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ORIGINAL ARTICLE

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The deeper the pouch is, the longer the radiofrequency duration and higher the radiofrequency energy needed—Cavotricuspid isthmus ablation using intracardiac echocardiography

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Abstract

Background: The aim of this study was to explore whether the pouch depth influenced the radiofrequency (RF) duration and total delivered RF energy for cavotricuspid isthmus (CTI) ablation and define the cutoff value for a deep pouch-specified ablation strategy.

Methods: This study included 94 atrial fibrillation (AF) patients (56 males, age 68 ± 8.0 years). With intracardiac echocardiography, the isthmus length and pouch depth were precisely measured. After a standard AF ablation, all patients underwent the CTI ablation along the lateral isthmus. If bidirectional block could not be achieved, the ablation catheter was deflected more than 90 degrees to ablate inside the pouch (knuckle-curve ablation).

Results: Seventy-two patients (76.6%) had a sub-Eustachian pouch. Bidirectional block could be achieved in all patients. By a univariate logistic regression analysis, only the pouch depth was significantly correlated with the RF duration ($P = .005$) and RF energy ($P = .006$). A multivariate logistic regression analysis also revealed the pouch depth was the sole factor that influenced the RF duration ($P = .001$) and RF energy ($P = .001$). Among the 72 patients, 21 patients needed a knuckle-curve ablation. Using a receiver operating characteristic curve, the optimal cutoff value of the pouch depth for a knuckle-curve ablation was 3.7 mm with a sensitivity of 90% and specificity of 69%.

Conclusions: The sub-Eustachian pouch depth was the sole factor that influenced the RF duration and energy in the CTI ablation. If the pouch was deeper than 3.7 mm, a deep pouch-specified ablation strategy would be needed.

KEYWORDS
atrial flutter, cavotricuspid isthmus, intracardiac echocardiography, pouch, radiofrequency catheter ablation

1 | INTRODUCTION

Achievement of bidirectional conduction block across the cavotricuspid isthmus (CTI) is the endpoint of typical atrial flutter (AFL) ablation.[1–3] Despite high success rates, it is sometimes difficult to achieve conduction block due to variations in the CTI morphology. Previous studies have shown that the presence of a sub-Eustachian pouch is related to a prolonged radiofrequency (RF) time and recurrence of conduction.[4–6] Under the presence of a deep pouch, it is useful to deform the ablation catheter into a deflected shape of more than 90 degrees in order to ablate deep inside the pouch (knuckle-curve ablation). A previous case report showed that the knuckle-curve ablation enabled conduction block in cases with a failed CTI ablation despite irrigated RF ablation.[7]

Recently, various imaging studies, including angiography, multiple-detector computed tomography, transthoracic echocardiography (TTE), transesophageal echocardiography, and intracardiac echocardiography (ICE), have been used to evaluate the isthmus.[4–17] In particular, using ICE provides a direct visualization and detailed assessment of the CTI anatomy and facilitates the ablation procedure.[7,14–17]

However, to the best of our knowledge, there have been no studies that have investigated the geometry of the CTI precisely with ICE and the occasional need for a knuckle-curve ablation during the CTI ablation. It is already known empirically and literally that, if there is a deep pouch, the CTI ablation would be tough. However, the exact clinical situation in which the knuckle-curve ablation would be feasible in tough cases is not known. Therefore, the aim of the present study, in which the precise anatomy of the pouch was evaluated using ICE, was to explore whether the pouch depth influenced the RF duration and delivered RF energy of the CTI ablation and define the cutoff value for a deep pouch-specified ablation strategy.

2 | METHODS

2.1 | Study population

In this prospective study, 94 consecutive patients (56 males; mean age 68 ± 8.0 years) who underwent catheter ablation of atrial fibrillation (AF) were included. Paroxysmal AF was evident in 50 patients and persistent AF in 44. They all received a CTI ablation after a standard AF ablation, including a wide circumferential pulmonary vein isolation. All patients gave their written informed consent. All antiarrhythmic drugs were discontinued for at least five half-lives before the study. Amiodarone had never been prescribed in any of the patients in this study.

