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ORIGINAL RESEARCH

A Clinical Score for Predicting the Paroxysmal Supraventricular Tachycardia's Recurrence Risk; a Retrospective Cross-sectional Study

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Abstract: **Introduction:** Identifying prognostic variables associated with the probability of recurrent paroxysmal supraventricular tachycardia (PSVT) would aid decision-making regarding disposition of the patients. This study aims to develop a clinical scoring system to predict PSVT recurrence after adenosine administration in the emergency department (ED). **Methods:** This retrospective cross-sectional study was conducted on patients who were referred to the emergency department of Ramathibodi Hospital, a university-affiliated super-tertiary care hospital in Bangkok, Thailand, with diagnosis of PSVT during a 10-year period from 01 January 2010 until 31 December 2020. The cases were divided into recurrent and non-recurrent PSVT based on the response to standard treatment and the independent predictors of recurrence were studied using multivariable logistic regression analysis. **Results:** 264 patients were diagnosed with PSVT and successfully converted by adenosine. 24 (9.1%) had recurrent PSVT, and 240 (90.9%) had no recurrent PSVT in the same ED visit. The risk of PSVT recurrence in ED corresponded with the history of hypertension ($p = 0.059$), valvular heart disease ($p = 0.052$), heart rate ≥ 100 ($p = 0.012$), and systolic blood pressure < 100 after electrocardiogram (ECG) converted to sinus rhythm ($p = 0.022$) and total dose of adenosine ($p = 0.002$). We developed a clinical prediction score of PSVT recurrence with an accuracy of 79.5%. A score of 0 (low risk), 1–2 (moderate risk), and > 2 (high risk) had a positive likelihood ratio (LR+) of 0.31, 0.56 and 2.33, respectively. **Conclusion:** It seems that, using the PSVT recurrence score we could screen the high-risk patients for PSVT recurrence (score>2) who need to be observed for at least 6-12 hours and receive cardiologist consultation in ED. In addition, the moderate and low-risk group (score 0-2) need to be observed for 1 hour and can be discharged from ED.

Keywords: Tachycardia, Supraventricular; Recurrence; Emergency Service, Hospital; Adenosine; Clinical Decision Rules

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1. Introduction

Supraventricular tachycardia (SVT) is defined as atrial and ventricular rates exceeding 100 beats per minute (bpm) at rest. Its mechanism involves tissue from the His bundle or above (1, 2). SVT, which includes atrioventricular nodal reentrant tachycardia (AVNRT), atrioventricular reentrant tachycardia (AVRT), and atrial tachycardia (AT), is a common tachyarrhythmia that causes approximately 50,000 emergency department (ED) visits annually in the United States of America (3).

Paroxysmal supraventricular tachycardia (PSVT) is a clinical syndrome characterized by the presence of a narrow QRS complex, regular, and tachycardic electrocardiograph with abrupt onset and termination (1). The diagnosis and treatment of PSVT are often made in the emergency department (ED). Adenosine has been commonly used as a diagnostic and therapeutic agent for PSVT since the 1990s (4, 5).

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According to the international guidelines for managing SVT by the American Heart Association (AHA) and the European Society of Cardiology (ESC), adenosine is still recommended as a first-line treatment option for subjects with hemodynamically stable SVT (2, 6). An initial dose of 6 mg should be administered intravenously over 1-2 seconds, then the second dose of 12 mg can be repeated once if there is no response within 1-2 minutes (1). Efficacy of initial and repeat dose of adenosine on sinus rhythm conversion reported by previous studies is approximately 90% (7).

Although adenosine yields high efficacy on sinus rhythm conversion and nearly half of SVT patients were discharged from the ED without clinical follow-up (3), two observational studies revealed that the number of ED revisits due to recurrent PSVT was approximately 30%, with total number of revisits ranging from 70-90 times over three years (8, 9). Identifying prognostic variables associated with the probability of recurrent PSVT after adenosine administration would aid the clinicians in deciding to hospitalize or discharge the patient. This strategy may reduce ED overcrowding, unnecessary resource utilization, and complications related to unsuitable management (9, 10).

