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The safety and efficacy of zero-fluoroscopy ablation versus conventional ablation in patients with supraventricular tachycardia

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Short title: The safety of 3D mapping in zero-fluoroscopy ablation
What’s New?

Zero-fluoroscopy radiofrequency catheter ablation of arrhythmia is an alternative to traditional conventional fluoroscopy for treating various types of tachycardia. The CARTO™ and EnSite™ mapping systems have become an important auxiliary tool for ablation. We analyzed three types of procedures; conventional fluoroscopy, end-zero-fluoroscopy, and CARTO™ zero-fluoroscopy. There was no statistical difference in these groups in the immediate success rate, recurrence rate, total success rate, and procedure time. We conclude that a zero-fluoroscopic approach, guided by the CARTO™ system, is not inferior to the zero-fluoroscopic approach guided by the EnSite™ or conventional fluoroscopy in efficiency and safety.
Abstract

Background: Zero-fluoroscopy radiofrequency catheter ablation is an alternative to traditional conventional fluoroscopy for the treatment of tachycardia.

Aims: To compare the safety and efficacy of the zero-fluoroscopic ablation of supraventricular tachycardia (SVT) guided by the CARTO™ mapping system (CZF) alone, the EnSite™ zero-fluoroscopic mapping system (EZF) alone, or the conventional fluoroscopy (CF) ablation method.

Methods: From July 2015 to March 2017, patients admitted for SVT ablation were consecutively enrolled in the CF, EZF, and CZF groups in a 1:1:1 ratio. The procedures for the CF group were performed using the traditional method and typically used fluoroscopy and three-dimensional mapping. All data were prospectively recorded by an independent researcher. Procedure and fluoroscopic time, and rate of success, recurrence, and complications in the three groups were analyzed.

Results: One patient in the CZF group switched to the CF group because of severe venous malformation during catheter insertion. Finally, 100 (100%) patients in the CF group, 100 (100%) patients in the EZF group (100%), and 99 (99%) patients in the CZF group successfully completed the electrophysiology study. There were no severe complications in any group. The mean (SD) procedure time was 61.8 (36.2), 66.5 (24.2), and 65.4 (27.5) minutes in the CF, EZF, and CZF groups, respectively. The median/quartile fluoroscopy time was 3.6 (2.1, 8.8) minutes in the CF group.
Conclusions: A zero-fluoroscopic approach guided by the CARTO™ system is not inferior to a zero-fluoroscopic approach guided by the EnSite™ system or a conventional fluoroscopic approach in terms of efficiency and safety for SVT ablation.

Keywords: ablation; CARTO™; EnSite™; supraventricular; zero-fluoroscopy

Introduction

Fluoroscopic radiofrequency ablation is effective in patients with cardiac arrhythmias who do not tolerate medications [1]. The radiation exposure during fluoroscopy may harm the patient and medical personnel [2]. Prolonged radiation exposure is associated with dermatitis, cataract, malignancies, and congenital malformations [3]. Reducing radiation exposure in the electrophysiology laboratory requires shielding and increasing the distance from the X-ray beam [4]. The patients get exposed to radiation several times during various examinations and therapies. Furthermore, patients often require procedures involving radiation [5-7]. Therefore, approaches and modalities that use less or no ionizing radiation are preferred, which are medically appropriate, acceptable, and safe for the patients [8].

The new 3-dimensional (3D) electroanatomical mapping software can achieve a significant reduction and even complete elimination of radiation in electrophysiology laboratories for most patients, particularly children and pregnant women [9, 10].

The evolution of mapping and anatomic imaging is effective for fluoroscopic imaging [11, 12]. In the past decade, there have been many reports on the use of zero and near-zero-fluoroscopic approaches for catheter ablation of cardiac tachycardia, particularly for
right-sided tachycardia [13-17]. EnSite\textsuperscript{TM} NavX is an electric field-dependent mapping system, and CARTO\textsuperscript{TM} is a magnetic field-dependent mapping system. Though both have similar effectiveness and safety, and both reduce X-ray exposure, NavX has a significantly greater effect than CARTO\textsuperscript{TM} [18].