2.2 | Intracardiac echocardiography

At the beginning of the AF and CTI ablation, an ICE probe with a CARTO navigation sensor imbedded close to the phased array (10Fr AcuNav™/SoundStar™; Biosense Webster, Diamond Bar, CA, USA) was positioned into the low right atrium through the left femoral vein. Two-dimensional images were acquired with an ACUSON × 300 system (SIEMENS).

Imaging from the low RA allowed us visualization of the anatomic landmarks, such as the CTI, tricuspid valve (TV), and Eustachian ridge. Based on those images, two-dimensional measurements were performed, including of the CTI length and pouch depth. The CTI length was defined as the distance between the TV and inferior vena cava (IVC), and was measured at the septal, medial, and lateral aspects, respectively. The pouch was defined as a depression within the CTI, and the pouch depth was measured from the line connecting the TV and orifice of the IVC to the deepest site of the depression. The pouch depth was defined as “0”mm in the case of the lack of a pouch. The pouch depth was measured at the septal, medial, and lateral aspects, respectively, in each patient. Every measurement was performed at a timing when the tricuspid valve was closed. The ICE catheter was used not only for the CTI ablation but also for the guidance of the trans-septal puncture and generation of a 3D anatomic shell with a sequential acquisition of ECG gated 2D images of the left atrium (LA).

2.3 | Ablation procedure

A decapolar electrode catheter was placed adjacent to the tricuspid valve annulus through the femoral vein (Livewire™, St. Jude Medical, Inc., St. Paul, MN, USA). A multipolar electrode catheter was placed within the coronary sinus (CS) through the right subclavian vein (BeeAT, Japan Lifeline, Tokyo, Japan, or Inquiry™ Luma-Cath™, St Jude Medical, Inc., St. Paul, MN, USA). Ablation data was calculated and stored by an EP recording system (BARD LabSystem Plus EP Laboratory, Boston Scientific). Bipolar electrograms were filtered between 30 and 300 Hz and recorded digitally. RF ablation was performed using a 3.5 mm tip electrode irrigation catheter through the right femoral vein (ThermoCool Surround Flow, SF® Navistar catheter, Biosense Webster, Diamond Bar, CA, USA). An SL-0 sheath (St. Jude Medical, Inc., St. Paul, MN, USA) was used to stabilize the ablation catheter.

Firstly, an ipsilateral wide circumferential pulmonary vein isolation was performed after a trans-septal puncture under guidance with ICE. After achievement of the electrical isolation of all pulmonary veins, ablation of the CTI was performed as a standard protocol of the AF ablation procedure at our institution. The patients underwent mapping and ablation during pacing from the proximal pair of the CS electrodes. Otherwise, ablation of the CTI was performed during typical atrial flutter. We hypothesized that the lateral isthmus would be a desirable site to ablate because the pouch in the lateral isthmus is much shallower than that in the others. Therefore, with a point by point technique, the ablation catheter was withdrawn along the lateral isthmus with a power setting of 35-40 W in all patients as a procedural protocol. The ablation power setting was titrated according to the impedance drop at that site. To be more specific, if the impedance drop was more than 10 ohms within 10 seconds after commencing the ablation application, the RF power was reduced by 5 W. The endpoint of the procedure was defined as the achievement of complete bidirectional block of the ablation line of the CTI. A differential pacing technique was performed to confirm the bidirectional block of the isthmus. Activation mapping using the pair of pacing electrodes at the CS ostium was created if necessary. If bidirectional block was not achieved even after abolishment of the local potentials along the ablation line, the ablation catheter was deflected more than 90 degrees to ablate inside the pouch ("knuckle-curve ablation"; Figure 1). Even if a deep pouch in the CTI was confirmed by ICE beforehand, the first pass of the CTI ablation was performed without this technique as a protocol of this study. All these procedures are performed by two experienced operators (K.Y, K.K). K.Y has 15 years of experience as a RFCA operator, and K.K has 5 years of experience.

