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Maximum voltage gradient technique for optimization of ablation for typical atrial flutter with zero-fluoroscopy approach

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Abstract

Radiofrequency catheter ablation (RFCA) is an established effective method for the treatment of typical cavo-tricuspid isthmus (CTI)-dependent atrial flutter (AFL). The introduction of 3-dimensional electro-anatomic systems enables RFCA without fluoroscopy (No-X-Ray [NXR]). The aim of this study was to evaluate the feasibility and effectiveness of CTI RFCA during implementation of the NXR approach and the maximum voltage-guided (MVG) technique for ablation of AFL.

Data were obtained from prospective standardized multicenter ablation registry. Consecutive patients with the first RFCA for CTI-dependent AFL were recruited. Two navigation approaches (NXR and fluoroscopy based as low as reasonable achievable [ALARA]) and 2 mapping and ablation techniques (MVG and pull-back technique [PBT]) were assessed. NXR + MVG ($n=164$; age: 63.7 ± 9.5; 30% women), NXR + PBT ($n=55$; age: 63.9 ± 10.7; 39% women); ALARA + MVG ($n=36$; age: 64.2 ± 9.6; 39% women); and ALARA + PBT ($n=205$; age: 64.7 ± 9.1; 30% women) were compared, respectively. All groups were simplified with a 2-catheter femoral approach using 8-mm gold tip catheters (Osypka AG, Germany or Biotronik, Germany) with 15 min of observation. The MVG technique was performed using step-by-step application by mapping the largest atrial signals within the CTI.

Bidirectional block in CTI was achieved in 99% of all patients (P = NS, between groups). In NXR + MVG and NXR + PBT groups, the procedure time decreased (45.4 ± 17.6 and 47.2 ± 15.7 min vs. 52.6 ± 23.7 and 59.8 ± 24.0 min, $P<.01$) as compared to ALARA + MVG and ALARA + PBT subgroups. In NXR + MVG and NXR + PBT groups, 91% and 98% of the procedures were performed with complete elimination of fluoroscopy. The NXR approach was associated with a significant reduction in fluoroscopy exposure (from 0.2 ± 1.1 [NXR + PBT] and 0.3 ± 1.6 [NXR + MVG] to 7.7 ± 6.0 min [ALARA + MVG] and 9.1 ± 7.2 min [ALARA + PBT], $P<.001$). The total application time significantly decreased in the MVG technique subgroup both in NXR and ALARA ($P<.01$). No major complications were observed in either groups.

Complete elimination of fluoroscopy is feasible, safe, and effective during RFCA of CTI in almost all AFL patients without cardiac implanted electronic devices. The most optimal method for RFCA of CTI-dependent AFL seems to be MVG; however, it required validation of optimal RFCA's parameters with clinical follow-up.

Abbreviations: 3D-EAM = 3-dimensional electro-anatomic systems, AFL = atrial flutter, ALARA = as low as reasonable achievable, AVB = atrioventricular block, BDB = bidirectional block, CIED = cardiac implanted electronic devices, CS = coronary sinus, CTI = cavo-tricuspid isthmus, ECG = 12-lead electrocardiogram, EPS = electrophysiological study, LAO = left anterior oblique, MINI CA = minimally invasive, nonfluoroscopic imaging and catheter ablation, MVG = maximum voltage-guided, NXR = No-X-Ray, PBT = pull-back technique, RFCA = radiofrequency catheter ablation, RV = right ventricle, TEE = trans-esophageal echocardiography.

Keywords: atrial flutter, near-zero fluoroscopy, radiofrequency catheter ablation, the maximum voltage-guided technique

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1. Introduction

Radiofrequency catheter ablation (RFCA) is an effective method for treatment of typical cavo-tricuspid isthmus (CTI)-dependent atrial flutter (AFL).[1] Better knowledge of anatomic and electric details can demonstrate a new method of RFCA in CTI-dependent AFL—the maximum voltage-guided (MVG) technique. MVG method is based on mapping the highest potentials on CTI during AFL or atrial pacing due to fact that CTI is build by interconnected muscle bundles. MVG can reduce the number of applications, time of applications, and fluoroscopic exposure compared with the classical "pull-back" technique (PBT).[2–10]

Advances in the development of 3-dimensional electroanatomic systems (3D-EAM) and electrophysiological knowledge allow RFCA to be performed in various supraventricular arrhythmias without using fluoroscopy (No-X-Ray [NXR]) or near-zero fluoroscopy. Classic mapping involves fluoroscopy for catheter guidance and navigation; however, the medical staff are encouraged to reduce radiation exposure with the principles of as low as reasonable achievable (ALARA).[11–18] However, no study has yet combined the NXR approach and the MVG method of RFCA in CTI-dependent AFL. The purpose of this study was to compare procedural data on RFCA for CTI AFL during implementation of the NXR approach and the MVG technique.

