents. We would like to thank John Martin for the linguistic assistance in the preparation of the manuscript.

Data Availability Statement

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

ORCID

Shigeki Kusa http://orcid.org/0000-0002-3781-2171
Hitoshi Hachiya http://orcid.org/0000-0003-2808-1933
Yoshikazu Sato http://orcid.org/0000-0002-3939-4954
Tetsuo Sasano http://orcid.org/0000-0003-3582-6104

References

1. Takigawa M, Takahashi A, Kuwahara T, et al. Impact of non-pulmonary vein foci on the outcome of the second session of
catheter ablation for paroxysmal atrial fibrillation. J Cardiovasc Electrophysiol. 2015;26(7):739-746.

2. Hojo R, Fukumizu S, Kitamura T, et al. Development of nonpulmonary vein foci increases risk of atrial fibrillation recurrence after pulmonary vein isolation. JACC Clin Electrophysiol. 2017;3(6):547-555.

3. Arruda M, Miccocha H, Prasad SK, et al. Electrical isolation of the superior vena cava: an adjunctive strategy to pulmonary vein antrum isolation improving the outcome of AF ablation. J Cardiovasc Electrophysiol. 2007;18(12):1261-1266.

4. Corrado A, Bonso A, Madalosso M, et al. Impact of systematic isolation of superior vena cava in addition to pulmonary vein antrum isolation on the outcome of paroxysmal, persistent, and permanent atrial fibrillation ablation: results from a randomized study. J Cardiovasc Electrophysiol. 2010;21(1):1-5.

5. Wang XH, Liu X, Sun YM, Shi HF, Zhou L, Gu JN. Pulmonary vein isolation improving the outcome of AF ablation. J Cardiovasc Electrophysiol. 2007;18(12):1261

6. Sharma SP, Sangha RS, Dahal K, Krishnamoorthy P. The role of empiric superior vena cava isolation in atrial fibrillation: a systematic review and meta-analysis of randomized controlled trials. J Interv Card Electrophysiol. 2017;48(1):61-67.

7. Cluckey A, Perino AC, Yunus FN, et al. Efficacy of ablation lesion sets in addition to pulmonary vein isolation for paroxysmal atrial fibrillation: findings from the SMASH—AF meta-analysis study cohort. J Am Heart Assoc. 2019;8(1):e009976.

8. Winkle RA, Moskowitz R, Hardwin Mead R, et al. Atrial fibrillation ablation using very short duration 50 W ablations and contact force sensing catheters. J Interv Card Electrophysiol. 2018;52(1):1-8.

9. Chen S, Schmidt B, Bordignon S, et al. Ablation index-guided 50 W ablation for pulmonary vein isolation in patients with atrial fibrillation: Procedural data, lesion analysis, and initial results from the FAFA AI high power study. J Cardiovasc Electrophysiol. 2019;30(12):2724-2731.

10. Chen S, Schmidt B, Seeger A, et al. Catheter ablation of atrial fibrillation using ablation index-guided high power (50 W) for pulmonary vein isolation with or without esophageal temperature probe (the AI-HP ESO II). Heart Rhythm. 2020;17(11):1833-1840.

11. Calkins H, Hindricks G, Cappato R, et al. HRS/EHRA/ECAS/APHRS/SOLAECE expert consensus statement on catheter and surgical ablation of atrial fibrillation. Heart Rhythm. 2017;14(10):e275-e444.

12. Miyazaki S, Usui E, Kusa S, et al. Prevalence and clinical outcome of phrenic nerve injury during superior vena cava isolation and circumferential pulmonary vein antrum isolation using radiofrequency energy. Am Heart J. 2014;168(6):846-853.

13. Neuzil P, Reddy VY, Kautzner J, et al. Electrical reconnection after pulmonary vein isolation is contingent on CF during initial treatment: results from the EFFICAS I study. Circ Arrhythm Electrophysiol. 2013;6(2):327-333.