2.4 | Statistical analysis

The continuous variables are expressed as means ± SD. Comparisons among groups were analyzed by an ANOVA. The categorical variables are expressed as numbers and percentages and compared by chi-square tests. Univariate and stepwise multivariate linear regression analyses were used to evaluate the respective contribution of the explanatory variables for the RF duration and delivered RF energy. Univariate and multivariate logistic regression analyses were performed to identify the patients requiring a knuckle-curve ablation among the patients who had a pouch. In addition, a receiver operating characteristic (ROC) curve was used to evaluate whether the pouch depth could predict the need for a "knuckle-curve ablation". A *P*-value of <.05 was considered to be statistically significant. The analyses were performed using JMP 11 software (SAS Institute Inc, Cary, NC, USA).

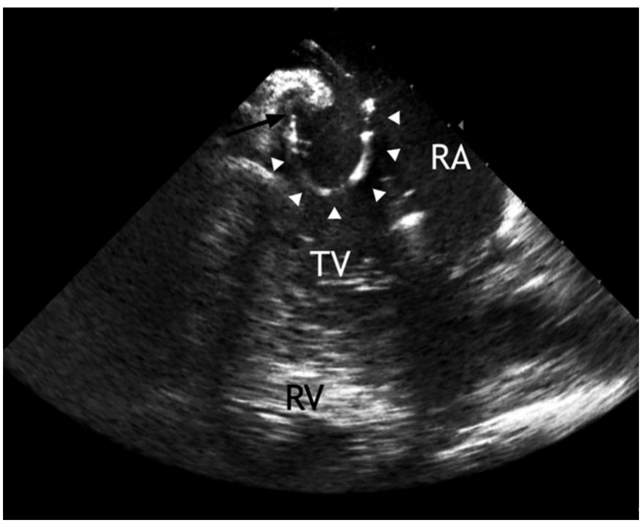

FIGURE 1 Intracardiac echocardiographic image of the "knuckle-curve ablation". The pouch depth is 7.8 mm in this case. The white arrowheads indicate the ablation catheter, of which the tip is placed deep inside the pouch (black arrow). RA, right atrium; RV, right ventricle; TV, tricuspid valve

3 | RESULTS

3.1 | Study population

The patient characteristics are presented in Table 1. Bidirectional block could be achieved in all patients, and there were no major complications.

3.2 | Characteristics of the CTI geometry

The CTI length of the lateral site was significantly longer compared to the others (septal vs medial vs lateral, 25.7 ± 7.2 mm vs 29.0 ± 8.3 mm vs 32.5 ± 9.1 mm, respectively, $P < .0001$). The pouch depth of the lateral aspect was significantly shallower compared to the others (septal vs medial vs lateral, 4.8 ± 3.0 mm vs 4.0 ± 3.0 mm vs 3.2 ± 2.5 mm, respectively, $P < .0001$; Figure 2).

3.3 | Pouch depth and ablation results

CTI ablation was performed during ongoing AFL rhythm in two patients. In the remaining 92 patients, it was performed during sinus rhythm (pacing from the proximal pair of the CS electrodes). In all patients, bidirectional block was finally achieved. Seventy-two patients (76.6%) had a sub-Eustachian pouch. Lateral CTI length was shorter in patients with a sub-Eustachian pouch (n = 72) than without a sub-Eustachian pouch (n = 22) (30.9 ± 1.0 mm vs 37.8 ± 1.9 mm, $P = .002$). Furthermore, older patients have significantly a sub-Eustachian pouch (69.2 ± 0.9 years vs 64.6 ± 1.7 years, $P = .017$). There was no difference with respect to other factors such as hypertension and LA diameter (LAD) between the patients with and without a sub-Eustachian pouch. Among the 72 patients with a sub-Eustachian pouch, conduction gaps of CTI were identified inside the pouch in 21 patients. Therefore, 21 patients needed a knuckle-curve ablation to ablate inside the pouch. On the other hand, a knuckle-curve ablation

TABLE 1 Patient characteristics

Parameters	Values (n = 94)
Age (years)	68 ± 8.0
Male (%)	56 (59.6)
History of heart failure (%)	28 (29.8)
Hypertension (%)	58 (61.7)
Diabetes mellitus (%)	16 (17.0)
Left atrial diameter (mm)	41.9 ± 6.3
Bidirectional block at the CTI (%)	94 (100)
Procedure duration (sec)	300 ± 158
Total RF energy (J)	10760 ± 5918
Presence of a pouch (%)	72 (76.6)
Necessity of a knuckle-curve ablation (%)	21 (22.3)

CTI, cavotricuspid isthmus; RF, radiofrequency.