2. Methods

Periprocedual data were obtained from a multicenter prospective standardized ablation registry from January 2012 to June 2016. Consecutive patients with the first RFCA for CTI-dependent AFL were recruited. The NXR method was compared with the ALARA method as well as MVG and PBT. Patients provided written informed consent, and the local institutional review board approved the study according to the Declaration of Helsinki.

All patients who underwent the RFCA procedure had effective anticoagulation treatment with oral vitamin K anticoagulants with an INR between 2 and 3 for at least 3 weeks or were on non-vitamin K anticoagulants. If an effective anticoagulation could not be documented, then trans-esophageal echocardiography (TEE) to exclude a thrombus in left atrial appendage was mandatory before the RFCA procedure.

For safety reasons (evaluation of lead position, lead dislodgement prevention, etc.), all patients with cardiac implanted electronic devices (CIED) (pacemakers or implantable cardioverter-defibrillators or cardiac resynchronization therapy devices) were excluded from the NXR approach and underwent the ALARA procedure and were divided into another subgroup. Patients with persistent left-sided AFL, non-CTI dependent right-sided AFL, and CTI-depended AFL with simultaneous ablation of AF were excluded. Therefore, both groups (ALARA and NXR) consisted of patients with typical or reverse typical CTI-dependent AFL.

An electrophysiological study (EPS) was performed just before ablation to confirm a CTI-dependent AFL with mapping and entrainment maneuver. In patients presenting with a sinus rhythm without inducible AFL, ablation was performed when a typical clockwise/counterclockwise CTI-AFL was previously documented in a 12-lead electrocardiogram (ECG).

2.1. Procedural protocol/approach

2.1.1. EPS and simplified approach. The simplified 2-catheter femoral access approach consisted of the following: the use of 2 catheters—an ablation catheter (8 mm nonirrigated Gold tip catheters, Osypka AG, Medizintechnik, Germany or Biotronik, Berlin, Germany) and a decapolar diagnostic catheter (nonsteerable decapolar Viacath, St. Jude Medical, St. Paul, MN or Biotronik MultiCath, Berlin, Germany); standardized catheter positioning during procedure (decapolar catheter in coronary sinus [CS] and mapping/ablation catheter in RA, the His region and the right ventricle [RV]); standardized ventricular and atrial EP were performed prior and after ablation with 15 min of observation. If the CS cannulation was not achieved within 5 min, then the decapolar catheter was positioned on lateral site of the tricuspid annulus (Fig. 1).

Electrophysiological recording system (EP-Tracer, CardioTek, Maastricht, The Netherlands) was used during procedures at papers speeds of 100 and 150 mm/s and standards filters. Standard settings (max. 60–65°C and 60–65 W) of RF generator (Stockert, Biosense-Webster, Diamond Bar, CA) were used.

2.1.2. NXR approach. In the NXR group, a simplified approach was used and combined with minimally invasive, nonfluoroscopic imaging and catheter ablation (MINI CA) protocol. The mapping was performed by creating a simplified map of CTI and the area around the His bundle with the 3D-EAM system (Ensite Velocity NavX, St. Jude Medical). The 3D map was projected in 30° left anterior oblique (LAO) position and 30° right anterior oblique position. Medical staff did not use a lead apron until it became necessary to use it due to the X-ray scanner. If it became necessary based on operator decision, then the medical staff took a 5-min preparation period to wear the lead aprons (Fig. 2).

2.1.3. X-ray approach. In the ALARA group, a similar simplified approach was performed (2 catheters, femoral access, standardized catheter positioning, ECG recording system, radiofrequency generator and its settings, and also observation period) except that the 3D-EAM system was not used. In all cases, the X-ray scanner was used with fluoroscopy performed at 4 to 6 frames/s with the patient in the LAO position. Medical staff also wore lead aprons during all parts of the procedure.

