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Catheter inversion during cavotricuspid isthmus catheter ablation: The new shaft visualization catheter reduces fluoroscopy use

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Abstract

Aims: Catheter ablation (CA) is the choice therapy of cavotricuspid isthmus (CTI) atrial flutter. The aim of this study was to describe our approach to improve the CTI ablation using a zero-fluoroscopy (ZF). The procedural difficulties could be related to anatomical characteristics of the CTI.

Methods: One hundred eighty-eight patients that performed CA of CTI were retrospectively and consecutively evaluated between 2017 and 2019. The studied population was divided into two groups. Eighty-eight patients who were undergone CA using ablation catheter without shaft visualization catheter (NSV) were Group 1. One hundred patients were undergone CA using ablation catheter with a shaft visualization (SV); they were Group 2. The catheter was looped at the Eustachian ridge after 200 seconds of radiofrequencies (RF) without elimination of local electrogram.

Results: A conduction line block of CTI was obtained in all patients of Group 2 using a ZF approach. In 16 patients of Group 1, the catheter inversion was obtained using fluoroscopy to avoid damages during its loop. In Group 2, a complete CTI block was obtained with a catheter inversion approach in ten patients without fluoroscopy, visualizing the shaft and the tip of the ablation catheter on the electroanatomic (EAM) map. In the overall population studied the use of SV had a linear correlation with the ZF approach ($r = .629$; $P < .001$). The duration of RF was lower in Group 2 than in Group 1 (Group 1: 27.8 ± 6.3 vs Group 2: 15.6 ± 7.2 minutes; $P < .01$). The procedure time between two groups was lower in Group 2 than in Group 1 (Group 1: 58.4 ± 22.4 vs Group 2: 42.2 ± 15.7 minutes; $P < .01$). No differences between two groups were documented regarding success and complications.

Conclusions: The visualization of the shaft's catheter on the EAM permitted the catheter inversion safely in order to overcome some complex CTI anatomy and obtain bidirectional block. The SV reduced procedure time, RF applications and fluoroscopy exposition during CTI ablation.

KEYWORDS

atrial flutter ablation, zero fluoroscopy catheter ablation

1 | INTRODUCTION

Catheter ablation of typical counter-clockwise atrial flutter (AFL) is the choice therapy to eliminate this arrhythmia.[1,2] An ablation catheter with a distal ablation tip-electrode of 3.5 or 8 mm is generally used.[3,4] The AFL ablation is successful in more than 90% of cases, occasionally some difficulties can be encountered when attempting to terminate the CTI and bidirectional conduction block line.[5] Despite high overall success rates, the AFL ablation is occasionally challenged because of variations in the anatomical characteristics of the CTI.[5] The poor catheter contact, sometimes because of inadequate power delivery, discontinuous ablation line, and the presence of pouches, recesses, ridges, and trabeculations of CTI, could be the potential contributor to the failure of CTI ablation.[5] The use of irrigated catheter, the drop impedance value, the contact force, Visitag, and ablation index have permitted a more precise assessment of the lesion development during RF.[6] The catheter inversion and the use of the force sensor provided an improved approach to CTI ablation, to achieve a bidirectional block of CTI in difficult anatomies.[7] The catheter inversion was described using fluoroscopy to avoid accidental damage of atrial and atrioventricular structures.[7–9] The electroanatomical mapping (EAM) systems can reproduce a precise spatial localization of the ablation catheter and potentially help shorten fluoroscopy time.[8] In our electrophysiology laboratory, a ZF approach was used to perform AFL ablation. The aim of this study was to describe our approach to overcome procedural difficulties related to anatomical characteristics of CTI.

2 | METHODS

This study was approved by the local ethics board. The study protocol was conformed to the ethical guidelines of the 1975 Declaration of Helsinki. One hundred eighty-eight patients were retrospectively enrolled between 2017 and 2019. The number of CA procedures performed was 188. The demographics and general characteristics of the enrolled population are summarized in Table 1. All patients underwent a CTI catheter ablation.