CARTO\textsuperscript{TM} and EnSite\textsuperscript{TM} mapping systems are available for cardiac catheter ablation. The mapping and ablation catheters in both systems are based on a 3D reconstruction of the heart chamber. Low-energy electromagnetic fields are used in the CARTO\textsuperscript{TM} system. The orientation of the magnetic field allows accurate localization of the catheter in space. The CARTO\textsuperscript{TM} system integrates the latest technologies for magnets and impedance for catheter positioning. The EnSite\textsuperscript{TM} system uses body-surface patch electrodes where electrical signals are transferred. Intracardiac catheters with sensing electrodes determine the position of the electrode, and the catheter in space is identified upon analysis of the voltage [19]. The position of the catheter is estimated based on the impedance gradient in relation to a reference electrode. The minimally fluoroscopic approach procedure with the EnSite\textsuperscript{TM} was complicated by a non-linear impedance from the human body [20]. The CARTO\textsuperscript{TM} system allows precise spatial localization of the ablation catheter and lowers fluoroscopy duration during catheter ablation for atrial fibrillation as compared with the EnSite\textsuperscript{TM} system and ablation performed without 3D mapping [20]. An on-site catheter can reconstruct images of the chest and abdomen from the puncture point in the femoral artery or vein to the heart and allows tracking the catheter in vessels using an electric field principle. Due to the CARTO\textsuperscript{TM} magnetic field, it is limited to track the catheter in vessels between the access point and the heart. In a case with catheter torsion, impaction, kinking, vessel branches, stenosis, and
malformations, tracking the catheter in the vessels is essential to enable the CARTO™ system to cover vessels with magnetic fields and track the catheters inside the vessels without moving the ablation catheter tip to the desired part. We studied the feasibility and safety of changing the patch position from the upper back to the lower back and from the chest to the lower abdomen during insertion. We also studied the feasibility and safety of relocating the catheter position in the heart. Recent randomized trials show that zero-fluoroscopy (ZF) catheter ablation is effective and safe [20, 21]. To the best of our knowledge, there is no comparative study between the CARTO™ and the EnSite mapping system.

Methods

Study design

A prospective analysis was conducted in 300 patients with supraventricular tachycardia (SVT) at our center. Patients were subjected to three different interventional approaches in a 1:1:1 ratio; conventional fluoroscopy (CF), which used X-ray imaging with one of the 3D mapping systems; EnSite™ system zero-fluoroscopy (EZF), which used the EnSite™ 3D navigation system alone, and the CARTO™ zero-fluoroscopy (CZF) system. CZF was performed using the CARTO™ navigation system alone. All patients were numbered according to the sequence of their inpatient identification numbers (Table 1). All the operators performed ablation procedures independently for at least 75 cases. The CF, EZF and CZF procedure was performed by 4, 2 and 2 operators, respectively. The ethics committee of the Tongji Medical College approved the study protocol in accordance with the Declaration of Helsinki.
Study population

Between January 2015 and August 2017, consecutive patients (n=300) with SVT admitted to the center for ablation procedures were included. SVT indicated AVNRT and AVRT, confirmed by a transesophageal electrophysiological study. The following were the exclusion criteria; (1) suspected atrial tachycardia, atrial flutter, or combined mechanism multiple tachycardia; (2) severe congenital heart diseases or a thoracic anomaly; and (3) patients with cardiac implantable devices. Preoperative preparation was carried out in all patients, including blood tests, blood electrolyte analysis, electrocardiogram (ECG), chest X-ray imaging, and cardiac echocardiography. Antiarrhythmic agents were discontinued over five half-life periods before the procedure. Holter recordings were collected before and after admission, and wireless telemetry monitors were used to assess arrhythmia burden for at least 48 hours after admission and throughout the inpatient period.

Operative procedures

All operative procedures included conscious sedation with local anesthesia, and our standard electrophysiology protocol was followed.

We used a low magnetic field CARTO3™ navigation system (Biosense-Webster, Diamond Bar, CA) alone in the CZF group and generated a 3D image by moving the catheter along the cavity surface to record the activation time of local endocardium for mapping and recording the location points.

