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Evaluation of the operator learning curve for radiofrequency ablation for atrioventricular nodal reentrant tachycardia

Aim The aim of this study was to determine the average minimum number of slow pathway ablation procedures required to reach a steady success rate among inexperienced operators.

Material and Methods We analyzed the consecutive AVNRT ablation procedures of three inexperienced operators for the rate of operational success and complications.

Results Operators performed a total of 156 AVNRT ablation procedures. There was no statistical significance between the three operators regarding the rate of success (p=0.69) and complications. There were significant differences between the operators in terms of procedure time, fluoroscopy time, and cumulative air kerma. The variability of procedure time and cumulative air kerma, both among three operators and within each operator, decreased significantly after the 25th case. Each operator was analyzed individually for the probability of success as related to the cumulative number of ablations. All trainee operators reached a success rate of 90% at the 27th procedure.

Conclusion An average of 27 slow pathway ablation procedures should be performed by a beginner operator to achieve proficiency.

Keywords Atrioventricular nodal reentrant tachycardia; catheter ablation; learning curve

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Introduction

Atrioventricular nodal re-entrant tachycardia (AVNRT) is one of the most common causes of supraventricular tachycardia (SVT) [1]. Many patients with AVNRT suffer from symptoms including palpitations, chest pain, shortness of breath, and dizziness. Although this tachyarrhythmia is not considered to be life-threatening, it adversely affects patients' quality of life. Catheter ablation is recommended by current guidelines as the first-line treatment in patients with symptomatic, recurrent AVNRT. Catheter ablation therapy has been proven to be safe and curative, with a low risk of complications and a high success rate [2].

In the literature there are operator learning curve data for various invasive cardiac practices; however, electrophysiological procedures have not been standardized according to the learning threshold. We are a high-volume center providing electrophysiology training. Catheter ablation of the AVNRT is one of the most frequent procedures we perform. Ablation procedure is performed by experienced operators as well as by inexperienced trainees under the supervision of experienced operators.

This study aimed to determine the average number of slow pathway ablation procedures performed necessary to reach a steady success rate among inexperienced operators.

Material and methods

Study Population

AVNRT is defined as tachycardia caused by a re-entrant circuit in the AV node area. Diagnostic tests aim to show dual AV node physiology that is the underlying substrate of this re-entrant circuit [3]. Modification of the slow pathway is an effective treatment for both typical and atypical AVNRT. Thus, AVNRT has been established as the first-line therapy.

According to international cardiology guidelines, the definition of the term "experienced operator" is based on the number of procedures performed and on the success rate [4]. The experienced operator will have worked at a center where more than a thousand electrophysiological procedures were performed per year for at least 5 yrs. An inexperienced operator is defined as a cardiologist with less than 1 yr of experience. Inexperienced operators receive theoretical lectures from experienced operators on invasive electrophysiology for 2 hrs daily for 2 wks. After this theoretical education, the inexperienced operator attends and observes AVNRT ablation procedures as the second operator assisting an experienced first operator.

Each trainee operator attended their first 25 AVNRT procedures as the second operator. Then they began to perform AVNRT ablation procedures as the first operator under the supervision of an experienced operator. If the trainee operator failed to complete the procedure, it was completed by the experienced operator. We analyzed the rate of operational successes and complications for consecutive AVNRT ablation procedures performed by three consecutive, inexperienced operators in our EP laboratory. We tried to determine the minimum cumulative number of AVNRT ablation procedures required for each inexperienced operator to reach a steady-state rate of success.

Procedure

The procedure was explained to each patient, and informed consent was obtained. Use of antiarrhythmic drugs was discontinued >5 days before the procedure. With local anesthesia, a standard electrophysiological study was performed from the femoral vein. A coronary sinus (CS) catheter, a diagnostic right ventricle catheter, and an ablation catheter, which was placed at the high right atrium, were used during the procedure. The AVNRT diagnosis was made with meticulous atrial and ventricular pacing maneuvers following established criteria [5]. Anatomical slow pathway ablation was performed according to standard techniques [6]. A conventional 4-mm tip ablation catheter (Marinr, Medtronic, USA) was withdrawn from the His site to the posteroseptal portion of the tricuspid annulus until an atrioventricular signal ratio of < ¼ was recorded. An early far-field atrial signal followed by a late relatively high-amplitude near-field atrial signal (Jackman potential) was searched and targeted for ablation as a representative of the slow pathway area. When multicomponent, fragmented, and low-amplitude potentials were obtained, radiofrequency (RF) current, 30 to 50 Watt, aiming temperature of 60°C, was delivered for up to 20 sec until the nodal rhythm with 1:1 retrograde ventriculoatrial (VA) conduction was achieved. Once nodal rhythm with 1:1 VA conduction was observed, RF energy delivery was continued for 20 to 40 s or until termination of the nodal rhythm. If 1:1 retrograde VA conduction was not seen, RF delivery was immediately ceased. During the ablation procedure, meticulous attention was paid to avoid displacement of the ablation catheter from the targeted area. The upper limit of ablation level was set as the level of the roof portion of CS ostium determined from the left and right 30-degree anterior oblique projections.