Previous studies have found that older patients, those with diabetes, cardiovascular diseases, or illicit drug use, and those with heart rates more than 200 bpm before treatment have a higher probability of PSVT recurrence after adenosine administration (8, 9, 11, 12). However, there have been no prediction tools to assess the probability of recurrent PSVT. Immediately discharging the patient after a successful conversion with adenosine is a challenging decision for the emergency physicians. There is no clinical prediction score to predict the recurrence of PSVT after a successful conversion with adenosine and facilitating judgment regarding patient disposition. In groups with low risk of recurrence, we hypothesized that we could immediately discharge the patient from ED. This study aims to develop a clinical scoring to predict PSVT recurrence after adenosine administration in the ED.

2. Methods

2.1. Study design and settings

This retrospective cross-sectional study was conducted on patients who were referred to the emergency department of Ramathibodi Hospital, a university-affiliated super-tertiary care hospital in Bangkok, Thailand, with diagnosis of PSVT during a 10-year period from 01 January 2010 until 31 December 2020. The cases were divided into recurrent and non-recurrent PSVT based on the response to standard treatment and the independent predictors of recurrence were studied using multivariate analysis. This study was approved by the Faculty of Medicine, Committee on Human Rights Related to Research Involving Human Subjects, Ramathibodi Hospital, Mahidol University (COA. NO MURA2021/463). The ethics committee waived obtaining consent for this research as the patients' medical records were used for data gathering, and a statement covering patient data confidentiality and compliance with the Declaration of Helsinki was provided.

2.2. Participants

Patients with the final diagnosis of supraventricular tachycardia (based on ICD-10 I -471 definition) in the hospital database and Emergency Medical Record (EMR) were included. Patients were included if they were aged >15 years, visited the emergency department with the diagnosis of PSVT, and converted with adenosine in ED. The exclusion criteria were PSVT not responding to adenosine or patients having a concurrent medical disease requiring admission.

2.3. Data gathering

The study variables were recorded for all eligible patients, including the baseline characteristics and potential prognostic factors for recurrent PSVT. Clinical variables included gender, age, vital signs (heart rate, systolic blood pressure before receiving adenosine and after conversion to normal sinus rhythm), underlying diseases (history of hypertension, diabetes mellitus, coronary artery disease, congestive heart failure, dyslipidemia, and cardiac arrhythmia), clinical symptoms (chest pain, syncope, and palpitations), tobacco use, Illicit drug use, previous treatment with the antiarrhythmic agent, the dose of adenosine used for treatment, and time to recurrence in the same visit. Recurrent PSVT was defined as the new onset of PSVT after being successfully converted to normal sinus rhythm using adenosine in the same ED visit.

2.4. Outcome measures

The outcome of interest was that PSVT failed to respond to adenosine in the first, second, or third dose of adenosine in ED. We defined "the recurrence group" as the patients whose transient response to adenosine and return to normal sinus rhythm on electrocardiogram was converted to PSVT during the same ED visit. The non-recurrence group includes the patients who responded to adenosine in the first, second, or third dose, and electrocardiogram did not convert to PSVT in the same visit to ED.

2.5. PSVT management

All PSVT patients received 6 mg of adenosine using a double syringe technique (bolus adenosine via a large peripheral vein immediately followed by 10 mL of saline flush) during electrocardiogram (ECG) monitoring. If the ECG converted to normal sinus rhythm, the patient was sent for 6-12 hours of observation with laboratory blood testing in an observational area in ED. Otherwise, the PSVT patient who did not

respond to the first dose of adenosine (within 10 seconds) received the second dose of 12 mg. If the ECG converted to normal sinus rhythm, the patient was sent for 6-12 hours of observation with laboratory blood testing in an observational area in ED.

Furthermore, the PSVT patient who did not respond to the second dose of 12 mg adenosine (within 10 seconds) received the third dose of 12 mg. If the ECG converted to normal sinus rhythm, the patient was sent for 6-12 hours of observation with laboratory blood testing in an observational area in ED. The patients who did not respond to a total of three doses of adenosine were sent to cardiologist consultation and were not included in our study.

After 6-12 hours of observation, the patients who did not have a recurrence of PSVT were discharged and given an appointment for radiofrequency catheter ablation with the cardiologist. The patients who had recurrent PSVT during the observation received cardiologist consultation for in-patient care.

2.6. Statistical analysis

We used STATA version 16.0 (StataCorp, College Station, TX, USA) to calculate the sample size. A pilot study was performed to determine the rates of recurrent PSVT and non-recurrent PSVT. The assumptions were as follows: alpha = 0.05 (two-sided test), power of sample size = 0.8, and the ratio of sample size was 1:10. The sample size of 180 was obtained in the non-recurrent PSVT group, and the sample size of 18 was calculated for the recurrent PSVT group.