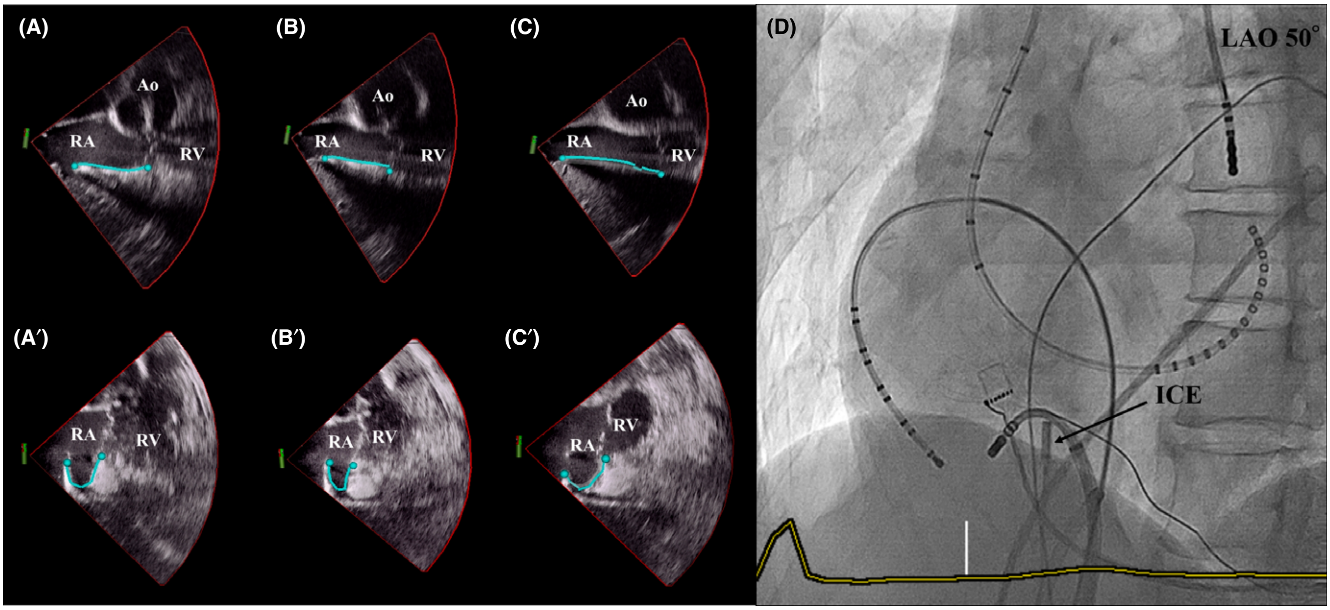

FIGURE 2 Intracardiac echocardiography (ICE) viewed from the RA. The light blue tracings demarcate the CTI. **Upper panels**: a case without a pouch. A, B, C: septal, medial, and lateral aspects of the CTI, respectively. The length of the lateral, medial, and septal CTI was 51 mm, 44 mm, and 37 mm, respectively. The lateral CTI was clearly the longest. **Lower panels**: a case with a deep pouch. A', B', C': septal, medial, and lateral aspects of the CTI as above. The pouch depth was 12 mm in this case along the lateral CTI. The pouch depth of the lateral site was significantly shallower compared to the others. D: Cine fluoroscopic image from LAO50°. ICE catheter positioned at the low right atrium. CTI, cavotricuspid isthmus; RA, right atrium; RV, right ventricle; Ao, aorta; ICE, Intracardiac echocardiography; LAO, left anterior oblique