After the ablation, tachycardia induction with the use of isoproterenol infusion was attempted. Endpoints for procedural success were the demonstration of RF-induced nodal rhythm with 1:1 VA conduction and non-inducibility of AVNRT with programmed or burst stimulations during the isoproterenol infusion. Transient or permanent AV block and access site-related vascular complications, e.g., arteriovenous fistula or hematoma, were accepted as procedural complications [7].

Statistical analysis

The primary goal of this study was to evaluate the time-dependent procedural success rate. To assess the effect of time, i.e., procedure volume, on operator procedural success, we used a logistic regression model. Numerical variables are presented as mean and standard deviation (SD) if normally distributed or as median and interquartile range (IQR) if not normally distributed. Categorical variables are presented as numbers and percentages. We included operators (operator 1, operator 2, and operator 3) and numbers of procedures (from 1 up to 53) to the regression model with an interaction term. The number of procedures was included, using restrictive cubic spline (3 knots) to capture nonlinearities. ANOVA test performed for comparison among three operators. Afterward, we estimated the predicted probability of procedural success and plotted the predicted probability of procedural success depending on total procedure time for the three operators. The odds ratio was used to quantify the association between procedural success and operators. All statistical analyses were performed by R-software v. 3.5.1 (R statistical software, Institute for Statistics and Mathematics, Vienna, Austria).

Results

A total of three volunteer, inexperienced operators were included in the current study. Operators performed a total of 156 AVNRT ablation procedures and operational data from each procedure were recorded prospectively. A total of 52 cases were conducted by operator 1, 51 by operator 2, and 53 by operator 3. Procedures performed primarily by an experienced operator were excluded from the study.

A total of 105 (67.3%) female and 51 (32.7%) male patients with a median age of 47 yrs (39–57 IQR) constituted

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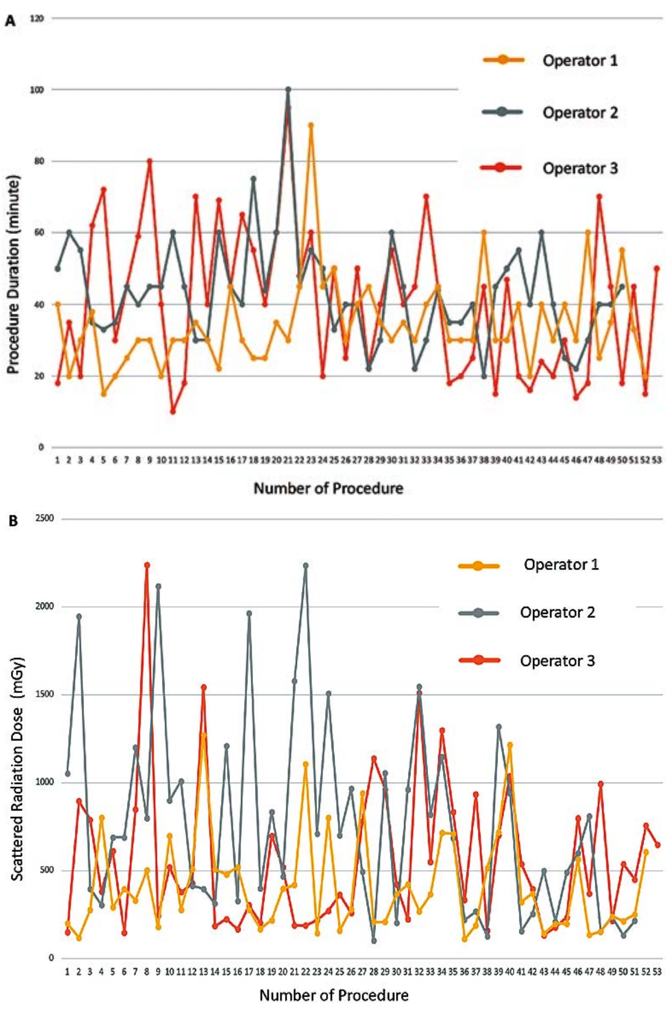
Table 1. Baseline clinical characteristics and procedural details

