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Abstract

Aim: The relationship between arrhythmia induction and ablation with palpitation characteristics has been demonstrated in electrophysiological study (EPS) patients. However, there is insufficient data on palpitation characteristics and their sensitivity and specificity. We aimed to identify the relationship between scoring composed of palpitation characterics with the supraventricular tachycardia (SVT) induction and the success rate of the procedure.

Method: A total of 119 patients, diagnosed as paroxysmal supraventricular tachycardia (PSVT) by electrocardiography, rhythm Holter or symptoms, and underwent EPS, were enrolled in the study. A psychiatrist administered the Hospital Anxiety and Depression Score (HADS) questionnaire.

Results: In SVT induced group, palpitation duration (p = 0.048), palpitation spread to neck (p = 0.004), responsiveness to medication (p = 0.008), induction with stress (p = 0.007), admission to emergency (p = 0.021) and documented PSVT (p = 0.017) were more common. Atropine administration (p = 0.001) was higher, and the Wenckebach cycle length (p < 0.001) was longer in the non-induced arrhythmia group. The presence of dual AV pathways was higher in SVT induced group (p = 0.002). There were no differences between groups in terms of anxiety score (p = 0.192), depression score (p = 0.730), and total psychiatric results (p = 0.280) in the HADS questionnaire. In scoring designed by the palpitation characteristics, the score of four and over predicted SVT induction with 63.6% sensitivity and 92.5% specificity. Radio-frequency ablation (RFA) was performed succesfully in 82.1% of patients with a score of ≥4.

Conclusion: Supraventricular tachycardia induction score obtained from the palpitations characteristics and arrhythmia documentation can be useful in predicting the induction of SVT and the success of RFA.

Keywords: Electrophysiological study, Supraventricular tachycardia induction, Radio-frequency ablation, Documented arrhythmia, Palpitation

1. Introduction

Palpitation is a common complaint in patients presenting to the cardiology clinic. The complaint of palpitation caused by arrhythmias is usually due to paroxysmal supraventricular tachycardias (PSVT). Supraventricular tachycardias (SVT) include atrioventricular nodal reentrant tachycardia (AVNRT), atrioventricular reentrant tachycardia (AVRT) and atrial tachycardia. Although these

arrhythmias do not increase cardiovascular mortality, recurrent attacks affect patient's quality of life [1,2].

Electrophysiological study (EPS) is an effective procedure in the treatment of PSVT. In a majority of the patients undergoing EPS, palpitation complaints due to PSVT are permanently terminated by successful radio-frequency ablation (RFA) with a low complication rate [3]. So, in the current guideline, ablation is recommended with a class-I indication for the treatment of PSVT [4].

Paroxysmal SVT is commonly diagnosed by recording the patient's electrocardiogram (ECG) at the time of palpitation or less often by rhythm Holter recordings. Patients with nondocumented PSVT may be misdiagnosed as panic disorder. Unfortunately, the 24-h rhythm Holter record used to document arrhythmias is very low in terms of sensitivity and specificity in the diagnosis [5,6]. Another alternative method to diagnose the possible PSVT is a loop recorder. The effectiveness of this device is higher than the 24-h rhythm Holter recording, but it is time-consuming and rather expensive. Also, in studies using the event recorder, clinically significant arrhythmias could not be detected in at least half of the patients [7].

Medical history, symptoms, and physical examination are the basis of clinical practice and are accessible. The presence of palpitation complaint may be helpful in diagnosis even if the arrhythmia could not be documented. There is a relation between arrhythmia induction in EPS and the characteristics of the palpitations. However, the sensitivity and specificity of the relationship between SVT induction and characteristics of palpitation were not established [7—9].

We aimed to demonstrate the efficacy of the scoring system created by palpitation characteristics for predicting the necessity for SVT induction and RFA in EPS.

2. Method

2.1. Study Population

The current research is a cross-sectional study that included 119 consecutive patients who underwent EPS between March 2017 and April 2018. Patients were diagnosed as PSVT by ECG, rhythm Holter, or clinically. The study was performed under the principles stated in the Declaration of Helsinki. The local ethics committee approved the study protocol, and patients gave informed consent.