was not needed in any of the 22 patients without a pouch (21/72 [29.2%] vs 0/22 [0%], *P* = .004). By a univariate linear regression analysis, the pouch depth was correlated with the RF duration (β = 0.0046, 95% CI 5.46-30.02, *P* = .005) and RF energy (β = 0.0012, 95% CI 189.9-1114.4, *P* = .006; Tables 2 and 3). To evaluate the independent determinants of the RF duration and delivered RF energy, stepwise multivariate linear regression analyses were used. The age, gender, congestive heart failure (CHF), hypertension, LAD measured by TTE, CTI length at the lateral site, and pouch depth at the lateral site were included as explanatory variables. Among them, the pouch depth was the sole factor that influenced the RF duration (β = 21.88, 95% CI -0.35-6.88, *P* = .001) and delivered RF energy (β = 809.50, 95% CI 321.5-1297.5, *P* = .001; Tables 2 and 3).

3.3.1 | ROC curve to predict the necessity for a knuckle-curve ablation

To assess whether the pouch depth could predict the necessity for a knuckle-curve ablation, a receiving ROC curve analysis was performed. The area under the ROC curve (AUC) for the knuckle-curve ablation was 0.83 for a cut off value of > 3.7 mm with a sensitivity of 90% and specificity of 69% (Figure 3).

3.3.2 | Characteristics of patients who needed a knuckle-curve ablation

To identify the patients requiring a knuckle-curve ablation among the 72 patients who had a pouch, univariate and multivariate logistic

TABLE 2 Univariate and multivariate linear regression analyses for the RF duration

	Univariate analysis			Multivariate analysis		
Variables	β	95% CI	*P* value	β	95% CI	*P* value
Age	0.0027	−0.008 to 0.01	.61			
Gender	−0.0004	−106.24 to 24.90	.22			
CHF	−0.000059	−77.84 to 64.02	.85			
Hypertension	0.00016	−50.23 to 83.08	.63			
LAD	0.0022	−3.83 to 6.56	.60			
CTI length	0.0037	−2.45 to 4.68	.54	3.27	8.91 to 34.85	.08
Pouch depth	0.0046	5.46 to 30.02	**.005**	21.88	−0.35 to 6.88	**.001**
				R^2 = 0.11, F value = 5.83, *P* = .004		

CHF, congestive heart failure; CTI, cavotricuspid isthmus; LAD, left atrial diameter; RF, radiofrequency.
Values in bold are statistically significant.

TABLE 3 Univariate and multivariate linear regression analyses for the delivered RF energy

Variables	Univariate analysis β	95% CI	P value	Multivariate analysis β	95% CI	P value
Age	0.000087	−105.8 to 201.6	.54			
Gender	−0.0000082	−3651.3 to 1292.0	.35			
CHF	−0.0000032	−3194.7 to 2131.3	.69			
Hypertension	0.0000021	−2193.1 to 2820.0	.80			
LAD	0.00010	−102.0 to 287.0	.35			
CTI length	0.00011	−89.1 to 178.8	.51	124.41	−11.6 to 260.5	.07
Pouch depth	0.00012	189.9 to 1114.4	**.006**	809.50	321.5 to 1297.5	**.001**
				R^2 = 0.11, F value = 5.67, *P* = .005		

CHF, congestive heart failure; CTI, cavotricuspid isthmus; LAD, left atrial diameter; RF, radiofrequency.
Values in bold are statistically significant.