The EnSite™ NavX system (EnSite™, St. Jude Medical Inc., St. Paul, MN) was used in the
EZF group, which generates 3D images of the catheter, based on a low current electric field generated by three pairs of nominally orthogonal skin patches on the X, Y, and Z axes.

X-ray imaging, CardioLab EP 2000 (GE Medical System, Fairfield, CT, USA) was used in the CF group with or without one of the 3D mapping systems. The navigation system and catheter ablation are given in Table S1.

Zero-fluoroscopy (ZF) approach

CARTO zero-fluoroscopy (CZF) approach

The fluoroless approach was used in the CZF group. The X-ray machine was in standby status, and none of the catch lab staff wore lead apparel during the procedure (unless cross over to a CF approach). The CARTO™ system was used for catheter positioning and mapping to visualize the vessels and the heart. A coronary sinus (CS) catheter was used for reference during mapping and ablation.

Catheter insertion

All catheters were placed via femoral vein access, first inserted into the heart through vessels in the right and left anterior oblique views. The patches of vessels were recorded during catheter insertion. The 3D navigation was used to assess the proper position of the catheters in the vessels, which were rotated gently until the desired position was reached. A typical right intracardiac electrogram was observed. The left heart catheter was placed via the femoral artery. We routinely performed re-optimization after electrophysiology, when the ablation catheter entered the targeted chamber and rechecked the location of important
markers such as the His bundle before ablation. All catheters were introduced into the right atrium via the femoral vein. The first catheter was placed at the right ventricular apex, the second catheter at the His bundle, and the third catheter in the CS, as shown in Figure S1. The measurement of insertion time started when the catheter accessed the femoral vein, as shown in Fig. 1.

Mapping and ablation

The electrophysiological study was diagnosed definitively using a D-curve catheter (Celsius). The right atrium was reconstructed and then mapped with a tricuspid annulus. Ablation endpoint results were freedom from spontaneous arrhythmia, and arrhythmia after multiple-site programmed arterial stimulation (S1S1\S1S2\S1S2S3) and/or after intravenous infusion of adrenaline and other kinds of stimulations.

EnSite™ zero-fluoroscopy (EZF) approach

Fluoroscopy was not used, X-ray imaging was set in standby and no staff wore lead apparel during the procedure. Under the guidance of the EnSite™ system with external skin patches set as the reference, all catheters were used via femoral vein access for right-sided heart ablation and via femoral artery access for left-sided heart ablation, as shown in the snap technique in Figure S2. Initial optimization and respiratory compensation were performed. All catheters were then placed and arrhythmias ablated.

Conventional fluoroscopy approach

All steps for radiofrequency ablation in the CF group, including catheter insertion via
vessels, placement in the heart, electrophysiological study, mapping, and ablation were guided by X-ray plus the EnSite™ or CARTO™ 3D mapping system.

Data collection

All procedures were performed by experienced operators, and the average number of ablation cases per year per operator was calculated using records from the 2 years prior to the study. All preoperative, operative, and follow-up data were gathered and stored in paper spreadsheets by independent technicians. The following data were collected; the names of the operators, assistants, and technicians; type of study; clinical and demographic variables (age, sex, body weight, height, arrhythmia type, underlying heart disease, primary or redo procedure); and procedure-related variables (procedure date, assigned group, procedure time, fluoroscopy time, number of lesions, total ablation time, immediate success rate, complications, catheter type, time from first puncture of the skin to reach the right atrium, and time required for electrode placement in the CS and in the right ventricle, and recurrences during follow-up). All complications were validated based on our original medical records and divided into two types, mild or severe. The following complications were labeled as mild: large peripheral hematoma, vessel rupture, peripheral pseudoaneurysm, arteriovenous fistula, first-degree atroventricular block, right bundle branch block, and/or left bundle branch block. The following complications were labeled as severe: sinus node injury; second or third-degree atroventricular block, severe valve injury, cardiac rupture, cardiac tamponade, myocardial infarction, stroke, and any injury requiring thoracic surgery. Procedure time was defined as the duration from the first puncture of the skin to the complete removal of the catheter. CF
time was the total duration of the X-ray used in the procedure. All patients were monitored by continuous wireless telemetry for at least 24 hours before discharge.