14. Kimura M, Sasaki S, Owada S, et al. Comparison of lesion formation between contact force-guided and non-guided circumferential pulmonary vein isolation: a prospective, randomized study. Heart Rhythm. 2014;11(6):984-991.

15. Borne RT, Sauer WH, Zipse MM, Zheng L, Tzou W, Nguyen DT. Longer duration versus increasing power during radiofrequency ablation yields different ablation lesion characteristics. JACC Clin Electrophysiol. 2018;4(7):902-908.

16. Bhaskaran A, Chik W, Pouliopoulos J, et al. Five seconds of 50-60 W radio frequency atrial ablations were transmural and safe: an in vitro mechanistic assessment and force-controlled in vivo validation. Europace. 2017;19(5):874-880.

17. Kholver I, Kautzner J. Morphology of atrial myocardial extensions into human caval veins: a postmortem study in patients with and without atrial fibrillation. Circulation. 2004;110(5):483-488.

18. Hussein A, Das M, Chaturvedi V, et al. Prospective use of Ablation Index targets improves clinical outcomes following ablation for atrial fibrillation. J Cardiovasc Electrophysiol. 2017;28(9):1037-1047.

19. Hussein A, Das M, Riva S, et al. Use of ablation index-guided ablation results in high rates of durable pulmonary vein isolation and freedom from arrhythmia in persistent atrial fibrillation patients: the PRAISE study results. Circ Arrhythm Electrophysiol. 2018;11(9):e006576.

20. Miyazaki S, Takigawa M, Kusa S, et al. Role of arrhythmogenic superior vena cava on atrial fibrillation. J Cardiovasc Electrophysiol. 2014;25(4):380-386.

21. Zang T, Wang Y, Liang Z, et al. Effect of combined pulmonary vein and superior vena cava isolation on the outcome of second catheter ablation for paroxysmal atrial fibrillation. Am J Cardiol. 2020;125(12):1845-1850.

22. Haines DE. The biophysics of radiofrequency catheter ablation in the heart: the importance of temperature monitoring. Pacing Clin Electrophysiol. 1993;16(3 Pt 2):586-591.

23. Ho SY, Sanchez-Quintana D, Cabrera JA, Anderson RH. Anatomy of the left atrium: implications for radiofrequency ablation of atrial fibrillation. J Cardiovasc Electrophysiol. 1999;10(11):1525-1533.

24. Sacher F, Monahan KH, Thomas SP, et al. Phrenic nerve injury after atrial fibrillation catheter ablation: characterization and outcome in a multicenter study. J Am Coll Cardiol. 2006;47(12):2498-2503.

25. Sanchez-Quintana D, Cabrera JA, Climent V, Farre J, Weiglein A, Ho SY. How close are the phrenic nerves to cardiac structures? Implications for cardiac interventionists. J Cardiovasc Electrophysiol. 2005;16(3):309-313.

26. Ejima K, Henni R, Iwamori Y, Yagishita D, Shoda M, Hagiwara N. Comparison of the efficacy of empiric thoracic vein isolation for the treatment of paroxysmal and persistent atrial fibrillation in patients without structural heart disease. J Cardiovasc Electrophysiol. 2017;28(3):266-272.

27. Miyazaki S, Yamao K, Hasegawa K, et al. SVC mapping using an ultra-high resolution 3-dimensional mapping system in patients with and without AF. JACC Clin Electrophysiol. 2019;5(8):958-967.

28. Bourier F, Duchateau J, Vlachos K, et al. High-power short-duration versus standard radiofrequency ablation: Insights on lesion metrics. J Cardiovasc Electrophysiol. 2018;29(11):1570-1575.

How to cite this article: Kusa S, Hachiya H, Sato Y, et al. Superior vena cava isolation with 50 W high power, short duration ablation strategy. J Cardiovasc Electrophysiol. 2021;1–8. https://doi.org/10.1111/jce.15060