2.1 | Procedure description

A mild sedation was performed using Fentanyl and Midazolam. A small lead apron was located over the genital area of all patients. The sanitary staff performed AFL ablation without lead apron. Two separate punctures were used to cannulate the common right femoral vein using the modified Seldinger technique. The vein punctures were obtained using an echo-guided approach to avoid the accidental femoral artery or superficial femoral vein puncture. The common femoral vein puncture permitted to move the catheters in a large vessel. Guidewires and catheters placement into common femoral vein was directed exclusively using linear echo-probe and intracardiac electrograms. All catheters were displayed on the EAM system using a real-time reproduction and were manipulated without difficulties (ablation catheter, coronary sinus, and pentaray catheter when used). All the difficulties of catheter movements were overcome with a catheter rotation and with anatomic mapping acquisition through the venous system. The catheter was advanced up to the right atrium. An anatomical map of right atirum was obtained after tagging of His deflection and coronary sinus (CS) ostium identification. The CA of CTI was performed using only two catheters and EAM system. In patients with CHADSVASC score >3 or without anticoagulation in the last 3 weeks (total n. 25) an intracardiac echocardiography was used to check potentially atrial thrombosis. In these patients, the anatomy of the right atrium was then reproduced using ICE and CARTOSOUND module. If the ICE was necessary, we performed a third echo-guided venous puncture on the left leg.

2.1.1 | Mapping and ablation procedural details

Briefly sequential two-dimensional (2D) ICE contours were acquired and used to create a 3D map of the right atrium and to check adequate contact of ablation catheter during RF delivery. During AFL mapping, the precise localization of the arrhythmic circuit was confirmed by analyzing the sequence of activation of the right atrium and CS on the 3D activation map. Using the ablation catheter, an "entrainment mapping" was performed to demonstrate the

TABLE 1 Demographics and general characteristics of the two groups

	Group 1 (NSV catheter used) (88 CA)	Group 2 (SV catheter used) (100 CA)	*P* value
Age (Y)	70.2 ± 9.7	64.1 ± 8.5	NS
Female n.	16	26	NS
BMI	24.2 ± 4.1	24.6 ± 3.4	NS
CAD (n.)	34	50	—
Hypertension (n.)	14	38	—
Diabetes (n.)	48	60	—
Dyslipidemia (n.)	42	58	—
Smoke (n.)	42	30	—
Renal failure (n.)	22	18	—

Abbreviations: BMI, body mass index; CAD, coronary artery disease; NSV, ablation catheter without shaft visualization; SV, ablation catheter with shaft visualization.

dependence on the CTI. For patients in sinus rhythm, an atrial burst pacing from the CS or lower lateral atrium was tried to induce AFL. Almost 300-400 dots were acquired to perform the activation map; the color threshold was 5. During local activation time map, the stability of the acquisition point was at 6 ms and 6 mm. In Group 2, the force value stored during EAM was between 6-30 g. The time necessary to obtain EAM was almost 5-8 minutes in both groups. We applied RF in a "point-by-point" with a power control catheter setting (power of 35 W and temperature of 35°C); the irrigation filling was 15 mL/min. The duration of RF was delivered for a minimum of 60 seconds or until local electrogram amplitude become <0.1 mV. The catheter was looped at the Eustachian ridge after 200 seconds of RF if the local atrial electrogram did not become <0.1 mV. Isolation of pulmonary vein (PVI) was performed in 39 patients for paroxysmal atrial fibrillation (PAF) before AFL ablation; all PAF patients had a documented atrial flutter; in these patients, we used ICE and CARTOSOUND module (Soundstar, Biosense-Webster Inc). All PAF began AFL ablation in sinus rhythm or atrial flutter after PVI. One hundred forty-four were in AFL at beginning of the procedure as reported in Table 2, but in all patients, the AFL was induced with atrial burst or programmed atrial stimulation protocol. Forty-two patients had a history of cardiac surgery. The validation of bidirectional block was valuated after CTI line-block creation. In summary, the pacing stimulation maneuvers and noninduction of tachycardia after 20 minutes from the last RF, was considered as acute success.