2.2. Ablation method/technique

2.2.1. MVG technique. The CTI was mapped in the 6 O'clock position in LAO 30° view starting from the ventricular site (with dominating V potential) and ending on the venous site (with no atrial potentials). During mapping of the CTI bipolar, the high and the highest A bipolar potential were marked as an ablation target. The difference between the high, highest, and no target potential was performed using the visual rating (grading at least 6 dots with white color [border of CTI, vena cava inferior or RV], red small [A potentials], yellow color [high A/V ratio with dominant A potentials], and green color [the highest A potentials]) by the first operator. CTI was performed after potentials were mapped with RFCA using a step-by-step application according to marked potentials starting from the ventricular site of CTI and ending on venous site (Fig. 2).[2–6]

2.2.2. Pull-back technique. A typical PBT was performed using the standard CTI line isolation approach with no earlier marking preparations. RFCA applications were started from ventricular to venous site of CTI. Also, if the RFCA was performed during AFL after loss of AFL, then standard pacing from CS ostium was performed.[2–10]

2.3. Study group

All patients recruited to this study were divided into 4 study subgroups according to the performed procedural approach and

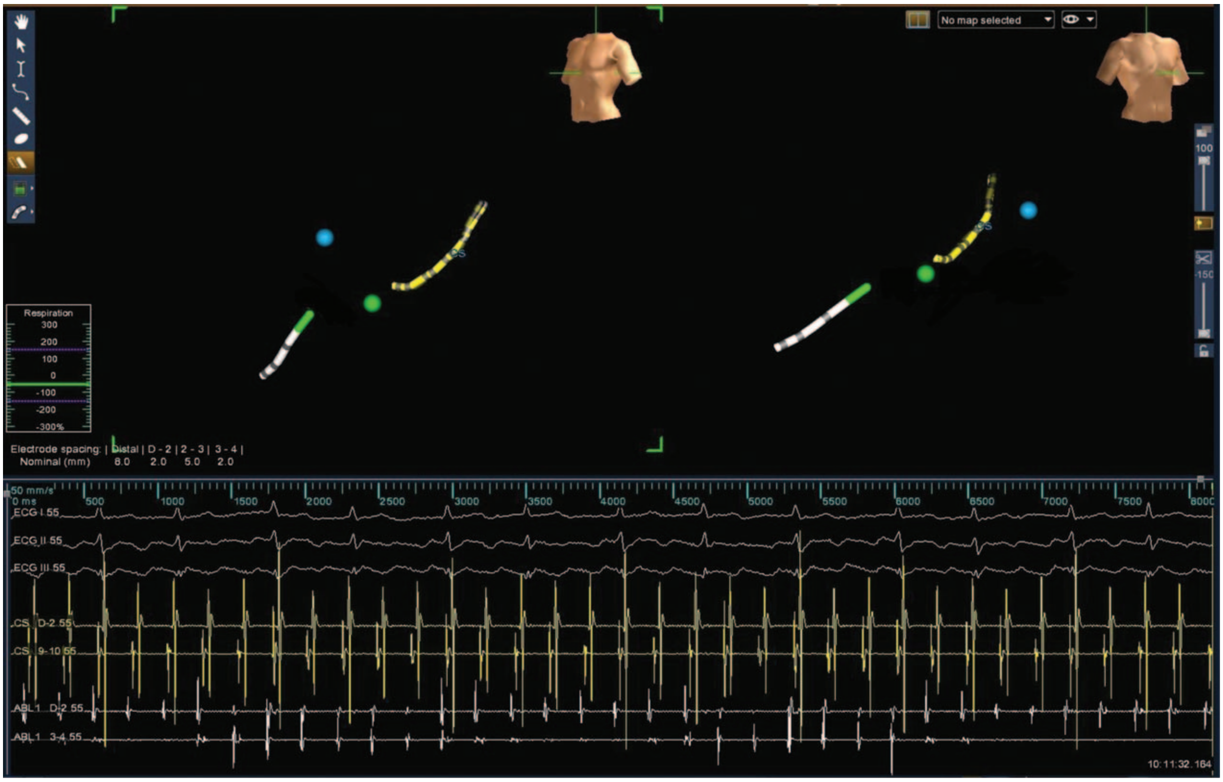

Figure 1. Example of 3-dimensional electro-anatomic systems with a standard mapped point and standard electrodes positions. ABL=mapping/ablation catheter, CS=decapolar catheter localized in coronary sinus.

ablation protocol: MINI CA + MVG, MINI CA + PBT, ALARA + MVG, and ALARA + PBT. All patients were prospectively allocated into subgroups according to the mapping approach and ablation protocol. Prospectively, the MVG and MINI CA protocols were incorporated into a multicenter registry from data.

After implementation of new protocol and approach, the use of the MINI CA approach with MVG protocol became a standard procedure in centers with 3D-EAM (1 center without 3D-EAM).