Follow-up

After the ablation procedure, the patients were followed-up at 1, 3, and 12 months post-discharge by an independent technician. Echocardiography, 12-lead ECG, and 24-hour Holter monitoring were included in the assessment.

Statistical analysis

Continuous data were used to describe as mean with standard deviation, and categorical data are expressed as numbers with percentages. ANOVA and Fisher’s exact tests were used to compare the differences between the groups. All analyses were performed using Statistical Package for the Social Sciences Graphpad Prism 8, and a $P$-value of 0.05 was considered statistically significant.

Results

Baseline characteristics

The baseline characteristics of the patients are presented in Table 1. There were 101, 100 and 99 patients in the CF, EZF and CZF group, respectively. There were no differences among the groups in sex or the number of redo cases. There was a significant difference in the mean age of the CZF group ($P <0.01$). The mean (SD) follow-up period was 16 (2.3) months.

Operator’s experience
The CZF approach was performed by two operators who had the experience with the EZF and CF approaches. The two operators and an expert in conventional fluoroscopy, but not in zero fluoroscopy, performed the EZF approach. The CF approach was performed by four experienced operators. The average number of ablations performed per year in the 2 years prior to this study was 120.

3D mapping

All 100 cases in the CF group were mapped using the EnSite™ or the CARTO™ mapping system. All 100 cases in the EZF group were mapped using the EnSite™ system, and the 99 cases in the CZF group were mapped using the CARTO™ mapping system.

Catheter placement

Right ventricle

We compared the average time required for the electrode placement in the right ventricle via a femoral vein in the CF, EZF, and CZF groups, and compared the average time in the initial 20 patients and the following 20 patients. There was no difference between the three groups. The mean (SD) time was 21 (1.8), 22.4 (1.7) and 26.6 (23) seconds in the CF, EZF group and CZF group, respectively.

CS

No operator in the ECF group had previous experience with the insertion of the CS electrode via a femoral vein with CARTO before this study.
As shown in Figure 1, there was no difference in the EZF, CZF, and CF approach in the first or second set of 20 patients (p>0.05). We compared the average time required for placement of the electrode in the CS via the femoral vein. The efficiency of CS electrode insertion using the ZF approaches (EZF and CZF) was not inferior to the CF approach.

Electrophysiology study

For the electrophysiology study, both ZF approaches were as efficient and safe as the CF approach. Both ZF groups had an immediate success rate of 99% with no severe complications. There was similar efficiency using the two approaches.

Ablation procedure

Fluoroscopy time

In the CF group, the median/quartile fluoroscopy time was 3.6 (2.1, 8.8) minutes in patients with SVT. Ninety-nine (99.0%) patients in the CZF group (1 patient was switched to the CF group because of venous malformation, as shown in Figure S3), and 99 (99.0%) patients in the EZF group completed the procedure without fluoroscopy.

Procedure time

There was no significant difference in the average procedure time in the CZF, EZF, and CF group when all cases were considered, as shown in Figure 2. The mean (SD) procedure time was 65.4 (27.5), 66.5 (24.2) and 60.99 (34.67) minutes with the CZF, EZF, and the CF approach, respectively (P >0.05). The CZF approach was as efficient as the CF or EZF
Success, recurrence, and complication rates

In the CZF approach, 99/100 patients completed the procedure without fluoroscopy. One patient with a venous malformation was switched to the CF approach. After electrophysiology study with the ZF approach, the average fluoroscopy time in the switched case was 1.52 minutes.

All three approaches had a similar immediate success rate (99.0% for each). There was no recurrence in the CZF and ECF group with 1.0% recurrence in the CF group. A severe complication of pseudoaneurysm was seen in only one patient in the ECF group. There was no large hematoma, vessel rupture, hemothorax, new-onset left bundle branch block, myocardial infarction, stroke, or severe valve injury in any group (Table 3).

Learning curve for the ZF approach

The average procedure time for SVT ablation in the first 50 cases of CZF were similar to the next 50 cases.