The data were analyzed using STATA version 16.0. The continuous data are presented as mean (standard deviation) or median (interquartile range), and categorical data are presented as frequency (%). All study variables were compared between recurrent and non-recurrent PSVT using the exact probability test for categorical variables and the t-test for continuous variables. We used the univariable logistic regression to discriminate variables corresponding to recurrence of PSVT and reported the results using P-value, the area under the receiver operating characteristic curve (AuROC), and 95% confidence interval (CI).

Clinical predictors with high discriminative performance, statistical significance, and clinical relevance were analyzed using multivariable logistic regression and reported with odds ratios. The coefficients for each level of clinical predictor were divided by the smallest coefficient of the model and rounded to the nearest 0.5, resulting in an item risk score.

The coefficients were changed into item scores and added together resulting in a single score, and patients were classified into low-, moderate-, and high-risk groups according to this score and results were presented as positive likelihood ratio, 95% CI, and p-value.

Discrimination of the prediction scores was presented as AuROC and 95% CI. Calibration of the prediction was tested using Hosmer–Lemeshow goodness-of-fit test. The score-predicted risk of recurrent PSVT and the observed risk were then compared in a graph.

3. Results

3.1. Baseline characteristics of studied cases

264 patients diagnosed with PSVT who underwent treatment with adenosine in ED were enrolled in the study. 24 (9.1%) had recurrent PSVT in the same ED visit. Based on the univariable logistic regression analysis, history of hypertension (AuROC= 59%, 95%CI: 49% - 70%, p = 0.059), history of valvular heart disease (AuROC= 55%, 95%CI: 48% - 62%, p = 0.052), heart rate ≥ 100 after ECG converted to sinus rhythm (AuROC= 63%, 95%CI: 53% - 74%, p = 0.012), systolic blood pressure < 100 after ECG converted to sinus rhythm (AuROC= 57%, 95%CI: 49% - 64%, p = 0.022), and need for full dose of adenosine (AuROC= 67%, 95%CI: 56%- 78%, p = 0.002) had high discriminative performance (AuROC) and were significantly and clinically associated with recurrent PSVT (Table 1).

3.2. Multivariable logistic regression analysis

Multivariable logistic regression analysis included the five prognostic factors form table 1 to predict recurrence of PSVT in ED (Table 2). Based on multivariable logistic regression analysis, history of hypertension (OR=2.36, 95% CI: 0.92 - 6.05, p=0.074), history of valvular heart disease (OR=4.62, 95% CI: 0.97 - 22.03, p=0.055), heart rate ≥ 100 after ECG converted to sinus rhythm (OR=3.68, 95% CI: 1.44 - 9.35, p=0.006), systolic blood pressure < 100 after ECG converted to sinus rhythm (OR=4.73, 95% CI: 1.08 - 20.85, p=0.040) and need for full dose of adenosine (2^{nd} dose of 12 mg adenosine OR=3.66, 95% CI: 1.24 - 10.80, p=0.019 and 3^{rd} dose of 12 mg adenosine OR=3.65, 95% CI: 1.11 - 12.04, p=0.034) were independent predictors of PSVT recurrence. The AuROC was 79.5% (95% CI: 64.5%- 85.5%) for the ability of the clinical risk score to predict recurrent PSVT (Figure 1).

3.3. Designing a predictive model

The coefficients for each level of clinical predictor were divided by the smallest coefficient of the model and rounded to the nearest 0.5, resulting in an item risk score, with scores ranging from 0 to 2 (Table 2). Figure 2 shows the distribution plot of the score in predicting recurrent PSVT and the calibration of the prediction model using the Hosmer–Lemeshow goodness-of-fit test. The score-predicted risk of recurrent PSVT and the observed risk were then compared in a graph. The score-predicted risk increased in close association with the observed risk.