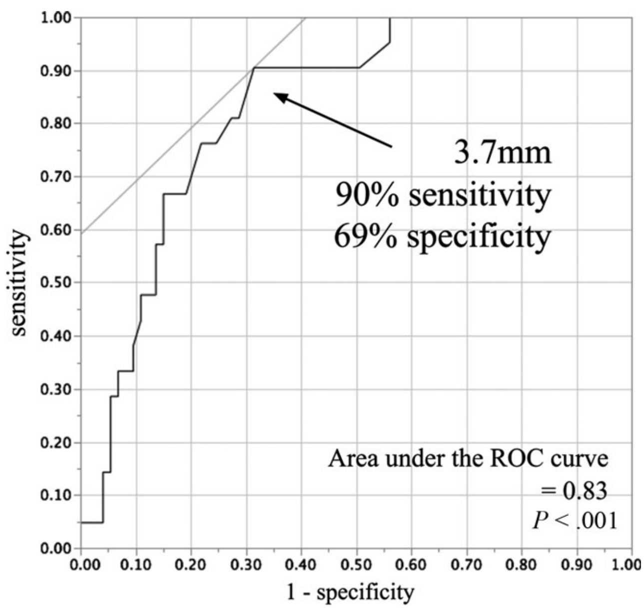

FIGURE 3 Receiver operating characteristic (ROC) curve to predict the necessity of a "knuckle-curve ablation" according to the pouch depth. The area under the ROC curve (AUC) was 0.83 with a cut off value of > 3.7 mm, having a sensitivity of 90% and a specificity of 69% (*P* < .001)

regression analyses were performed. A multivariate logistic regression analysis revealed that the lateral CTI depth was a sole factor associated with necessity of a knuckle-curve ablation among the patients who had a pouch (Table 4). Furthermore, the patients were divided into three groups: the patients with a pouch needed a knuckle-curve ablation (PK), those with a pouch not needed a knuckle-curve ablation (PNK), and those without a pouch (NP). The RF duration in the patients with a pouch needed a knuckle-curve ablation was longer than that in the other two groups (PK vs PNK vs NP, 459 ± 202 second vs 251 ± 102 second vs 262 ± 116 second, respectively, *P* < .0001). The RF energy in the patients with a pouch needed a knuckle-curve ablation was also higher than that in the other two groups (PK vs PNK vs NP, 16429 ± 7787 J vs 9013 ± 3852 J vs 9398 ± 4531 J, respectively, *P* < .0001).

TABLE 4 Univariate and multivariate logistic regression analyses for the necessity of a knuckle-curve ablation among the patients who had a pouch (n = 72)

Variables	Univariate analysis: Odds ratio (95% confidence interval)	P value	Multivariate analysis: Odds ratio (95% confidence interval)	P value
Age, per year	0.99 (0.92-1.06)	.76	0.66 (0.06-7.05)	.73
Gender	0.69 (0.25-1.92)	.48	1.22 (0.35-4.51)	.75
CHF	3.22 (1.12-9.53)	**.03**	2.91 (0.84-10.5)	.09
Hypertension	0.77 (0.28-2.16)	.62	1.25 (0.37-4.43)	.72
LAD, per mm	1.01 (0.93-1.09)	.81	0.97 (0.87-1.08)	.59
CTI length, per mm	1.05 (0.98-1.12)	.16	1.05 (0.97-1.14)	.27
Pouch depth, per mm	0.69 (0.50-0.90)	**.0004**	0.71 (0.50-0.95)	**.03**

CHF, congestive heart failure; CTI, cavotricuspid isthmus; LAD, left atrial diameter; RF, radiofrequency.
Values in bold are statistically significant.

3.3.3 | Recovered CTI conduction in the second procedure

Forty-four patients had recurrent AF or atrial tachycardia and received a second procedure during a follow-up period of 14 ± 16 months. In the second procedure, 12 of the 44 patients (27%) exhibited recovered CTI conduction (Recovered Group) and the remaining 32 (73%) did not show any recovery (Blocked Group). No patient showed CTI-dependent AFL. There was no difference with respect to the CTI pouch depth, CTI length, RF duration, or RF energy between Recovered Group and Blocked Group (Table 5). Although the data was not available enough in each of these patients, recurrences of electrical conduction were observed inside the pouch in 4 patients and they all needed a knuckle-curve ablation in the second procedure.

TABLE 5 CTI measurements and RF ablation data during the first ablation procedure in the two groups

Parameters	Recovered group (n = 12)	Blocked group (n = 32)	*P* value
Pouch depth (mm)	3.5 ± 0.6	2.9 ± 0.4	.46
CTI length (mm)	32.6 ± 2.4	35.6 ± 1.5	.28
RF duration (sec)	360 ± 52	306 ± 32	.38
RF energy (J)	12711 ± 1960	11006 ± 1200	.46
Knuckle-curve ablation	4/8	7/25	.44

CTI, cavotricuspid isthmus; RF, radiofrequency.