2.1.2 | Procedural times

The duration of the procedure referred from the vein puncture to the removal of the venous introducers. The fluoroscopy time was defined from the beginning to the end of the procedure. Regarding the patients undergone PVI isolation, the procedure time of the AFL ablation was calculated from venous puncture to the exchange of the long sheath to positioning the long introducer. The procedure time was restarted from the end of the PVI isolation to the end of AFL ablation. The long introducer was removed after the end of the PVI isolation and replaced with a 9 French short introducer. We excluded from procedural time of the ICE advancing and long sheath positioning when used.

2.1.3 | Groups of the studied population

The studied population was divided into two groups. No differences were present between the groups about demographics and general characteristics.

Group 1 characteristic

Group 1 was composed of 88 patients. They underwent CA using a Thermocool-SF (Biosense Webster, Inc) ablation catheter without shaft visualization (NSV). In this group, the CA was performed using a 3.5 mm irrigated ablation catheter. The visualization of the ablation catheter on the EAM was limited to the tip as reported in Figure 1. The contact force was absent. In Group 1 before catheter inversion guided by fluoroscopy, the sanitary staff wore the lead apron. Seventy-one patients had an AFL at beginning of the CA. Eighteen patients were affected by PAF and performed PVI CA.

Group 2 characteristic

Group 2 was composed of patients who underwent CA using ablation catheter with a shaft visualization catheter (SV). Since January

TABLE 2 Detailed parameters of catheter ablation procedures

	Group 1 (NSV) (88 CA)	Group 2 (SV) (100 CA)	*P* value
Procedure time (min)	58.4 ± 22.4	42.2 ± 15.7	<.01
AFL at begin CA (n.)	71	73	
FT (min)	11.1 ± 9.8	0 ± 0	<.001
FLd (μGy.m^2)	5.1 ± 4.2	0 ± 0	<.001
PAF ablation (n.)	18	21	NS
PWRF (W)	32 ± 2.5	33.6 ± 2.2	NS
Contact force (g)	-	14.6 ± 9.3	
Dots during mapping	330 ± 420	315 ± 411	NS
CA line length (mm)	28.1 ± 4.1	27.9 ± 5.5	NS
Total RF (min)	27.8 ± 6.3	15.6 ± 7.2	<.01
SR during RF	73	82	
IR 20 min	12	4	<0.05
6 month recurrence	2	1	NS

Abbreviations: AFL, atrial flutter; CA line length, length of line of radiofrequencies; FLd, fluoroscopy dose, microGray/m^2; FT, fluoroscopy time; IR 20 min, isthmus reconnected 20 minutes after successful ablation; NSV, ablation catheter without shaft visualization; PAF, paroxysmal atrial fibrillation; PWRF, power radiofrequencies; RF, radiofrequencies; SR, sinus rhythm; SV, ablation catheter with shaft visualization .

