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ORIGINAL RESEARCH

Different Resuscitation Termination Criteria for Out of Hospital Cardiac Arrest; A Prognostic Accuracy Study

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Abstract: **Introduction:** Termination of resuscitation (TOR) rules in out of hospital cardiac arrest (OHCA) varies across different healthcare settings and populations. This study aimed to externally validate ten TOR rules for predicting death before hospital admission among OHCA patients. **Methods:** A retrospective prognostic accuracy study analyzed 379 non-trauma OHCA patients (≥18 years) in Bangkok who were either treated by the emergency medical services (EMS) of Ramathibodi Hospital or transported to Ramathibodi's emergency department by another EMS provider (January 2010 - March 2023). The predictive performance of ten TOR rules (AHA-BLS, AHA-ALS, Korean Cardiac Arrest Research Consortium (KoCARC) rules I, II, and III, Goto's rule, Shihabashi's rule, the New Model I, Helsinki's, and Petrie's rule) in predicting death before hospital admission as well as false positive rates (FPRs) of rules at various resuscitation times were calculated and reported with 95% confidence interval (CI). **Results:** Among 379 OHCA patients, 308 (81.27%) died before hospital admission and 71 (18.73%) survived to discharge. The New model I demonstrated the most conservative predictive performance with sensitivity of 96.7% (95% CI: 93.0-98.8), NPV of 91.5% (95% CI: 82.5-96.8), and area under the curve (AUC) of 0.74 (95% CI: 0.70-0.79). The KoCARC III showed FPR of 2.8%. Based on the initial presenting criteria, the FPR varied at different resuscitation time points, with increasing FPR over 30 minutes. Among all rules, Helsinki's and AHA-BLS showed the highest FPRs (1.14 – 21.13 and 1.14 – 23.94, respectively) while the KoCARC TOR rules III demonstrated the most conservative consistency in maintaining a low FPR (0-2.82%) throughout time. **Conclusion:** The KoCARC III demonstrated relatively high safety for TOR decisions in Bangkok's OHCA population, with the lowest FPR, and high sensitivity and NPV. TOR rules showed higher FPRs compared to previous studies. These findings should be interpreted with caution due to the retrospective design, potential selection bias, and EMS protocol changes over the 10-year study period.

Keywords: Out-of-Hospital Cardiac Arrest; Resuscitation; Emergency medical services; Guideline

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1. Introduction

Termination of resuscitation (TOR) requires balancing potential benefits against medically futile interventions in cardiac arrest patients (1, 2). The purpose of resuscitation is to ensure survival with optimal neurological function and enable a return to an acceptable quality of life, preserving the patient's capacity to engage in activities of daily living to the greatest extent possible (3). However, a substantial proportion of cardiac arrest cases are associated with a poor prognosis, rendering resuscitative interventions futile (4). Previous studies have demonstrated that out-of-hospital cardiac arrest (OHCA) patients demonstrate lower survival and favorable neurological outcomes compared to in-hospital cardiac arrest (IHCA) (5, 6).

The global incidence of OHCA ranged from 30.0 to 97.1 cases per 100,000 population, with survival rates varying from 3.1% to 20.4% and favorable neurological outcomes from 2.8% to 18.2% (7). The survival rates varied significantly across continents, with Asia having the lowest survival rates of all continents at 4.5% (8), influenced by population characteristics and emergency medical services (EMS) quality (9). In Thailand, the Pan-Asian Resuscitation Outcomes Study (PAROS) registry reported a 3.4% survival rate for OHCA patients between 2017-2020 (10).

Despite increasing success rates in resuscitation over the past decade due to EMS development, overall survival and favorable neurological outcomes remain low (11-13). Any OHCA resuscitation attempts are unsuccessful despite full efforts, resulting in high resource utilization. While Thailand's EMS system provides free services with the support of National Institute of Emergency Medicine (NIEM) (1,100 baht per case), this funding may be insufficient, creating resource allocation challenges and hindering long-term EMS system development in Thailand.

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Previous studies have identified factors associated with non-survival to establish termination of resuscitation (TOR) rules (11-15), aiming to reduce medical futility and optimize resource allocation for patients with a higher likelihood of survival. While TOR rules serve as decision-making guidelines, their application depends on operator judgment, experience, and unit protocols. The accuracy of TOR rules varies with patient factors, treatment approaches, and population characteristics (9, 16). Therefore, the International Liaison Committee on Resuscitation (ILCOR) Consensus on Science with Treatment Recommendations (CoSTR) recommends that each region adopt and externally validate TOR rules within their specific context (17).

The current EMS practice in Bangkok faces unique challenges due to regional factors such as extreme traffic congestion, limited EMS coverage in some areas leading to variable response times, differences in EMS training levels and protocols, and inconsistent rates of bystander CPR. These factors differ significantly from settings where most TOR rules were developed, potentially affecting both survival rates and the practical implementation of existing TOR rules in our context.

This study aimed to evaluate the screening performance of 10 TOR rules that can be applied in the prehospital setting for predicting death before hospital admission and analyze false positive rates across resuscitation time points in OHCA patients.