4 | DISCUSSION

4.1 | Major findings

All procedures were performed under ICE guidance. The usage of ICE enabled the direct visualization and a detailed assessment of the CTI anatomy.

The sub-Eustachian pouch depth was independently associated with the total RF duration and delivered RF energy in the CTI ablation. A pouch depth of >3.7 mm was a predictor of the necessity for a deep pouch-specified ablation strategy.

4.2 | CTI anatomy and radiofrequency ablation

According to previous studies that reported the anatomic variability of the CTI, the CTI length at the lateral aspect ranges from 19 to 49 mm. A pouch was identified in 52%—83% of patients, and the pouch depths ranged from 0.5 to 12.4 mm.[4,5,15,18,19] In the present study, the mean length of the lateral CTI was 32.5 mm, and it was longer than that of the medial and septal aspects. A pouch was identified in 76.6% of patients, and the mean depth of the lateral pouch was 3.2 mm. The pouch depth at the lateral aspect was shallower compared to the other aspects. It was consistent with the results of the previous studies.[15,18,19] Those findings helped us to understand the characteristics of the CTI morphology. To be more specific, we need to be aware that the septal isthmus is the most deeply pouched even though it is the narrowest. Furthermore, older patients have significantly a sub-Eustachian pouch. Tissue degeneration by aging might increase recess at the CTI.

In addition, there is a high heterogeneity of the CTI anatomy as represented by the pectinate muscles, Eustachian ridge, the presence of a pouch, thickness of the myocardium, and running of the right coronary artery. Among these CTI variations, the presence of a pouch, long CTI, and prominent Eustachian ridge/valve have been shown to be the factors related to a longer RF duration.[4,5,8,11,12] Da Costa, et al[4] reported that the CTI characteristics, such as the concavity and the presence of a pouch, are the factors that increase the procedure duration. In particular, the presence of a pouch increased the RF duration even though the length of the CTI was short. In the present study, the length of the CTI was not associated with the RF duration and RF energy. CTI length was shorter in patients with a pouch than without a pouch and short-pouched type patients seemed to need a long RF duration and much RF energy, which consequently caused the length of the CTI not to be significantly associated with the RF duration and energy.

In this way, the presence of a pouch is strongly related to a longer RF duration of the CTI ablation than that without. It is presumably because of the inadequate contact of the ablation catheter and poor blood flow within the pouch. The presence of a prominent Eustachian ridge makes the pouch deeper and contact of the catheter more difficult. In the present study, we tried to visualize the successful ablation site inside the pouch using ICE. In some cases, the tip of the ablation catheter was confirmed to be located at the deepest site of the pouch (Figure 1). However, unfortunately, it was usually difficult to visualize the tip by the ICE because of the acoustic shadow caused by the shaft of the ablation catheter itself in most of the cases.

In the present study, the pouch depth was measured precisely using ICE, and it correlated with the RF duration and total delivered RF energy. As a result of the multivariate analysis, the pouch depth was shown to be the sole factor that influenced the RF duration and RF energy. It indicated that the deeper the pouch was, the longer the RF duration and the higher RF energy needed.

4.3 | Pouch depth and knuckle-curve ablation

In a case in which bidirectional block of the CTI is not easily achievable, it may be feasible to change the ablation catheter to another one or to deflect the ablation catheter more than 90 degrees (knuckle-curve ablation). A previous case report showed that the knuckle-curve ablation enabled creating conduction block in the case of a failed CTI ablation.[7] In particular, in the case of a deep pouch, the knuckle-curve ablation technique would be feasible for ablating deep inside the pouch. To the best of our knowledge, there have been no systematic studies that have referred to the deflection of the ablation catheter during the CTI ablation. In the present study, 29.2% of the patients with a pouch needed a knuckle-curve ablation, but none of the flat-type isthmus patients without a pouch needed that technique. Among the patients who had a pouch, the CTI depth was a sole factor associated with necessity of a knuckle-curve ablation. Furthermore, the RF duration was longer and the RF energy was higher in the patients with a pouch needed a knuckle-curve ablation than that in the other patients. It means that switching to a knuckle-curve ablation strategy at an early stage can reduce unnecessary RF applications and radiation exposure, among the patients with a deep pouch.