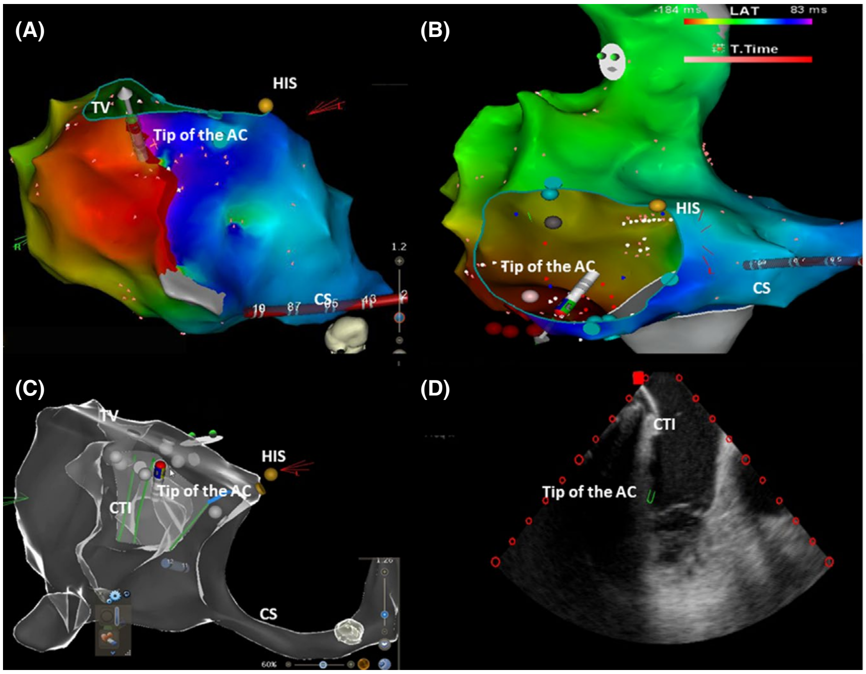

FIGURE 1 Cavotricuspid isthmus (CTI) ablation using ablation catheter without shaft visualization. In this figure, the tip of the ablation catheter is visible. (A) Inferior view of the CTI before catheter ablation. (B) Left anterior oblique view of the CTI during ablation. (C) CTI with a merged reconstruction between electroanatomical map and intracardiac (ICE) 3D map. (D) Real-time visualization of the ablation catheter on the ICE 2D echocardiography during radiofrequencies delivery

2018 all CTI CA were performed using an irrigated 3.5 mm ablation catheter with shaft visualization and a tip sensor that quantify the contact force of the interface tip catheter-tissue: Thermocool Smart touch; Biosense-Webster, Inc. All CTI ablation of the patients enrolled in Group 2 was performed using SV Thermocool Smart-toutch. The visualization of the shaft's catheter and the contact force sensor permits to see all catheter movements during its looping, avoiding accidental bumping of the His, or other accidental traumatic movements with excessive force value. All RF were delivered using a contact force >5 g. The inversion of the catheter was performed as necessary (Figure 2). Seventy-three patients had an AFL at beginning of the CA. Twenty-one patients performed PVI because of PAF.

2.1.4 | Follow-up

All parameters from clinical variables to all procedural details were stored. The CA complications, and acute and mid-term procedural success at 6 months follow-up were collected systematically. After 6 months, patients underwent clinical and instrumental follow-up by recording symptoms and 3 hours Holter ECG recording.

2.2 | Statistical analysis

Continuous parameters were reported as means and standard deviations. One-way analysis of variance (ANOVA) was the statistical test used to compare the groups. The relationships between continuous variables were calculated using a Pearson's correlation coefficients. A P-value <.05 was considered statistically significant. A multiple stepwise regression analysis was performed in order to assess the independent predictor of ZF. SPSS 20 for Windows (SPSS Inc) was the software used to perform statistical analysis.

3 | RESULTS

The sedation has been performed as specified in the methods. No one patient moved during the procedure, making necessary a new electroanatomic mapping. Zero fluoroscopy AFL ablation was performed in all patients of Group 2 (Group 1: 72/88 patients vs Group 2: 100/100 patients; $P < .0001$). Fluoroscopy duration of AFL ablation excluded time necessary to transseptal puncture during PAF procedure. All detailed parameters of CA procedures are summarized in Table 2. In Group 1, a catheter inversion was used to obtain a complete CTI block in 16 patients. In these patients, the catheter inversion was obtained using fluoroscopy to avoid damage during its loop.[9] In Group 2, a complete CTI block was obtained with a catheter inversion approach without fluoroscopy use in 10 patients. The loop of the catheter was improved by visualization of all its part. In the overall population, the studied SV had a linear correlation with ZF approach ($r = .629$; $P < .0001$). The steam pops were stored in 10 patients of Group 1. The RF delivered in Group 1 were more numerous than in Group 2 (Group 1: 27.8 ± 6.3 vs Group 2: 15.6 ± 7.2 minutes; $P < .01$). After 20 minutes a reconnection of the conduction was stored in 12 patients of Group 1 and 4 of Group 2. Remap and other RF were delivered until CTI conductional block. The acute success was obtained in all studied population. No differences between two groups were documented regarding acute and late success, and complications. The procedural time was lower in Group 2 than Group 1 (Group 1: 58.4 ± 22.4 vs Group 2: 42.2 ± 15.7 minutes; $P < .01$).