2.4. Follow-up

Prospectively collected procedural data were extracted from a standardized database used by all centers. The database included medical records, clinical data, and procedural and follow-up data prospectively collected by medical staff involved in ablation procedures. All patients were evaluated in CHA2DS2-VASc and HASBLED scores.

2.5. Statistical analysis

Data are presented as the means ± standard deviations. Continuous variables were compared using an unpaired *t* test; $P < .05$ was considered significant. Data were analyzed using STATISTICA 12.5 (Dell, TX, Round Rock) statistical software.

3. Results

Of the 483 patients (age: 64.3 ± 9.4 range: 25–88 years old; women: 32%), bidirectional block (BDB) was achieved in 99% of patients. In 2.5% of patients, another substrate of arrhythmia was ablated that was induced during EPS or documented prior to ablation: ventricular arrhythmia, accessory pathway-dependent atrioventricular tachycardia, atrioventricular node modification in 1 case, and atrioventricular nodal reentry tachycardia in 8 cases. The MINI CA was performed in 219 (45%) patients, and 206 (43%) patients underwent MVG. From all study groups, 26 (5%) of patients underwent an X-ray protocol due to implanted CIED before procedure.

3.1. NXR approach and MVG technique

Procedural data of 164 patients were evaluated (age: 63.7 ± 9.5; range: 32–84; women: 31%) which consist of 34% from all study population (Table 1). The mean procedural time was 45.4 ± 17.6 min. The mean fluoroscopy time was 0.3 ± 1.6 min. Conversion to X-ray procedure was necessary in 15 (9%) of patients from this group because of positioning of decapolar electrode on tricuspid annulus due to its instability in CS (n = 6), verifying positions of ablation catheter (n = 4), suspicions of anatomical anomaly within the right atrium and CTI (n = 2), checking peripheric venous access cannulation (n = 2), and 3D map instability (n = 1). In the first 50% of procedures, the conversion was needed in 6 patients and in the second 50% of procedures, this was needed in 9 patients. The mean ablation time was 470 ± 312 s (median: 371; 1st and third quartiles: 242 and 599; range: 96–1921) with 16.1 ± 17.5 applications. Audible pop phenomenon occurred in 16 (10%) of patients. Acute BDB was achieved in 100% of patients (Table 2, Fig. 3).

3.2. NXR approach and PBT

This subgroup included 55 patients (age: 63.9 ± 10.7; range: 28–80; women: 39%). This was 11% from all study populations