We created a medical history form for the patients. By adhering to this form the characteristics of arrhythmia - history and frequency of palpitation, response to anti-arrhythmic drugs, sudden onset

Abbreviations	
PSVT	paroxysmal supraventricular tachycardias
SVT	Supraventricular tachycardias
AVNRT	atrioventricular nodal reentrant tachycardia
AVRT	atrioventricular reentrant tachycardia
EPS	electrophysiological study
RFA	radio-frequency ablation
ECG	electrocardiogram
A-H	Atrium-His
H—V	His-ventricle
BCL	basal cycle length
HADS	Hospital Anxiety and Depression Scale

and termination of palpitation, palpitation spread to the neck, emergency admission due to palpitation, triggering with stress, vagal maneuver response (straining, coughing) and history of syncope - were questioned and recorded. With a total score of 6, we gave 1 point to each of the variables that made up the Arrhythmia Inducibility Prediction Score (AIPS), based on its presence in the patient. Patients with ≥2 of these features and presented with palpitation were accepted as clinical PSVT. We compared patients with a score of 2 or over and with a score of 4 or over according to prediction of SVT inducibility and need for RFA. Electrophysiology study was not performed in patients with less than two arrhythmia characteristics.

ECG or rhythm Holter recordings with a heart rate >100 bpm, a QRS duration of <120 ms, and lasted for at least 30 s were accepted as documented PSVT.

2.2. Exclusion Criteria

Patients with preexcitation on ECG, a basic rhythm other than sinus rhythm before EPS, a history of broad QRS tachycardia or atrial fibrillation, a history of ablation therapy, congenital heart disease, moderate or severe valve disease, severe left ventricular systolic dysfunction, permanent cardiac pacemaker, intracardiac defibrillator, cardiac resynchronization therapy device, chronic renal failure, endocrine disorder, malignancy, acute coronary syndrome, infectious and inflammatory disease, pulmonary embolism, severe comorbid disease were excluded from this study.

2.3. Electrophysiological Study

In the anti-arrhythmic usage, drugs were discontinued for at least four half-lives before the procedure. The femoral vein was the access path. Unfractionated heparin (2500 IU) was administered

Table 1. Baseline characteristics data of both groups.

	Inducible arrhythmia (n = 66)	Non-inducible arrhythmia (n = 53)	p value
Age, years	50.6 ± 14.6	46.9 ± 18.3	0.534
Age of first palpitation attack, years	37.6 ± 14.8	39.9 ± 16.6	0.718
Women, n (%)	41 (62.1)	31 (58.5)	0.687
Hypertension, n (%)	25 (37.9)	17 (32.1)	0.510
Dyslipidemia, n (%)	8 (12.1)	6 (11.3)	0.893
Tobacco use, n (%)	7 (10.6)	6 (11.3)	0.901
Family arrhythmia history, n (%)	3(4.5)	3(5.7)	0.782

after insertion of the catheters. 7-Fr decapolar 2 mm electrode spacing (The Marinr™ CS, Medtronic) catheter was placed to the coronary sinus, three 6-Fr 2 mm electrode spacing 1.3 mm electrode length quadripolar (The Soloist™, Medtronic) catheter was placed to the high right atrium, his bundle, and right ventricle respectively. The intracardiac electrocardiographic recordings were monitored at 100 mm/s through the EP-Tracer®. Atrium-His (A-H), His-ventricle intervals (H−V), and basal cycle length (BCL) were measured before stimulation. Atrioventricular refractory period (Wenckebach cycle length) was determined by atrial overdrive pacing. For arrhythmia induction, programmed stimulation was performed from the upper right atrium, right ventricle, distal, and proximal coronary sinus. Stimulation protocol consisted of atrial and ventricular incremental pacing, programmed atrial, and ventricular extra-stimulus. When tachycardia induced its refractor premature ventricular contraction, ventricular overdrive pacing was performed to make a differentiation diagnosis. Atropine was administered to patients with noninducable SVT. After atropine administration, stimulation was repeated. Atropine dose was titrated until the basal heart rate increased by 50%, or the heart rate was between 100/bpm to 150/bpm. Supraventricular tachycardia induced patients (diagnosed as AVNRT, AVRT, atrial tachycardia) were differentially diagnosed by atrial, ventricular, and His pacing maneuvers.