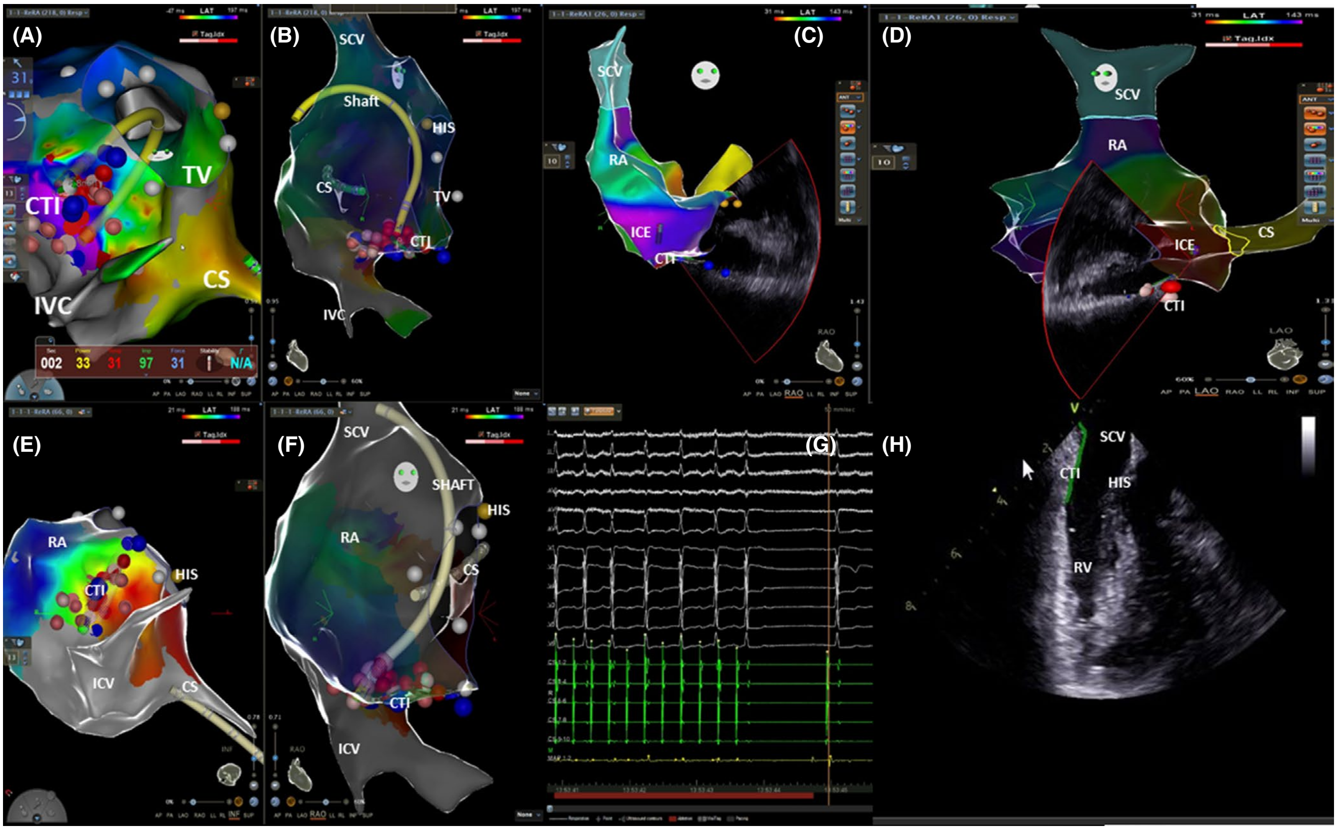

FIGURE 2 The ablation catheter can be entirely seen from the tip to the shaft. (A) Inferior view of CTI ablation. (B) An oblique anterior right view of right atrium during catheter ablation of cavotricuspid isthmus (CTI). (C) Antero-posterior view of right atrium with intracardiac echocardiography (ICE) that shows CTI; it permits to see eventually complex anatomy because of recesses or other structures. (D) Left oblique anterior view, ICE that shows CTI; "glass view" EAM and ICE. (E) Inferior view of ablation line of CTI. (F) Oblique right anterior view of ablation catheter with His visualization. (G) EGM atrial flutter interruption during radiofrequencies. (H) 2D visualization of CTI during echo-borders acquisition

4 | DISCUSSION

The use of the EAM to perform CTI ablation, permitted to use only two catheters to create a propagation and activation map.[9,10] Moreover, this CA approach permitted a reduction of fluoroscopy exposition for patients and all sanitary staff.[11,12] A program of fluoroscopy reduction is a concept that spreads in a lot of electrophysiology laboratory. The ALARA (as low as reasonably achievable) approach to CA is stressed in the consensus document and guidelines to CA of the ESC society.[13] The main aim of this study was to describe our ZF approach to perform CTI ablation. All patients of Group 2 underwent ZF CA. The only reason for fluoroscopy use in Group 1 was the need to employ for catheter inversion to overcome stratified CTI morphology. Some modalities of imaging (right atrium angiography, 3D map, ICE merged with EAM) have been used to characterize the CTI morphologies and improve the outcome of CTI CA without radiation exposure.[9] The stochastic effect of X-Ray exposure is the principal cause of our research of total exclusion of fluoroscopy as possible during electrophysiological procedures. In 2004, Sporton SC described the first case of catheter inversion approach.[7] The highest RF durations and the longest X-ray exposure were related to a long isthmus, to concave morphology of CTI and recesses.[14] Many anatomical variations of the CTI have been reported as a flat isthmus, as a uniform concavity, as a flat "vestibule" adjacent to the tricuspid annulus with a pouch-like recess at the IVC end, and a prominent Eustachian valve between the IVC and the isthmus.