Variables	Overall cases (n=156)	Operator1 (n=52)	Operator 2 (n=51)	Operator 3 (n=53)	p value
Age (yrs)	47 (39-57)	49 (41.5-60)	46 (37.3-55.5)	47 (38-55)	0.45
Gender (female)	105(67.3)	41(78.8)	32(62.7)	32(60.4)	0.09
Length (cm)	165 (160-170)	165 (162-172)	165 (160-169)	165 (159-172)	0.76
Weight (kg)	75 (65-86)	75.5 (70-84.8)	76 (64.8-92)	72 (65-80.5)	0.32
HT	38(24.4)	11(21.2)	13(25.5)	14(26.4)	0.80
DM	28(17.9)	11 (21.2)	10(19.6)	7(13.2)	0.53
CAD	12(7)	5(9.6)	4(7.8)	3(5.7)	0.75
Procedure Duration (min)	40 (30-47.3)	30 (30-40)	45 (35-51.3)	40 (20-55)	0.003#
Fluoroscopy Duration (min)	13.4 (9-22)	10.1 (7.1-15.1)	15.4 (10.2-23.9)	15.5 (10.6-25)	<0.001#,†
Total Air Kerma (mGy)	400 (219-801)	308 (199-517)	644 (278-1055)	409 (225-798)	<0.001#
Hematoma	7(4.5)	3 (5.8)	1(2)	3(5.7)	0.70
Transient AV block	2(1.3)	–	1 (2)	1(1.9)	0.77
Recurrence	5(3.2)	2(3.8)	1(2)	2(3.8)	0.99
Predicted Probability of Success	–	0.87 (0.81-0.92)	0.90 (0.81-0.95)	0.93 (0.81-0.97)	0.02†
Success of Ablation	136(87.2)	44(84.6)	46(90.2)	46(86.8)	0.69

Data are median (IQR) or n(%). AV, atrioventricular; CAD, coronary artery disease; DM, diabetes mellitus; HT, hypertension.
# p<0.05, versus operator 1 and operator 2; † p<0.05,versus operator 1 and operator 3.

Figure 1. Procedural duration and scattered radiation dose for each operator



the patient population (Table 1). Individual operational details of the three operators are displayed in Table 1. There were significant differences between the operators in terms of procedure time, fluoroscopy time, and cumulative air kerma (scattered dose of radiation) (Table 1). The mean procedure duration of operator 2 was longer than that of operator 1 [30 (30–40) vs 45 (35–51.3), p=0.003]. The variability of procedure time and cumulative air kerma, both among three operators and within each operator, decreased significantly after the 25th case (Figure 1A,1B). The mean fluoroscopy time of operator 1 was shorter than that of the other two operators [10.1 (7.1–15.1), 15.4 (10.2–23.9), 15.5 (10.6–25), respectively, p<0.001]. The cumulative air kerma for operator 1 was lower compared with the other two operators, however, only the difference between operator 1 and operator 2 was significant [308 (199–517), 644 (278–1055), 409 (225–798), respectively, p<0.001].

There was no statistical significance between the three operators regarding rate of success (operator 1, 84.6%; operator 2, 90.2%; operator 3, 86.8%; p=0.69) and complications (hematoma, transient or permanent AV block) (Table 1). In addition, AVNRT recurrence occurred in 5 of 156 patients (operator 12 recurrences; operator 2, 1 recurrence; operator 3, 2 recurrences).

Logistic regression analysis was conducted to estimate the predicted probability of success rate for each operator. The predicted probability of success rate for operator 1 was: 0.87 (0.81–0.92), operator 2, 0.90 (0.81–0.95), and operator 3, 0.93 (0.81–0.97). The difference between operator 1 and operator 3 was significant (p=0.02).