Multicurve ablation catheter (4 mm) and Medtronic ablation system (Marinr ®; Medtronic Inc., Minneapolis, MN, USA) as RF generator were used. Also, irrigation catheters, cryoablation, and electromechanical mapping systems were used where necessary.

Radio-frequency ablation was performed according to one of the following criteria: 1. Patients with induced SVT and differentially diagnosed in EPS. 2. Patients with narrow QRS SVT recording in ECG or rhythm Holter and had dual physiology with no inducible arrhythmia. 3. Patients with the presence of an accessory pathway, although no arrhythmia could be induced.

Induced tachycardias were considered as supraventricular tachycardias if they met the following criteria: 1) Heart rate >100 bpm, 2) Lasting over 30 s, 3) Regular A−A interval, 4) QRS duration <120 ms. Repeated SVT induction with programmed stimulation or arrhythmia stimulation by an accessory pathway was accepted as RFA criteria. No re-induction of arrhythmia, loss of an accessory pathway, and loss of dual AV node physiology were accepted as successful RFA.

Dual AV node physiology: Over 50 msec increase in A2H2 interval with ≤10 msec decrease in A1A2 interval over 50 ms increase in AH interval with 10 ms decrease in atrial pacing rate. Double response: Two ventricular responses to a single atrial activation due to simultaneous fast - and slow - pathway conduction.

Table 2. Study parametersin electrophysiology for both group.

	Inducible arrhythmia (n = 66)	Non-inducible arrhythmia (n = 53)	p value
Pre-inductive sedation, n (%)	10 (15.2)	5 (9.4)	0.350
Pre-inductive atropine, n (%)	17 (27.8)	29 (54.7)	**0.001**
Basal cycle length, ms	750 ± 125.6	748.4 ± 142.8	0.954
Atrium-His length, ms	56.5 ± 12.6	62.7 ± 17.9	0.074
His-Ventricul length, ms	51.4 ± 8.8	50 ± 8.6	0.462
Wenckebach point, ms	302.849.2	338.9 ± 40.4	**<0.001**
Dual atrioventricular pathway, n (%)	40 (60.6)	17 (32.2)	**0.002**
Atrium-His interval jump, n (%)	29 (43.9)	16 (30.2)	0.124

Bold numbers show statistical significance.

Table 3. Anxiety, depression and top score association of arrhythmia inducibility and EP success.

	Inducible arrhythmia (n = 56)	Non-inducible arrhythmia (n = 35)	p value	Successful ablation in EP (n = 61)	No ablation in EP (n = 26)	Unsuccessful ablation in EP (n = 4)	p value
Anxiety score	10.2 ± 4.4	8.9 ± 4.4	0.192	10.2 ± 4.3	8.9 ± 4.5	6.5 ± 5.5	0.101
Depression score	7.3 ± 3.2	7.1 ± 3.4	0.73	7.1 ± 3.1	7.3 ± 3.8	7.8 ± 3.7	0.694
Total score	17.5 ± 6	16 ± 7	0.28	17.4 ± 5.9	16.3 ± 7.6	14.3 ± 7.3	0.313

2.4. Hospital Anxiety and Depression Scale

The HADS (Hospital Anxiety and Depression Scale) was used to differentiate whether the palpitation was arrhythmic or psychological [10,11]. Surveys with standard questions were given to patients before EPS. Ninety-one of 119 participants accepted the HADS questionnaire and surveyed. The psychiatrist evaluated the answers to the HADS questionnaire and rated the patient's anxiety and depression scores.