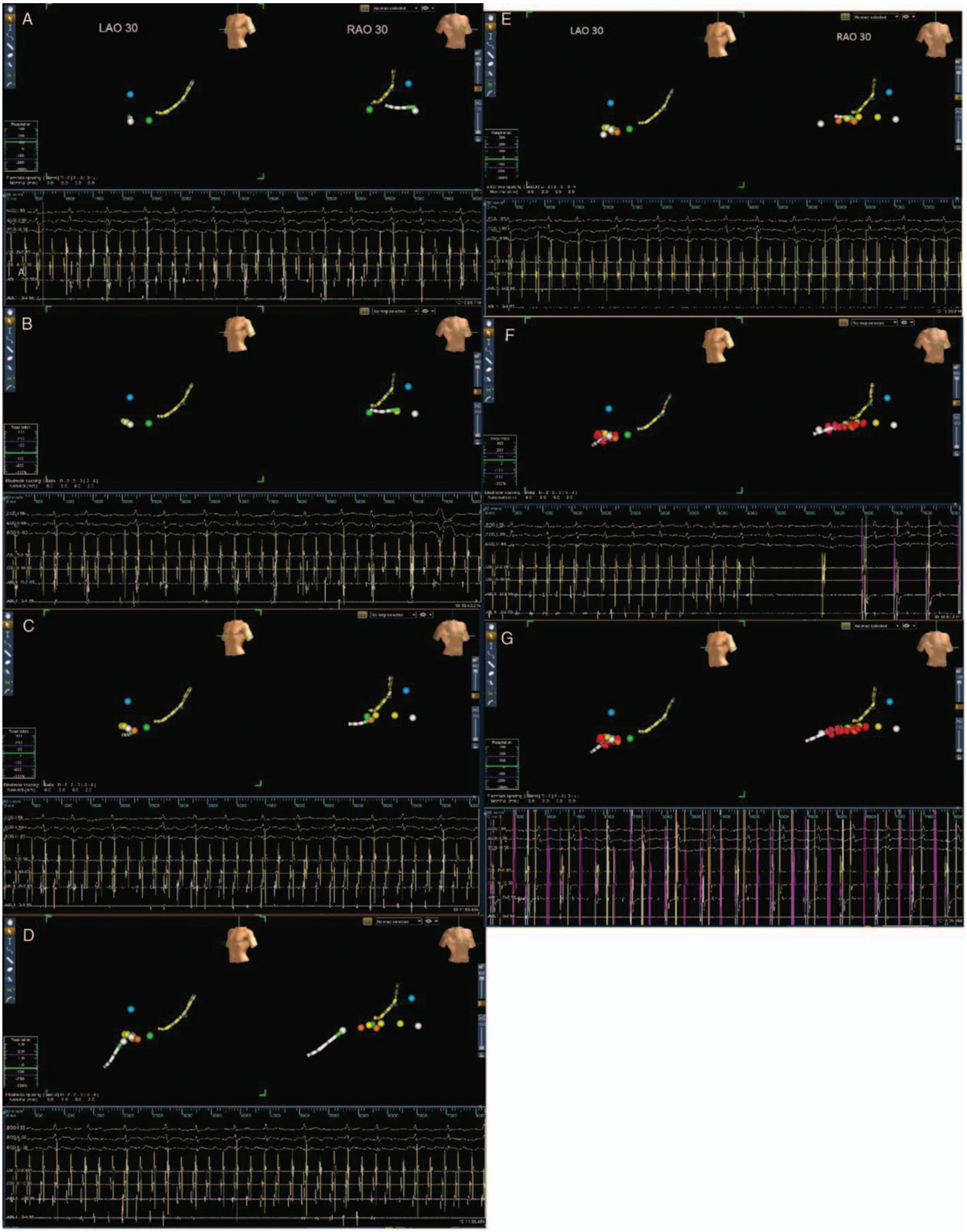

Figure 2. (A) Mapping of the ventricular site of isthmus. (B) Mapping high potential. (C) Mapping of highest potential. (D) Mapping of venous site of isthmus. (E) Start of applications. (F) Moment of successful isolation of atrial flutter. (G) End of application and moment of successful isolation of cavo-tricuspid isthmus-dependent atrial flutter. Blue dots—location of His bundle, green dots—mapped ostium of coronary sinus, white dots—ventricular and venal sites of isthmus, yellow dots—high potential on isthmus, orange dots—highest isthmus potential.

(Table 1). The mean procedure time was 47.2 ± 15.7 min, and the mean fluoroscopy time was 0.2 ± 1.1 min. Conversion to X-ray procedure was necessary in 4 (7%) patients from this group to verify the position of the ablation catheter in 3 cases and instability of the 3D map in 1 case. The conversion took place in 2 cases in the first 50% of procedures and in 2 cases in the second 50%. The mean ablation time was 510 ± 391 s (median: 383; 1st and third quartiles: 292 and 675; range: 96–2106) with 17.7 ±

Table 1

Patient characteristics across procedural methods and ablations techniques.

	MINI CA and MVG, n=164 (34%)	MINI CA and pull back, n=55 (11%)	ALARA and MVG, n=36 (7%)	ALARA and pull back, n=205 (42%)
Mean age, y	63.7±9.5	63.9±10.7	64.2±9.6	64.7±9.1
Female, %	30	39	39	30
BMI	27.7±5.8	28.6±3.5	29.0±5.6	29.0±5.1
Hypertension, %	80	75	83	82
History of MI, %	15	13	8	17
History of PCI, %	13	11	11	11
History of CABG, %	5	5	3	5
Dilated cardiomyopathy, %	4	0	0	2
AFL during procedure, %	42	27	44	38
Mean CHA2DS2-VASc	2.3	2.4	2.7	2.5
Mean HASBLED	1.5	1.8	1.6	1.7

AFL=atrial flutter, ALARA=as low as reasonable achievable fluoroscopic approach, BMI=body mass index, CABG=coronary artery bypass graft, MI=myocardial infarction, MINI CA=minimally invasive, nonfluoroscopic imaging catheter ablation, MVG=maximum voltage-guided technique, PCI=percutaneous coronary intervention.

11.3 applications. An audible pop phenomenon occurred in 7 (13%) patients. Acute BDB was achieved in 96% of patients (Table 2, Fig. 3).