Trainee operators failed in 20 of 156 (12.8%) cases; 19 (95%) of these cases were successfully ablated by experienced operators (Table 2). There were no significant differences between successful and failed ablation cases regarding gender, age, procedure duration, fluoroscopy time, radiation exposure, frequency of diabetes mellitus (DM),

Figure 2. The probability of success according to the number of procedures

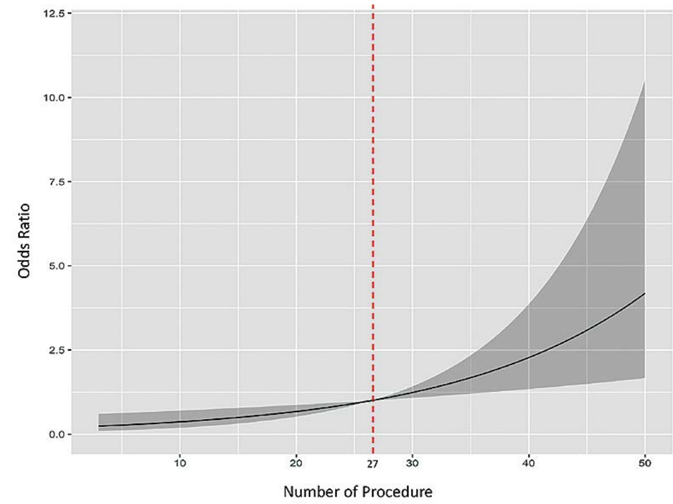


Table 2. Clinical characteristics and procedural details according to whether the inexperienced operator was unsuccessful or successful

Variables	Unsuccessful (n=20)	Successful (n=136)	p value
Age (yrs)	44 (29.8–52)	48.5 (41-58)	0.12
Female Gender	16 (80)	89 (65.4)	0.30
HT	1 (5)	37 (27.2)	0.05
DM	3 (15)	25 (18.4)	0.99
CAD	1 (5.0)	11 (8.1)	0.99
Procedure Duration (min)	30 (24-45)	40 (30–47.5)	0.68
Fluoroscopy Duration (min)	12 (9.5–22)	14 (9–21.4)	0.62
Total Air Kerma (mGy)	445 (208-557)	422 (224-835)	0.36

Data are median (IQR) or n (%). CAD, coronary artery disease; DM, diabetes mellitus; HT, hypertension.

hypertension (HT), or coronary artery disease (CAD) (Table 2).

Each operator was analyzed individually for the probability of success related to the cumulative number of ablations. Operator 1's initial probability of success was 72%, 80% at the 12th case, and 90% at the 34th case. For operator 2, the initial probability of success was 67%. The cumulative procedure number that was required to reach a success rate of 80% was 13; and the cumulative procedure number that was required to reach a success rate of 90% was 26. The initial probability of success was 60% for operator 3, and the required procedure numbers were 13 and 23 to reach 80% and 90% success rates, respectively. All trainee operators reached a success rate of 90% at the 27th procedure (Table 3).

AVNRT, atrioventricular nodal reentrant tachycardia. For example, the first operator's probability of success was 72% on the first AVNRT procedure, while at least 80% after the 12th and over 90% after the 34th procedure.

Table 3. Probability of success for each operator

Variables	Operator 1	Operator 2	Operator 3
Initial Probability of Success rate,	72%	67%	60%
Increase success rate after consecutive AVNRT procedure			
Probability of Success >80%, after n procedure	12th	13th	13th
Probability of Success >90%, after n procedure	34th	26th	23rd

The logistic regression model revealed that the operator-dependent effect on success rate was not significant (OR 1.21, 95% CI 0.37–3.99, p=0.755). In addition, the probability of success increased with the increasing cumulative number of procedures (OR 1.06, 95% CI 1.02–

Figure 3. Predicted probability of successw

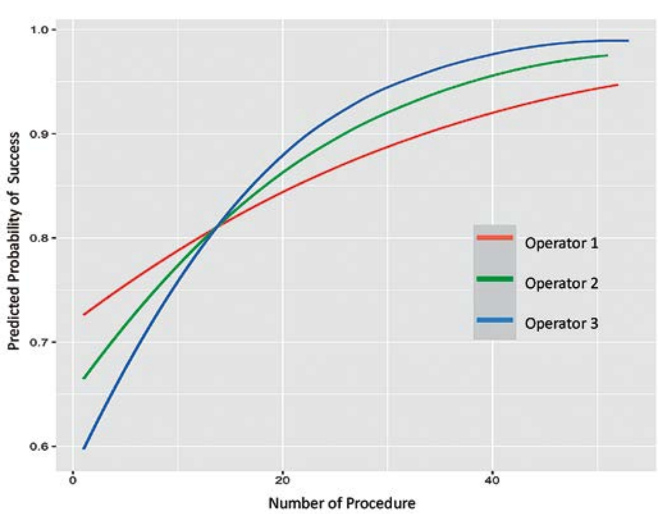
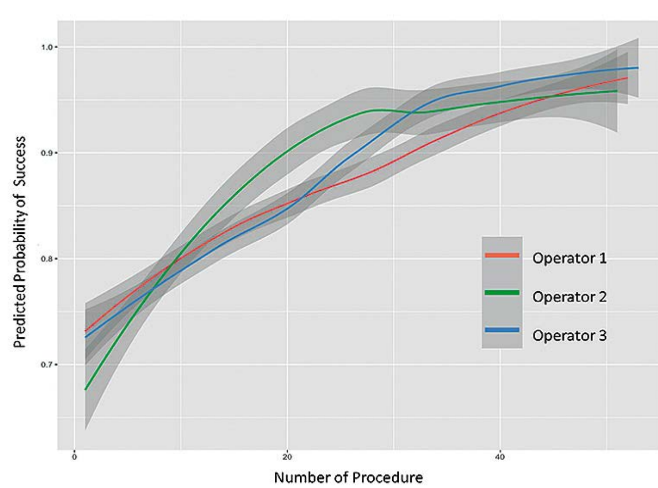