2.5. Statistical Analysis

Continuous variables were presented as mean ± standard deviation, and categorical variables were presented as percentages. The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov−Smirnov/Shapiro−Wilk's test) to determine whether or not the data are normally distributed. The Student t-test was used to compare these parameters among the inducible arrhythmia groups. The Mann−Whitney U-test tests were used for non-normally distributed data. A p-value of less than 0.05 was considered to show a statistically significant result. Cross-tabulations were used for comparison of the proportions of patients with categorical variables. The Chi-square or Fisher's exact test (when chi-square test assumptions do not hold due to low expected cell counts) was used to compare in different groups. A p-value of less than 0.05 was considered to show a statistically significant result. Statistical analyses were performed using the SPSS software (Version 14.0, SPSS, Inc., Chicago, IL).

3. Results

Patients were divided into two groups according to SVT inducibility. Supraventricular tachycardia was induced in 66 (55%) of 119 patients. Most of the patients were women (60%) and there was no difference in demographic characteristics of the groups (Table 1).

In SVT induced group, 52 of them had AVNRT, 11 had atrial tachycardia, and three had AVRT. Seventy-four patients underwent ablation during the EPS procedure and successful ablation was achieved in 70 of them. In eight patients with non-inducible arrhythmia, due to documented SVT and complain of palpitation, slow pathway ablation was performed as a result of EPS findings (jump, etc.).

Atropine administration (p = 0.001) was higher and Wenckebach cycle length (p < 0.001) was longer in patients with non-induced arrhythmia group. Presence of dual AV node pathway was higher in SVT induced group (p = 0.002) (Table 2).

Anxiety score, depression score, and total psychiatric results were similar between the groups (Table

Table 4. Palpipation characteristics data of both groups.

	Inducible arrhythmia (n = 66)	Non-inducible arrhythmia (n = 53)	p value
Sudden onset palpitation n (%)	39 (51.9)	24 (45.3)	0.134
Sudden offset palpitation n (%)	25 (37.9)	17 (32.1)	0.510
Palpitation duration<5 min, n (%)	32 (48.5)	37 (69.8)	**0.048**
Palpitation duration ≥5 min, n (%)	36 (51.5)	16 (30.2)	
Palpitation spread to neck,n (%)	32 (48.5)	12 (22.6)	**0.004**
Responsiveness to medication, n (%)	29 (43.9)	11 (20.8)	**0.008**
Responsiveness to vagal maneuvers, n (%)	10 (15.2)	5 (9.4)	0.350
Syncope,n (%)	20 (30.3)	16 (30.2)	0.989
Documented supraventricular tachycardia, n (%)	47 (71.2)	26 (49.1)	**0.017**
Admission to emergency, n (%)	46 (69.7)	24 (45.3)	**0.007**
Stress* induced, n (%)	39 (59.1)	20 (37.7)	**0.021**
Regularity of palpitation, n (%)	26 (39.4)	13 (24.4)	0.086

Palpitation complaint triggered by emotional or physical stress.
Bold numbers show statistical significance.

Table 5. Arrhythmia inducibility prediction score (AİPScore).

	Score
Palpitation duration >5 mn	1
Palpitation spread to neck	1
Responsiveness to medication	1
Documented supraventricular tachycardia	1
Admission to emergency	1
Stress induced	1
Total	6

3). Duration of palpitation (p = 0.048), spreading of palpitation to neck (p = 0.004), response to medication (p = 0.008), documented SVT (p = 0.017), history of admission to emergency (p = 0.021) and stress-triggered palpitation (p = 0.007) were more common in SVT induced group (Table 4).

We created a scoring to predict the inducible SVT with parameters significant in terms of palpitation characteristics (Table 5). Scoring was arranged to be a minimum of zero and a maximum of six points. Induction of SVT was statistically high in patients scoring four or over (Table 6). The sensitivity of the scoring was 63.6%, and specificity was 92.5% for inducing SVT. The sensitivity of arrhythmia induction of patients with Arrhythmia Inducibility Prediction Score (AIPS) ≥2 was 65.3%, and specificity was 59.6%, while the sensitivity of patients with AIPS ≥4 was 63.6%, and specificity was 92.5%. Succesfull ablation for patients with AIPS ≥4 was 82.1%, while it was 69.4% for patients with AIPS ≥2. We can emphasize that the higher the AIPS, the better the specificity of SVT induction and performing ablation (Table 7).