Discussion

Fluoroscopy and zero-fluoroscopy

There was no difference in the rate of immediate success, complications, or recurrences between the three groups. A zero-fluoroscopic approach was attempted during all procedures, and an electroanatomical mapping made it possible to avoid fluoroscopy during ZF, EZF and
CZF. Fluoroscopy was used only in one patient in the CZF group to guide the catheter to the vessels. The total procedure time, fluoroscopy, and radiofrequency times were similar. The position of important anatomical structures, such as the His bundle, should be rechecked if the ablation site is in a high-risk area. With EZF respiration, compensation should be repeated when the patient exhibits apparent changes in respiratory amplitude.

Catheter insertions and tracking

Although there was variation in follow-up and tracking of the catheter inside the vessels, the efficiency of catheter insertion by both ZF approaches (CZF and EZF) was equivalent to that of conventional fluoroscopy. Due to the lack of tacking during the passage through the vessels, the catheter was impeded in the vessel in one patient in the CZF group. The physician used tactile sensation to amend this issue but the pass-through failed. Therefore, fluoroscopy was used to guide the catheter. We believe that the new CZF approach is an option for operators who prefer using CARTO™ and have concerns with fluoroscopy procedures, especially in high-risk situations such as pregnancy.

CARTO™ and EnSite™ Mapping

A zero-fluoroscopic approach to the right atrium using the CARTO™ system is feasible in most procedures [21–25]. With the modified CARTO™ vessel tracking image quality, arrhythmia ablation has similar results as with the zero-fluoroscopic approach using the EnSite system.
Interest

While passing catheters through vessels with the zero-fluoroscopic CARTO™ system, a modified CARTO™ approach is an option to avoid kinking or obstruction in difficult cases.

Study limitations

This was a single-center study with small sample size. The selection was non-randomized and based on operator preference. Patients in CARTO™ group were younger than other groups. The exclusion of one patient after invasive electrophysiology is also a limitation.

Acknowledgments

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Electrophysiol Clin. 2019; 11: 405-408.


Table 1. Baseline characteristics of the patients.

<table>
<thead>
<tr>
<th></th>
<th>CF (n=101)</th>
<th>EZF (n=100)</th>
<th>CZF (n=99)</th>
<th>Total (n=300)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years [mean (SD)]</td>
<td>46.9 (16.2)</td>
<td>46.7 (16.0)</td>
<td>37.8 (14.5)</td>
<td>45.3 (15.4)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Weight, kg [mean (SD)]</td>
<td>65.0(6.0)</td>
<td>64.0 (6.2)</td>
<td>60.5 (4.8)</td>
<td>63.8 (11.7)</td>
<td>0.816</td>
</tr>
<tr>
<td>Height, cm [mean (SD)]</td>
<td>167.6 (6.2)</td>
<td>166.9 (6.1)</td>
<td>162.4 (24.3)</td>
<td>164.9 (8.3)</td>
<td>0.327</td>
</tr>
<tr>
<td>Male patients</td>
<td>45 (44.1%)</td>
<td>40 (40.0%)</td>
<td>39 (39.6%)</td>
<td>118 (39.3%)</td>
<td>0.851</td>
</tr>
<tr>
<td>BMI, kg/m2 [mean (SD)]</td>
<td>23.1 (4.1)</td>
<td>22.9 (4.2)</td>
<td>65 (28.0, 82.0)</td>
<td>23.0 (7.1)</td>
<td></td>
</tr>
<tr>
<td>EPS only</td>
<td>0 (0%)</td>
<td>4 (4.0%)</td>
<td>3 (3.0%)</td>
<td>7 (2.3%)</td>
<td></td>
</tr>
<tr>
<td>3-D mapping</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Ablation</td>
<td>101 (100%)</td>
<td>96 (96.0%)</td>
<td>96 (96.0%)</td>
<td>293 (97.7%)</td>
<td>0.104</td>
</tr>
<tr>
<td>AVNRT</td>
<td>63 (62.3%)</td>
<td>66 (56.0%)</td>
<td>67 (67.0)</td>
<td>196 (65.3%)</td>
<td>0.205</td>
</tr>
<tr>
<td>AVRT</td>
<td>37 (37.0%)</td>
<td>34 (34.0%)</td>
<td>33 (33.0%)</td>
<td>104 (34.6%)</td>
<td>0.363</td>
</tr>
<tr>
<td>Left freewall</td>
<td>16 (16.0%)</td>
<td>19 (19.0%)</td>
<td>18 (18.0%)</td>
<td>53 (17.6%)</td>
<td>0.864</td>
</tr>
<tr>
<td>Right freewall</td>
<td>9 (9.0%)</td>
<td>7 (7.0%)</td>
<td>8 (8.0%)</td>
<td>24 (8.0%)</td>
<td>0.882</td>
</tr>
<tr>
<td>Posteroseptal</td>
<td>11 (11.0%)</td>
<td>6 (6.0%)</td>
<td>6 (6.0%)</td>
<td>23 (7.6%)</td>
<td>0.328</td>
</tr>
<tr>
<td>Para-hisian</td>
<td>1 (1.0%)</td>
<td>2 (2.0%)</td>
<td>1 (1.0%)</td>
<td>4 (1.3%)</td>
<td>0.848</td>
</tr>
</tbody>
</table>