Finally, the risk scores were categorized into three groups:

Table 1: Comparing the baseline characteristics of studied cases between patients with and without recurrent paroxysmal supraventricular tachycardia (PSVT)

Variable	Recurrent PSVT		P	AUC	95%CI
	Yes (n = 24)	No (n = 240)			
Gender					
Female	13 (54.2)	162 (67.5)	0.138	0.43	0.33 - 0.54
Age (year)					
Mean ± SD	56.7 ± 17.2	52.3 ± 16.7	0.215	0.59	0.47 - 0.72
BMI					
Mean ± SD	23.52 ± 5.00	24.72 ± 6.39	0.372	0.44	0.30 – 0.58
Vital signs (baseline)					
HR (/minute)	181.4 ± 19.7	176.9 ± 21.2	0.319	0.57	0.46 - 0.69
SBP (mmHg)	131.6 ± 27.7	124.9 ± 22.1	0.165	0.56	0.43 - 0.70
Vital signs (after conversion)					
HR (/minute)	103.6 ± 14.2	93.6 ± 14.8	0.002	0.69	0.57 - 0.80
HR ≥ 100 (/min)	15 (62.5)	87 (36.3)	0.012	0.63	0.53 - 0.74
SBP (mmHg)	131.9 ± 24.1	127.1 ± 20.7	0.291	0.57	0.43 - 0.71
SBP < 100 mmHg	20 (83.3)	231 (96.3)	0.022	0.57	0.49 - 0.64
Underlying disease					
HT	12 (50.0)	76 (31.67)	0.059	0.59	0.49 - 0.70
DM	7 (29.17)	47 (19.58)	0.196	0.55	0.45 - 0.64
SVT	12 (50.0)	109 (45.42)	0.413	0.52	0.42 - 0.63
CAD	2 (8.33)	20 (8.33)	0.618	0.50	0.44 - 0.56
Paroxysmal AF	2 (8.33)	8 (3.33)	0.228	0.53	0.47 - 0.58
History of VHD	3 (12.5)	7 (2.92)	0.052	0.55	0.48 - 0.62
Thyroid disease	3 (12.5)	14 (5.83)	0.192	0.53	0.46 - 0.60
CHF	0 (0.0)	1 (0.42)	0.909	0.50	0.49 - 0.50
Antiarrhythmic drug	13 (54.17)	86 (35.83)	0.063	0.60	0.49 - 0.70
Chest pain	1 (4.17)	29 (12.08)	0.211	0.46	0.42 - 0.51
Syncope	2 (8.33)	17 (7.08)	0.534	0.51	0.45 - 0.57
Palpitations	23 (95.83)	230 (95.83)	0.657	0.50	0.46 - 0.54
SVT ablation	4 (16.67)	20 (8.33)	0.160	0.54	0.46 - 0.62
Adenosine					
1^{st} dose	10 (41.67)	181 (75.42)	0.002	0.67	0.56 - 0.78
2^{nd} dose	8 (33.33)	35 (14.58)			
3^{rd} dose	6 (25.00)	24 (10.00)			

Data are presented as mean ± standard deviation (SD) or frequency (%). AUC: area under the receiver operating characteristic (ROC) curve as discrimination power; CI: confidence interval. HR: heart rate; SBP: systolic blood pressure; BMI: body mass index; HT: hypertension; VHD: valvular heart disease; DM: diabetes mellitus; SVT: supraventricular tachycardia; CAD: coronary artery disease; AF: atrial fibrillation; CHF: congestive heart failure.

score =0 (low risk), score 1–2 (moderate risk), and score >2 (high risk). The mean score of patients with recurrent PSVT was significantly higher (2.90 ± 1.58 vs. 1.26 ± 1.18; p < 0.001). The positive likelihood ratio of recurrent PSVT in low-, moderate-, and high-risk cases for recurrence were 0.31, 0.56, and 2.53, respectively (Table 3).

4. Discussion

This study demonstrated that the independent predictive factors of recurrent PSVT were history of hypertension (1 point), history of valvular heart disease (2 points), heart rate ≥ 100 after conversion to sinus rhythm (1.5 points), systolic blood pressure < 100 after conversion to sinus rhythm (2 points), and second or third dose of adenosine (1.5 points).

The PSVT patient was categorized as high-risk (score>2), with a positive likelihood ratio of recurrent PSVT in the same ED visit of 2.33. There is a high risk of PSVT recurrence in ED. More than half of patients in this group (53%) had recurrence within 1 hour, and 47% had recurrence within 2-19 hours. These patients need to be admitted and remain under observation for at least 6-12 hours and receive cardiologist consultation for radiofrequency catheter ablation consideration during the same visit due to PSVT presentation.