A pouch depth of >3.7 mm was the predictor of the necessity for a deep pouch-specified ablation strategy using a knuckle-curve ablation, and it had a sensitivity of 90% and specificity of 69%. Thus, the pouch depth could predict the necessity for a knuckle-curve ablation. Furthermore, that cutoff value of "3.7 mm" was close to the length of the ablation catheter tip, which we used in the present study. A short-tip ablation catheter might be more likely to require a deep pouch-specified ablation strategy than an ablation catheter with a larger tip, which could reach more deeply and widely.

Lo, et al[6] reported that there was a high percentage of recurrence of the CTI conduction during the long-term follow-up, and a pouch type anatomy was related to the recurrence. However, the presence of a pouch was not associated with the recurrence of the CTI conduction in the present study. Adequate contact and RF energy delivery inside the pouch with a knuckle-curve ablation might have prevented the recurrence of the CTI conduction.

4.4 | Utility of ICE for the CTI ablation and the implications of the present study

In the present study, all procedures were performed under ICE guidance. As shown in the previous studies, ICE enabled the direct visualization and detailed assessment of the CTI anatomy and facilitated the ablation procedure.[7,14–17] It is reported that ICE-guided ablation of the CTI significantly shortens the procedure and fluoroscopy time and decreases the radiation exposure in comparison with fluoroscopy-only procedures in a randomized trial.[14] They also showed that those cases in which the fluoroscopy-guided approach failed were more likely to have pouches and were all treated successfully by changing to the ICE-guided procedure. In this way, ICE seems to facilitate the ablation procedure by real-time visualization of the ablation catheter position and contact especially in patients with deep pouches.

As a clinical implication, a tailor-made ablation approach adjusted to the individual anatomy of the CTI might be desired under ICE guidance. Performing a CTI ablation along the septal isthmus has the possibility of shortening the RF duration and reducing the RF energy in cases without a pouch because it is narrow. However, in patients with a deep pouch, ablation along the septal isthmus may cause a long RF duration of the CTI ablation. In that situation, performing the CTI ablation along the lateral isthmus would be desirable to avoid the deep pouch. Furthermore, in cases with a deep pouch of more than 3.7 mm, a knuckle-curve ablation should be considered as early as possible during the procedure.

4.5 | Study limitations

In the present study protocol, only a 3.5 mm tip electrode irrigation catheter was used for the CTI ablation. If the length of the ablation catheter tip has a relationship to the cutoff value of the deep pouch-specified ablation strategy, there might have been different results if an ablation catheter with a larger tip had been used. Furthermore, the CTI ablation was performed consistently along the lateral isthmus to avoid a deep pouch in this study protocol because the lateral isthmus was clearly the shallowest observed with ICE guidance. However, Nakagawa, et al[20] suggested that a CTI ablation at the septal isthmus was desirable because it was the shortest distance and smoothest in a previous study. It also would have resulted in different results if the CTI ablation had been performed septally. Our main purpose was to investigate the influence of the deepness and length of the pouch. If the ablation line differed from patient to patient, it would not appear to have consistent data because the thickness of the CTI differs according to the ablation line.[15] Therefore, the ablation target in the present study was consistently the lateral isthmus even if it was long or did not have a pouch.

Finally, in this study, only one type of ablation catheter was used. Contemporary force-sensing catheters or large-tip ablation catheters may mitigate some of the challenges. This was a single-center study, and ablation was performed by limited physicians. Some large multicenter studies would address these problems.

5 | CONCLUSIONS

The sub-Eustachian pouch depth was the sole factor that influenced the RF duration and delivered RF energy during the CTI ablation. If the pouch was deeper than 3.7 mm, a deep pouch-specified ablation strategy would be needed.

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CONFLICT OF INTERESTS

Authors declare no conflict of interests for this article.

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