Abbreviations: EPS, electrophysiological study; CF, conventional fluoroscopy approach; ZF, zero-fluoroscopy approach; AVNRT, atrioventricular nodal reentrant tachycardia; AVRT, atrioventricular reentrant tachycardia.
Table 2. Comparison of the efficiency and safety of ablation among the three groups.

<table>
<thead>
<tr>
<th></th>
<th>CZF (n = 100)</th>
<th>EZF (n = 100)</th>
<th>CF (n = 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure time, minutes [mean (SD)]</td>
<td>65.4 (27.5)</td>
<td>66.5 (24.2)</td>
<td>61.8 (36.2)</td>
</tr>
<tr>
<td>Ablation time, seconds [mean (SD)]</td>
<td>320.4 (207.1)</td>
<td>306.5 (30.5)</td>
<td>341.7 (33.3)</td>
</tr>
<tr>
<td>Complete ZF (n, %)</td>
<td>99 (99%)</td>
<td>100 (100%)</td>
<td>NA</td>
</tr>
<tr>
<td>Give up‡ (n, %)</td>
<td>0 (0.0%)</td>
<td>1 (1.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Immediate success (n, %)</td>
<td>99 (99.0%)</td>
<td>99 (99.0%)</td>
<td>100 (100.0%)</td>
</tr>
<tr>
<td>Recurrence (n, %)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>1 (1.0%)</td>
</tr>
</tbody>
</table>

*, Tentative ablations of less than 10 seconds were not included; ‡, some patients refused to receive ablation owing to the possible risk after electrophysiology study; ‡§, the patients who switched to the CF approach were excluded from the analysis. Abbreviations: NA, not applicable; other abbreviations were seen as in table 1.
Table 3. Complications in the CARTO zero-fluoroscopy (CZF), the Ensite zero-fluoroscopy (EZF), and conventional fluoroscopy (CF) groups.

<table>
<thead>
<tr>
<th>Complications</th>
<th>CZF (n=100)</th>
<th>EZF (n=100)</th>
<th>CF (n=100)</th>
<th>Total (n=300)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild-moderate</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Pseudoaneurysm, (n)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Arterial-venous fistula (n)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pneumothorax(n)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hemothorax (n)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cardiac tamponade, (n, %)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Severe</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>II-III degree of AVB, (n)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Thoracic surgery, (n)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Abbreviations: AVB, atrial ventricular block; other abbreviations were seen as in table 1.
Figure 1. The diagram showed insertion in the coronary sinus via a femoral vein was not significantly different among three groups; CF group, EZF group, and CF group. \( P < 0.05 \) compared with the time taken when using the same approach during the 1st set of 20 cases and the 2nd set of 20 cases.

CF, conventional fluoroscopy, EZF, Ensite zero-fluoroscopy, CZF, CARTO zero-fluoroscopy.
**Figure 2.** The diagram showed the learning curve of the zero-fluoroscopy (ZF)

The approach during the ablation of supraventricular tachycardia. Panels showed the average procedure time for the 1st to 20th cases, 21st to 40th cases, 41st to 60th cases, 61st to 80th and 81st to 99th when each of the 3 approaches was used.