The PSVT patient was categorized as low-risk (score =0) and moderate-risk (score 1-2) with a positive likelihood ratio of recurrent PSVT of 0.31 and 0.56, respectively. (Only two patients were in the low-risk group and five in the moderate-risk group). These groups of patients must remain under

Table 2: The independent predictors of recurrent paroxysmal supraventricular tachycardia (PSVT) and the assigned item score based on multivariable logistic regression

Predictors	Adjusted OR	95%CI	p-value	Coefficient*	Score
History of HT					
No	1.00	reference	-	-	0
Yes	2.36	0.92 – 6.05	0.074	0.86	1
History of VHD					
No	1.00	reference	-	-	0
Yes	4.62	0.97 – 22.03	0.055	1.53	2
HR ≥ 100 (mmHg)#					
No	1.00	reference	-	-	0
Yes	3.68	1.44 – 9.35	0.006	1.30	1.5
SBP < 100 (mmHg)#					
No	1.00	reference	-	-	0
Yes	4.73	1.08 – 20.85	0.040	1.55	2
Adenosine dose					
1^{st}	1.0	reference	-	-	0
2^{nd}	3.66	1.24 – 10.80	0.019	1.30	1.5
3^{rd}	3.65	1.11 - 12.04	0.034	1.30	1.5

After conversion to sinus rhythm; * Coefficients from multivariable logistic regression. OR: odds ratio;
VHD: valvular heart disease; HT: hypertension; HR: heart rate; SBP: systolic blood pressure; CI: confidence interval.

Table 3: Likelihood of recurrent paroxysmal supraventricular tachycardia (PSVT) in different probability categories based on the scores of the designed prediction scoring system

Probability categories	Score	Recurrent PSVT		LR+	95%CI	P
		Yes (n = 24)	No (n = 240)			
Low	0	2 (8.4)	80 (33.3)	0.31	0.08 – 1.18	0.031
Moderate	1-2	5 (20.8)	108 (45.0)	0.56	0.25 - 1.25	0.085
High	> 2	17 (70.8)	52 (21.7)	2.33	1.50 - 3.61	0.001

Data are presented as frequency (%).LR+: positive likelihood ratio; CI: confidence interval.

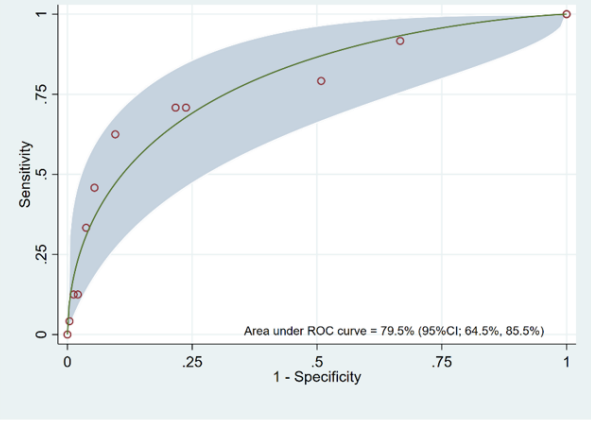

Figure 1: The area under the receiver operating characteristic (ROC) curve of the designed clinical risk score in predicting the risk of recurrent paroxysmal supraventricular tachycardia (PSVT).

observation in ED for at least 1 hour, be considered for discharge, and make an appointment with the cardiologist for follow-up.

Patients categorized as low- and moderate-risk can be discharged from ED. In this study, 90.9 % of PSVT cases could be discharged after 1-hour observation in ED. It is in concordance with the study of Luber et al., which showed that 71% of patients were discharged from the ED (11). Sawhney et al. showed that only 34% of patients had specialist referrals (13). The study of Honarbakhsh et al. showed that paramedics could successfully treat PSVT (81%) in the prehospital setting and reduce healthcare costs for transfer to ED (discharge at the prehospital setting) without compromising patient care (14).

The treatment of choice for PSVT is slow pathway modification (SPM). In this study, the success rate of adenosine administration was 100%. A study by Wegner et al. showed around 95% success using adenosine (15).