[15–17] In fact a catheter inversion helps to overcome these anatomically related difficulties by matching the convex outer curve of the ablation catheter with a concave isthmus, allowing access to the isthmus below a prominent Eustachian ridge. This provides a better and more stable catheter contact in these areas.[7] The visualization of the shaft's catheter is a characteristic of the Smart-Touch catheter.[6] It permits to see all the catheter (from tip to shaft) during looping movements in the right atrium to perform the inversion catheter technique, as described by Sporton using fluoroscopy in 2004.[7] In our experience, a real ZF approach is safe and feasible in Group 2.[17] Using SV all CA was performed with a ZF. In Group 1 the use of fluoroscopy was related to visualization of the catheter during its inversion as necessary to complete CTI block. A real interface tissue-contact is guaranteed by recording electrogram and by force tissue value. The approach described in this paper permits to overcome all anatomical difficulties because of ridges, pouches, recesses, and trabeculations of CTI adding a force value regarding the tip-tissue interface. The reduction of RF time reduced the steam pop formation and the delivery of excessive RF on the same tissue that represents a potential damage. The reduction of unnecessary RF permitted also a reduction of time necessary to obtain an electrical block of CTI. The usage of ICE enabled direct visualization and a detailed assessment of the CTI anatomy. The ICE permitted to assess real contact between the tissue and the tip catheter, to improve the precision of the RF line with a merged isthmus and continuous monitoring of the pericardium and to prevent the "steam pop" showing the increased bubbles production during RF before that steam pop occurred.[18,19] Furthermore, anatomic CTI variations represented by the presence of a flat isthmus, pouch, long CTI, and prominent Eustachian ridge/valve have been shown to be the factors related to a longer RF duration.[20] ICE-guided ablation of the CTI could short the CA procedure of CTI and the fluoroscopy exposure, in comparison with fluoroscopy-only procedures in a randomized trial.[21,22] Thus, the combination of EAM and ICE provided a more versatile and precise tool (compared to the flat 2D simil-RX views), to improve the safety and reproducibility of the ZF approach to CTI ablation.