Figure 4. Operator success rate adjusted to the cumulative air kerma



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1.10, p=0.002) (Figure 2). The overall probability of 80% success rate was achieved at the 17th procedure and 90% success rate was achieved at the 27th procedure (Figure 3). There was no significant difference between operators regarding the success rate that was adjusted according to the cumulative air kerma for each operator (Figure 4).

Discussion

We have shown that AVNRT ablation procedures conducted by trainee operators can be performed at a success rate of 80% by the 17th case and of 90% by the 27th case after proper theoretical and practical training. We also found that the success rate was not operator dependent, however, procedure volume was crucial for an adequate success rate.

The procedure duration and fluoroscopy time of operator 1 were shorter compared to the other two operators but with a slightly lower success rate. This observation might be related to the fact that operator 1 was eager to engage experienced operators in his cases.

Basic electrophysiology training and experience carry eminent importance in cardiology practice. However, electrophysiological training fellowship programs are not available in some countries, as in Turkey. Thus, operators are trained in educational centers with the capability of performing invasive electrophysiological studies. Standardization of the training and experience for invasive electrophysiology is important for an optimal procedural outcome. However, it might be difficult to provide standardization in the absence of fellowship programs.

Previous studies have shown that operator experience might influence the outcomes of invasive procedures such as percutaneous coronary intervention [8, 9]. Data obtained from those studies had led to recommendations related to the minimum procedure number that had to be performed by operators to indicate clinicians' proficiency. Recently, this has been addressed in the myocardial revascularization guidelines [10]. Similar recommendations exist for cardiac imaging and echocardiography [11]. Since the impact of operator experience is a well-recognized entity, new studies are being designed to determine objective standards for each procedure. However, the importance of operator experience has not been evaluated for invasive electrophysiological procedures. Therefore, we investigate the effect of the learning curve on the outcome of AVNRT ablation procedure and on reaching a cumulative procedure number associated with an adequate rate of success and complications.

The present study has several limitations. Firstly, this was a single-center study with a relatively small number of cases and only three trainee operators. Secondly, although all cases were similar, some operators may have reached the targeted learning level later due to anatomical differences. However, an acceptable success after a certain number of cases suggests that the new operators had achieved sufficient experience despite anatomical differences or relative difficulty in some cases. Thirdly, the present study did not include patients with initial 1st degree AV block, congenital heart defects, or patients under the age of 18 yrs, i.e., patients with an increased risk of developing complications of catheter ablation, primarily iatrogenic AV block of high degrees. Such patients should always be operated on exclusively by experienced operators. Fourthly, the results of the study may not be applicable when using mapping technologies (for example, «zero-fluoro») and ablation (for example, cryoablation) different from those used in the study, as well as for the ablation of other supraventricular arrhythmias (for example, with ablation of accessory pathways). In these cases, the learning curve is much longer [12–14]. Finally, all the operators in the study received training on cardiac anatomy, fluoroscopy, electrocardiogram evaluation, and AVNRT physiology determined by experienced operators, rather than in a standard core training curriculum such as EHRA.

In conclusion, we studied the effect of the operator learning curve on the success of AVNRT ablation procedure, as it is the most common type of paroxysmal supraventricular tachycardia. Based on our observations, we suggest that an average of 27 slow pathway ablation procedures should be performed by beginner operators to achieve proficiency. Further studies are needed to support our findings and to establish a standard learning curve for each arrhythmia and for relevant catheter-based therapies.

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