3.3. ALARA approach and MVG technique

To this subgroup, 36 patients were recruited (age: 64.2±9.6; range: 35–88; women: 39%). This was 7% of the study population (Table 1). Mean procedural time was 52.6±23.7 min and mean fluoroscopy time was 7.7±6.0 min. The mean ablation time was 584±331 s (median: 470; 1st and third quartiles: 350 and 811; range: 213–1565) with 19.1±13.3 applications. The pop phenomenon occurred in 4 (11%) of patients. The 3D-EAM was used in 55% of procedure, and those were not associated with reduce fluoroscopy and procedural time (P=NS). Acute BDB was achieved in 100% of patients (Table 2, Fig. 3).

3.4. ALARA approach and PBT

This subgroup included 205 patients (age: 64.7±9.1; range: 25–85; women: 30%) that consisted of 42% of the population (Table 1). The mean procedure time was 59.8±24.0 min, and the mean fluoroscopy time was 9.1±7.2 min. The mean ablation time was 726±454 s (median: 601; 1st and third quartiles: 395 and 980; range: 131–2569) with 16.9±11.3 applications. The pop phenomenon occurred in 6 (3%) of patients. The 3D-EAM was used in 68% of procedure. Acute BDB was achieved in 99% of patients (Table 2, Fig. 3).

3.5. Patients with CIED

Patients with CIED were primarily excluded from MINI CA approach; therefore, they were analyzed separately. MVG method was used in 6 and PBT in 20 patients with CIED. Mean procedural time was 57.0±28.5 min vs. 61.7±23.5 min (P=NS). In all patients, BDB was achieved without major complications. In patients with CIED, the use of MVG was associated with lower mean application time ([468±136 s vs. 732±365 s [$P<.01$]) and total fluoroscopy time (6.1±4.7 min vs. 12.0±8.6 min [$P<.01$]) as compared to PBT.

3.6. In-hospital follow-up

There were no major cardiovascular complications directly associated with the procedure in any group. In 5 cases, a large hematoma was noted without a significant hemoglobin level drop or the need for a prolonged stay or blood transfusion. One patient needed urgent implantation of a DDDR pacemaker due to bradycardia and severe sick sinus syndrome. Another patient underwent the NXR MVG procedure, and preablation EPS revealed an HV longer than 80 ms, wide QRS with left bundle branch block pattern, advanced second degree atrioventricular block (AVB) with family history of advanced AVB and dilated cardiomyopathy. Therefore, advanced second degree of AVB persisted after ablation, and the patient was referred to DDDR implantation and further genetic tests of suspected familial form of dilated cardiomyopathy.

4. Discussion

This study shows that the most reasonable compilation between procedural approach and ablation technique is the NXR approach and the MVG technique. These procedural protocols allowed lower procedural time, fluoroscopy, and ablation time compared with the X-ray approach and the PBT.

The acute success of ablation was 95% and 100% for the MVG MINI CA and X-ray groups, respectively, similar to Lewalter et al. This was 100% in gold tip catheters and 95% in platinum tip catheters. However, in our study, results were achieved with shorter fluoroscopic and procedural times (0.3 and 45.5 min) in the MINI CA MVG group and (7.7 and 52.6 min) in the X-ray MVG group according to Lewalter et al. This was 8.5 and 59 min with gold tip catheters and the 10.3 and 59 min with platinum tip catheters. This reduction in fluoroscopic time was achieved using NXR approach in MINI CA group and probably by using 3D-EAM in X-ray group. Shorter procedures could be achieved by using simplified approach with simplified stimulations protocols and only 2 catheters.[6]

The decrease in total application time due to use of MVG technique was achieved similar as in other studies on MVG technique. In Jacobsen et al, the total application time decreased from a mean 11 min in PTB to 6 min in the MVG technique. Lewalter et al reported a similar reduction (11–7 min as far as PBT and MVG are considered).[4–10]

Although the MVG technique was introduced more than 5 years ago, the knowledge on this technique is still limited. There are still limited data on consistency in conduction block after successful CTI RFCA. Our knowledge on the successfully ablated CTI-based AFL uses studies when the success of ablation was evaluated only by evaluation of BDB during ablation procedure,

Table 2

Data for each group.