4.1 | Limitations

This was an observational study; it was performed in a single Hospital. Some large multicenter studies would address these problems. Another limitation is the small size of the studied population. It is focused on describing our approach. The zero fluoroscopy experiences increase the cost of the electrophysiological procedure in European countries. In Tuscany (Italy) a conventional CA approach had a cost of 2000-2300 € respectively to ablation catheter, coronary decapolar in the RA catheter and coronary sinus catheter. The ZF approach costs 2200-2500 € respectively to ablation catheter and coronary sinus catheter. The activation map of the electroanatomic system permits to use two catheters. The use of the ICE increased the cost with the cost of 2000-2300 extra but the use of ICE was limited as described in the text. As reported in a previous study and trial, the additional cost of zero fluoroscopy approach is approximately equivalent to the extra cost resulting from cancer-derived therapy and from the reduction of quality of life. This high cost could be a limitation, but the reduction of fluoroscopy is recommended by electrophysiologist guidelines of SVT.

4.2 | Conclusion

Zero-fluoroscopy catheter ablation of AFL is safe and feasible. The use of ablation catheter with shaft visualization could improve the reproducibility of a successful zero-fluoroscopy CA. The visualization of the tip and shaft of the ablation catheter permits the catheter inversion safely in order to overcome some complex CTI anatomy. It permits to avoid numerous not necessary and potentially dangerous RF delivery and reduces the duration of CTI CA procedures. The use of intracardiac echocardiography can improve and help to paint CTI in complex anatomical CTI. It permits to monitor the pericardium, tissue-tip contact, and potentially the increasing of bubbles before steam-pop formation.

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CONFLICT OF INTEREST

Authors declare no conflict of interests for this article.

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REFERENCES

1. Cosio FG, Arribas F, Lopez-Gil M, Palacios J. Atrial flutter mapping and ablation I. Pacing Clin Electrophysiol. 1996;19(5):841–53.
2. Cosio FG, López-Gil M, Goicolea A, Arribas F, Barroso J. Radiofrequency ablation of the inferior vena cava-tricuspid valve isthmus in common atrial flutter. Am J Cardiol. 1993;71(8):705–9.
3. Iori M, Bottoni N, Quartieri F, Sassone B, Guerzoni S. Ablation of typical atrial flutter: a prospective study of cooled-tip versus 8-mm-tip catheters. Minerva Cardioangiol. 2014;62(3):283–6.
4. Hamaya R, Miyazaki S, Kajiyama T, Watanabe T, Kusa S, Nakamura H, et al. Efficacy and safety comparison between different types of novel design enhanced open-irrigated ablation catheters in creating cavo-tricuspid isthmus block. J Cardiol. 2018;71(5):513–6.
5. Asirvatham SJ. Correlative anatomy and electrophysiology for the interventional electrophysiologist. J Cardiovasc Electrophysiol. 2009;20(1):113–22.
6. Lin T, Ouyang F, Kuck K-H, Tilz R. THERMOCOOL® SMARTTOUCH® CATHETER - The evidence so far for contact force technology and the role of VISITAG™ MODULE. Arrhythmia Electrophysiol Rev. 2014;3(1):44–7.
7. Sporton SC, Davies DW, Earley MJ, Markides V, W. Nathan A, Schilling RJ. Catheter inversion: a technique to complete isthmus ablation and cure atrial flutter. Pacing Clin Electrophysiol. 2004;27(6p1):775–8.
8. Macias R, Uribe I, Tercedor L, Jimenez-Jaimez J, Barrio T, Álvarez M. A zero-fluoroscopy approach to cavotricuspid isthmus catheter ablation: comparative analysis of two electroanatomical mapping systems. Pacing Clin Electrophysiol. 2014;37(8):1029–37.
9. Kajihara K, Nakano Y, Hirai Y, Ogi H, Oda N, Suenari K, et al. Variable procedural strategies adapted to anatomical characteristics in catheter ablation of the cavotricuspid isthmus using a preoperative multidetector computed tomography analysis. J Cardiovasc Electrophysiol. 2013;24(12):1344–51.
10. Leonelli FM, Tomassoni G, Richey M, Natale A. Usefulness of three-dimensional non-fluoroscopic mapping in the ablation of typical atrial flutter. Ital Heart J. 2002;3(6):360–5.
11. Verbeet T, Castro J, Morissens M, Ngoc ET, Decoodt P. Use of a new non-fluoroscopic three-dimensional mapping system in type I atrial flutter ablation. Pacing Clin Electrophysiol. 2005;28(s1):S99–101.
12. Earley MJ, Showkathali R, Alzetani M, Kistler PM, Gupta D, Abrams DJ, et al. Radiofrequency ablation of arrhythmias guided by