4. Discussion

Characteristics of the palpitation such as duration >5 min, spreading to the neck, responsiveness to medication, documentation, triggering with stress were significantly more common in SVT induced group. As a result of the scoring consisted of using these criteria, score of four or over predicted SVT induction with 63.6% sensitivity and 92.5% specificity and predicted successful ablation with 82.1%. As the AIPS increased, the specificity of SVT induction and the necessity of ablation increased. Although our study patients had recurrent hospital

Table 6. Arrhythmia Inducibility Prediction Score (AİPScore) data of all patients.

	Inducible arrhythmia (n = 66)	Non-inducible arrhythmia (n = 53)	p value
AIPScore <4	24 (36.4)	49 (92.5)	0.001
AIPScore ≥4	42 (63.6)	4 (7.5)	
AIPScore	3.9 ± 1.9	1.98 ± 1.9	<0.001

admissions due to palpitations, our SVT induction rates lagged behind the literature (55 vs. 90%) [4]. We think that this group of patients we often encounter in the clinic may reflect the real-world data. The current study demonstrates the importance of careful questioning of the palpitation characteristics when selecting patients for EPS. This result is revealed in the literature for the first time.

Many studies have tried to reveal the clinical features of PSVT. Mayou et al. showed that the duration of palpitation and intense physical activity had a relationship with arrhythmia [12]. Bunch et al. demonstrated that the incidence of atrial arrhythmia increased with exercise [13]. In the present study, exercise and emotional stress appeared to be related with SVT induction. The relation was likely due to increased adrenergic stimulation with exercise and emotional stress [14].

Documented PSVT is one of the essential clinical basis for EPS [15]. However, documentation alone may not identify patients who can be treated by RFA. Previous research in our clinic revealed the importance of palpitation characteristics. In the study mentioned above, arrhythmia induction and RFA rates were found to be similar in patients with clinical PSVT to patients with documented PSVT [8]. In the present study, sudden onset and end of a palpitation, response to vagal maneuver, and regularity were found to be more frequent in the SVT induced group, but there was no statistical significance. The presence of documented PSVT did not reach a significancy in patients with induced SVT, but it tended to be common in this group (Table 1). Although the two clinical trials show a statistical inconsistency, the results support each other. This difference seems to be related to the number of patients included and the demographic characteristics.

Gonzalez-Torrecilla et al. found that age, female gender, and neck palpitation had a relationship with AVNRT induction in patients who underwent EPS procedure. However, only the neck palpitation was an independent predictor for AVNRT [16]. Laurent et al. confirmed the association of neck palpitation frequency with AVNRT [17]. In the current study, the palpitation spread to the neck was correlated to the induction of SVT, and the result was consistent with the other studies.

Psychiatric or cardiac causes may cause palpitation complaints [7]. Various psychiatric scoring systems have been established besides routine examinations to test whether the symptoms of palpitations are psychiatric or cardiac. One of these scoring systems is the Hospital Anxiety and Depression Scale (HADS), which guides on whether patient's current complaints are based on an organic

Table 7. Arrhythmia Inducibility Prediction Score (AIPScore) data of both groups.

	Documented SVT			Undocumented SVT			Total		
	Inducible arrhythmia (n = 47)	Non-inducible arrhythmia (n = 26)	P value	Inducible arrhythmia (n = 19)	Non-inducible arrhythmia (n = 27)	P value	Inducible arrhythmia (n = 19)	Non-inducible arrhythmia (n = 27)	p value
AIPScore<2	12 (63.2)	7 (36.8)	0.897	7 (25)	21 (75)	0.005	19 (40.4)	28 (59.6)	0.001
AIPScore ≥2	35 (64.8)	19 (35.2)		12 (66.6)	6 (33.3)		47 (65.3)	25 (34.7)	
AIPScore<4	28 (56)	22 (44)	0.027	14 (34.1)	27 (65.9)	0.005	24 (36.4)	49 (92.5)	0.001
AIPScore ≥4	19 (82.6)	4 (17.4)		5 (100)	0		42 (63.6)	4 (7.5)	