	MINI CA and MVG, n=164 (34%)	MINI CA and pull back, n=55 (11%)	ALARA and MVG, n=36 (7%)	ALARA and pull back, n=205 (42%)	*P*					
					MINI CA and MVG vs. MINI CA and pull back	MINI CA and MVG vs. ALARA and MVG	MINI CA and MVG vs. ALARA and pull back	MINI CA and pull back vs. ALARA and MVG	MINI CA and pull back vs. ALARA and pull back	ALARA and MVG vs. ALARA and pull back
Time of application, s	473±317	510±391	584±331	726±454	<.001	<.001	<.001	NS	NS	.05
Number of applications	16.1± 17.5	17.7±12.2	19.1±13.3	16.9±11.3	NS	NS	NS	NS	NS	NS
Total procedure time, min	45.4±17.6	47.2±15.7	52.6±23.7	59.8±24.0	NS	.05	<.001	NS	<.001	NS
Fluoroscopy time, min	0.3±1.6	0.2±1.1	7.7±6.0	9.1±7.2	NS	<.001	<.001	<.001	<.001	NS
No-X-Ray approach, %	91	93	0	0	NS	<.001	<.001	<.001	<.001	NS
Acute success rate, %	100	96	100	99	.05	NS	NS	NS	NS	NS
Pop phenomenon, %	10	13	11	3	NS	NS	NS	NS	NS	<.001
CS successful cannulation, %	95	98	100	99	NS	NS	.05	NS	NS	NS
Another substrate of arrhythmia, %	2	2	2	3	NS	NS	NS	NS	NS	NS

ALARA=as low as reasonable achievable fluoroscopic approach, CS=coronary sinus, MINI CA=minimally invasive, nonfluoroscopic imaging catheter ablation, MVG=maximum voltage-guided technique, NS=nonsignificant.

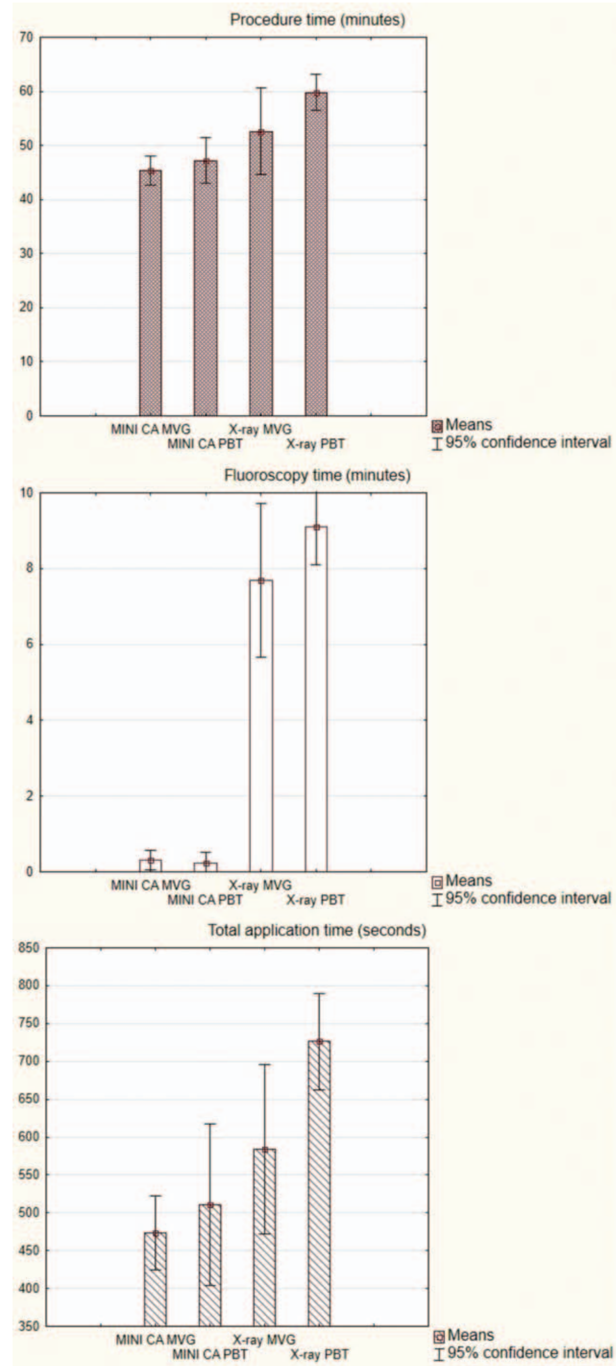

Figure 3. Procedure time, fluoroscopy time, and total application time. Means and 95% confidence intervals are shown. MINI CA=minimally invasive, nonfluoroscopic imaging catheter ablation, MVG=maximum voltage-guided technique.

observation, and clinical follow-up of recurrences. On the other hand, other arrhythmias like AF experience a brand new method of pulmonary vein isolation (laser ablation). In Dukkipati et al, patients underwent invasive EPS confirming pulmonary vein isolation. Such a study could be performed on AFL patients to determine a better method of CTI-dependent AFL ablation.[18]