non-fluoroscopic catheter location: a prospective randomized trial. Eur Heart J. 2006;27(10):1223–9.
13. Brugada J, Katritsis DG, Arbelo E, Arribas F, Bax JJ, Blomström-Lundqvist C, et al. 2019 ESC Guidelines for the management of patients with supraventricular tachycardiaThe Task Force for the management of patients with supraventricular tachycardia of the European Society of Cardiology (ESC). Eur Heart J. 2020;41:655–720.
14. Baccilleri MS, Rizzo S, De Gaspari M, Paradiso B, Thiene G, Verlato R, et al. Anatomy of the cavo-tricuspid isthmus for radiofrequency ablation in typical atrial flutter. Heart Rhythm. 2019;16:1611–8. https://doi.org/10.1016/j.hrthm.2019.05.030
15. Cabrera JA, Sanchez-Quintana D, Ho SY, Medina A, Wanguemert F, Gross E, et al. Angiographic anatomy of the inferior right atrial isthmus in patients with and without history of common atrial flutter. Circulation. 1999;99(23):3017–23.
16. Cabrera JA, Sanchez-Quintana D, Yen Ho S, Medina A, Anderson RH. The architecture of the atrial musculature between the orifice of the inferior caval vein and the tricuspid valve: the anatomy of the isthmus. J Cardiovasc Electrophysiol. 1998;9(11):1186–95.
17. Cheng J, Cabeen WR, Scheinman MM. Right atrial flutter due to lower loop reentry: mechanism and anatomic substrates. Circulation. 1999;99(13):1700–5.
18. Santoro A, Di Clemente F, Baiocchi C, Zacà V, Bianchi C, Bellini C, et al. From near-zero to zero fluoroscopy catheter ablation procedures. J Cardiovasc Electrophysiol. 2019;30(11):2397–404.
19. Shimizu Y, Yoshitani K, Murotani K, Kujira K, Kurozumi Y, Fukuhara R, et al. The deeper the pouch is, the longer the radiofrequency duration and higher the radiofrequency energy needed—cavotricuspid isthmus ablation using intracardiac echocardiography. J Arrhythmia. 2018;34(4):410–7.
20. Chang S-L, Tai C-T, Lin Y-J, Ong MG, Wongcharoen W, Lo L-W, et al. The electroanatomic characteristics of the cavotricuspid isthmus: implications for the catheter ablation of atrial flutter. J Cardiovasc Electrophysiol. 2007;18(1):18–22.
21. Bencsik G, Pap R, Makai A, Klausz G, Chadaide S, Traykov V, et al. Randomized trial of intracardiac echocardiography during cavotricuspid isthmus ablation. J Cardiovasc Electrophysiol. 2012;23(9):996–1000.
22. Casella M, Dello Russo A, Pelargonio G, Del Greco M, Zingarini G, Piacenti M. Near zero fluoroscopic exposure during catheter ablation of supraventricular arrhythmias: the no-party multicentre randomized trial. Europace. 2016;18:1565–72.

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