	Successful ablation (n = 51)	No or Unsuccessful ablation (n = 22)	p value	Successful ablation (n = 19)	No or Unsuccessful ablation (n = 27)	p value	Successful ablation (n = 70)	No or Unsuccessful ablation (n = 49)	p value
AIPScore<2	12 (63.2)	7 (36.8)	0.459	8 (28.6)	20 (71.4)	0.029	20 (42.6)	27 (57.4)	0.004
AIPScore ≥2	39 (72.2)	15 (27.8)		11 (61.1)	7 (38.9)		50 (69.4)	22 (30.6)	
AIPScore<4	33 (66)	17 (34)	0.289	14 (34.1)	27 (65.9)	0.005	47 (51.6)	44 (48.4)	0.004
AIPScore ≥4	18 (78.3)	5 (21.7)		5 (100)	0		23 (82.1)	5 (17.9)	

cause.[10] In a review of 747 studies, HADS performed efficiently in evaluating the severity of anxiety disorders and depression in both somatic and psychiatric cases.[11] Kitzlerová et al. found no difference in psychiatric measures evaluating anxiety and depression in a study comparing healthy subjects with PSVT patients [18]. In the present study, the anxiety and depression score obtained as a result of the HADS questionnaire was similar in both groups, as the stated study.

Lessmeier et al. reported that panic attack-like symptoms could mask arrhythmia in patients with PSVT attacks, and this might cause a missed diagnosis [19]. Eaker et al. showed the association of anxiety and depression with atrial fibrillation (AF) occurrence [20]. Lange et al. observed that relapse was more familiar with depressive symptoms during follow-up of patients who underwent cardioversion for AF [21]. Özlü et al. reported that for patients who underwent EPS due to non-documented palpitation, arrhythmia induction correlated with low quality of life and high anxiety levels [11]. In all these studies, psychiatric symptoms had association with arrhythmia. In the present study, the anxiety and depression score was statistically similar between the groups. The reason for the contradiction might be that all patients did not participate in the psychiatric questionnaire. Studies have shown that atrioventricular refractory cycle length (Wenckebach cycle) has an inverse relationship with arrhythmia induction in EPS [22]. Our findings support this result.

Although RFA has a low complication and high success rate, patients with documented arrhythmia are preferred in the indication process of PSVT. This may be due to the economic cost of the procedure and the concern of cardiologists for making unnecessary interventional procedures. The induction of SVT plays a critical role in successful ablation, and the general thought is that the induction of patients with documented PSVT will be easier, and ablation will be more successful. However, this approach may lead to insufficient treatment in patients with non-documentable PSVT. Although used in routine clinics, the rate of detecting arrhythmia by rhythm Holter is low in patients presenting with palpitations [23,24]. The results of the study are essential to show the role of the data obtained from the anamnesis. The AIPS may play an active role in identifying patients who will benefit from EPS or RFA. Given the limited number of patients, large patient-volumed trials can make this scoring system more sensitive and specific. Thus, patients with non-documented PSVT can be more accurately detected and treated based on their symptoms.

5. Limitation

A relatively small number of patients is the main limitation. Some patients did not accept a psychiatric questionnaire. Isoproterenol is often used to induce arrhythmia. That isoproterenol could not be used in the study might have resulted in a lower rate of SVT induction. Furthermore, the presence of AVRT in a small proportion of induced SVT makes it inadequate to demonstrate the efficacy of AIPS in this condition. Additionally, poor sensitivity of low scores (<4) may weaken the use of AIPS in the clinic. Further studies are needed to check and improve the accuracy of the results.

6. Conclusion

Palpitation duration >5 min, palpitation spreading to the neck, responsiveness of arrhythmia to medication, documented SVT, stress-triggered palpitation were more common in the SVT induced group. As a result of the scoring formulated by using these criteria, the score of four or over predicted SVT induction with 63.6% sensitivity and 92.5% specificity and predicted the successful ablation with 82.1%. The scoring system can help in the decision to perform EPS. Before the present data are used in clinical practice, they need to be ascertained by independent investigators in other cohorts with similar characteristics.

Disclosure of any conflict of interest

We declare no conflict of interest.

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