The prognostic factors' effect on the recurrence of PSVT in this study is concordant with the study of Piyanuttapull et al. about the recurrence of PSVT within 90 days, low systolic blood pressure (SBP < 90 mmHg) and valvular heart disease were associated with recurrence of PSVT (8). In this study, we also found that heart rate ≥ 100 and systolic blood pressure

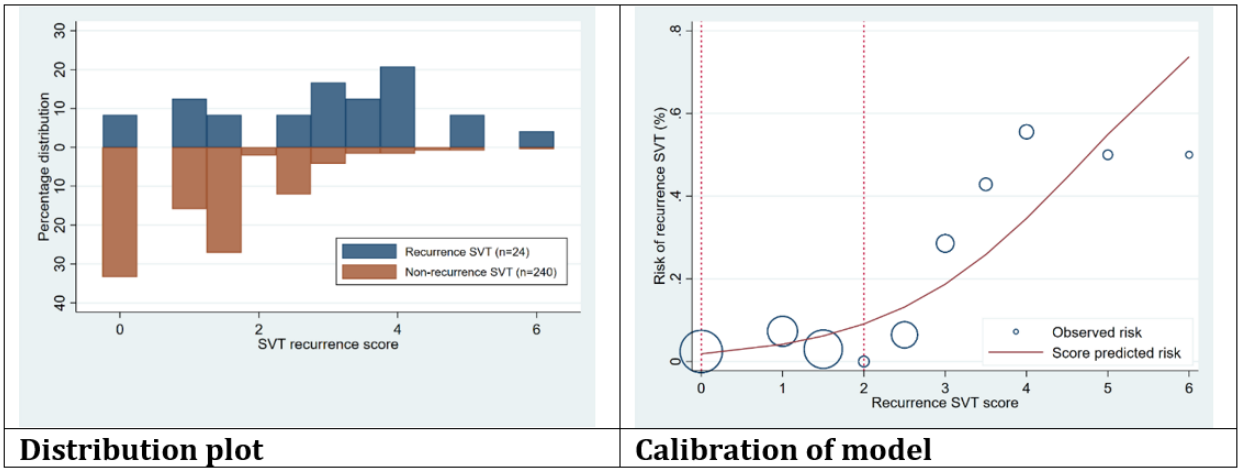

Figure 2: Distribution plot of recurrent paroxysmal supraventricular tachycardia (PSVT) based on the designed scoring system and the calibration curve of the prediction model using the Hosmer–Lemeshow goodness-of-fit test.

< 100 after ECG converted to sinus rhythm and the total dose of adenosine were associated with recurrence of PSVT. There is no result about this prognostic factor in other studies.

In the low- and moderate-risk groups for PSVT recurrence, the emergency physician can discharge the patient after 1 hour of observation in ED instead of 6-12 hours following the old Ramathibodi PSVT protocol. The new protocol can reduce ED overcrowding, resource utilization in ED, and overall healthcare costs in ED. The study by Thomas A. Dewland et al. showed that PSVT patients treated with catheter ablation had a significantly lower PSVT recurrence rate in ED (HR= 0.25, 95% CI: 0.10-0.62, p = 0.003) (9). The new protocol should include cardiologist consultation for catheter ablation to reduce ED revisit.

The strength of our model is predicting PSVT recurrence in the same ED visit for selecting the patients requiring disposition. The other existing model focuses on the recurrence of PSVT within 90 days and not the same ED visit.

5. Limitation

This study has some limitations. First, this was a retrospective study. There is reviewer bias in reviewing the data of emergency medical records. Some missing data affected the accuracy of the study. Second is the limitation in the number of patients in the recurrent group (n=24). It is a small sample size but enough to have statistically significant power. Third, this study was conducted in Ramathibodi hospital, and internally validated within the same dataset. External validation with different datasets may be required for the next project.

6. Conclusion

It seems that, using the PSVT recurrence score we could screen the high-risk patients for PSVT recurrence (score>2) who need to be observed for at least 6-12 hours and receive cardiologist consultation in ED. In addition, the moderate- and low-risk groups (score 0-2) need to be observed for 1 hour and can be discharged from ED.

7. Declarations

7.1. Acknowledgments

Not applicable.

7.2. Funding Source

No funding was obtained for this study.

7.3. Authors' contribution

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

7.4. Ethical considerations

This study was approved by the Faculty of Medicine, Committee on Human Rights Related to Research Involving Human Subjects, Ramathibodi Hospital, Mahidol University (COA. MURA2021/463). The ethics committee did not require consent for this research because medical records were reviewed and a statement covering patient data confidentiality and compliance with the Declaration of Helsinki was provided.

7.5. Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

7.6. Conflict of interest

The authors declare that they have no competing interests.

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