The shorter procedural time in the MINI CA protocol (in MVG and pull-back groups) compared with the X-ray protocol (MVG and pull-back groups) may be achieved with a more motivated and focused use of this safe procedure and medical stuff who perform this procedure without fluoroscopy. However, this is the first report of such an observation, and it requires more study. Most studies without fluoroscopy were performed on various supraventricular arrhythmias such as atrioventricular nodal reentry tachycardia or accessory pathways and rather small groups of CTI-dependent AFL. In those "other" arrhythmias, the time to induce and map location on arrhythmia could be localized on the left side of the heart. This might also increase the procedure time.[11–17]

The low number of conversions from the MINI CA (NXR) to the X-ray was previously reported in a study on various supraventricular arrhythmias by our team. This was successfully repeated, and it improved by lowering the procedural time in this study. However, in a large Italian study, fluoroscopy was necessary in 28% of planned NXR procedures (compared with the 9% and 2% achieved here). Including various supraventricular arrhythmias to generate different catheter manipulation protocols and anatomical problems might make a difference in the NXR protocol.

Bigelow et al showed that fluoroscopy was necessary in 3 of 524 patients recruited to the study. They also showed that with elimination of fluoroscopy ablation catheter ablation with the Navx Ensite 3D navigation system created maps of the inferior vena cava, superior vena cava, and right atrium with localization of the His bundle, tricuspidalis valve, and CS. In our study, only a simple map was created and only in the region of ablation and with precision-marked His bundle location (as critical heart conduction point) and CS ostium. Other anatomical structures were avoided, because they do not influence the safety and effectiveness of the procedure.[14] However, in this study, the 3D-EAM and TEE was used to navigate the catheters. Therefore, additional TEE or intracardiac echocardiography may further improve nonfluoroscopic approach results.[11,14,15]

In Stec et al study, the MINI CA protocol was introduced for the first time, a mean procedural time in CTI-dependent AFL was 50 min. In this study, the time in MINI CA groups was 49.9 and 47.4 min, which prove that the learning curve is fast with no further decrease in a very short procedure time. Lower procedure time was achieved in the learning curve in the MINI CA protocol procedure. However, there are limited data on the learning curve of young electrophysiologists with no X-ray training.

Patients with CIED do not achieve all benefits such as complete X-ray elimination from NXR procedures. In this group, only the reduction in fluoroscopy time is achieved. Here, moving the catheter in the NXR procedures without localization of the electrodes could damage the implanted system. In those patients, other navigation systems providing the NXR approach like MediGuide or intracardiac echocardiography could significantly reduce the X-ray use.[19]

The high number of patients with CTI-dependent AFL (especially the elderly) requires improvements in AFL ablation results. However, the traditional X-ray approach due to the necessity fluoroscopy and the lead apron may be associated with discomfort in medical stuff—especially in the spine and lower extremities. This may lead to joint problems and is limited in pregnant women.

To the improve ablation procedure and decrease the need of use lead apron, other NXR protocols should be compared with MINI CA protocol.[20] Lewalter et al studied acute BDB in MVG group. The value was 97.2% and 92.2% in cases with PBT. However, in this study, BDB was achieved with substantial efficacy (100% and 96% in MVG subgroups and 96% and 99% in PBT subgroups). Thus, long-term successful follow should be achieved similar to Lewalter et al in which the gold tip catheter subgroup was 98%.[5,21]

5. Limitations

Although this study is one of the largest reported group for patients undergoing RFCA for CTI-dependent AFL with MVG and NXR, the study does have some limitations.[3–12,15] First, it is a nonrandomized study performed by medical staff that are already trained in NXR.[11] The success of the ablation procedure was confirmed acutely and within the observation period. No long-term follow-up assessed the differences in recurrences between MVG and the PBT. On the other hand, only an invasive validation of CTI conduction could confirm consistent BDB after several months. Analysis of patients undergoing a pulmonary vein isolation or a re-do procedure for clinical recurrences of AFL is underway. There is still limited data on the learning curve for young electrophysiologists in training in NXR procedures with AFL ablation procedures and other arrhythmias.

6. Conclusions

Complete elimination of fluoroscopy is feasible, safe, and effective during RFCA of CTI-dependent AFL in almost all patients without CIED. The most optimal approach for RFCA of CTI-dependent AFL seems to be MVG and zero-fluoroscopy.

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