2. Methods

2.1. Study design and setting

This retrospective prognostic accuracy study was conducted on OHCA patients who were treated by the EMS or transported to the emergency department (ED) of Ramathibodi Hospital from January 2010 - March 2023. Patients were classified into two groups based on TOR criteria. Those who met all criteria of a selected rule were classified as 'Met all criteria,' indicating the rule would predict termination of resuscitation. Those who met only some criteria were classified as 'Did not fulfill,' suggesting continued resuscitation might offer a chance of survival. The accuracy of 10 TOR rules in predicting the risk of mortality in OHCA cases was studied.

The hospital is a tertiary medical institute in Bangkok, Thailand, which serves as an academic training center for multidisciplinary healthcare providers. EMS in Bangkok is coordinated and organized by the Erawan Center, which serves as the dispatch center accessible through the emergency number 1669. The emergency medical services are structured into three levels: Basic Life Support (BLS), led by emergency medical technicians (EMTs); Advanced Life Support (ALS), led by paramedics; and Comprehensive Life Support (CLS), led by comprehensive paramedics or emergency physician. The Erawan Center triages emergency calls by severity level to dispatch teams with appropriate capabilities: CLS teams respond to extremely critical emergencies, ALS teams respond to critical emergencies, and BLS teams handle urgent emergencies. RAMA-EMO was verified as a CLS team in 2023. For OHCA cases, BLS teams notify the dispatch center to request additional support from ALS or CLS teams.

In Thailand's EMS system, TOR protocols vary by provider level. BLS teams can terminate resuscitation efforts at the scene only if a patient shows obvious signs of death. In the absence of obvious death signs, BLS teams must initiate resuscitation and simultaneously request ALS team support through the dispatch center. Upon arrival and if their resuscitation efforts are unsuccessful, ALS teams have the authority to perform prehospital TOR.

This study was approved by the Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University (COA. MURA2024/322). The requirement for informed consent was waived due to the retrospective nature of the study and the use of de-identified patient data.

2.2. Participants

The study included adult patients aged 18 years or older who experienced OHCA and were either treated by the EMS of Ramathibodi Hospital between January 2021 and March 2023 or transported to the ED of Ramathibodi Hospital by another EMS provider between January 2010 and March 2023. Patients were excluded from the study if they had traumatic cardiac arrest, had a "do not resuscitate" order, showed obvious signs of death, or if their medical records were destroyed or had missing data.

2.3. Data gathering

The documentation of patient data by all EMS units and the transfer of these documents to the receiving hospital has been a standard requirement enforced for an extended period and encompasses the entire duration of this study. For external EMS units transporting patients to Ramathibodi's ED, protocols mandated the transfer of cardiac arrest patient care information, which was subsequently recorded in patients' medical records and scanned into the Electronic Medical Records (EMR) system. Similarly, the RAMA-EMO unit documented information for cardiac arrest patients in dedicated cardiac arrest record forms, which were also scanned into the EMR system.

We collected prognostic factors, including prehospital variables, variables in the ED, survival status (survival to hospital admission), and variables contained in the selected TOR rules.

The prehospital variables collected were age, sex, underlying conditions, type of initial cardiac arrest rhythm, presence of a witness, bystander cardiopulmonary resuscitation (CPR), no-flow time (defined as the duration from the onset of cardiac arrest until the initiation of CPR), low-flow time (defined as the duration from the initiation of CPR until return of spontaneous circulation (ROSC)), type of EMS team, EMS operation times (response time: duration between EMS activation until EMS arrival at the scene, and transport time: duration between EMS leaving the scene until arrival at the hospital), prehospital defibrillation, any prehospital ROSC, and total prehospital CPR time. The ED variables collected were initial cardiac arrest rhythm in the ED, any ROSC at ED, total ED CPR time, and survival to hospital admission.

2.4. Characteristics of studied TOR rules

This study evaluated ten TOR rules: two American heart association (AHA) rules AHA-BLS and AHA-ALS, six rules developed in Asian populations, and two Western rules. The Asian rules included the Korean Cardiac Arrest Research Consortium (KoCARC) rules I, II, and III, Goto's rule, Shihabashi's rule, and the New Model I, while the Western rules were Helsinki and Petrie rules. These rules incorporate various combinations of clinical criteria such as witnessed status, bystander CPR, initial cardiac rhythm, response time, and prehospital ROSC.

The 10 studied TOR rules for OHCA (supplementary table 1) incorporated various key criteria: witness status (8 rules), initial cardiac rhythm (5 rules), absence of prehospital defibrillation (5 rules), and absence of prehospital ROSC (9 rules). Additional criteria included age thresholds (3 rules), EMS response time (2 rules), and bystander CPR (1 rule). All rules except Goto's were designed for prehospital application.

2.5. Data extraction and quality control

Data extraction was performed in two stages. Initially, all data were extracted to Excel files by the first author using a data extraction form. Data extraction accuracy was verified through a two-step validation process: first, a second author independently reviewed all extracted data for completeness and accuracy. Second, after importing data into STATA, a third author performed systematic checks for data type consistency, numerical ranges, and out-of-bound values. Any discrepancies identified during either validation step were resolved through discussion and reaching a consensus among the authors, regarding the original medical records when necessary. For the missing data, we conducted a complete case analysis, excluding records with missing values for TOR criteria or outcome variables.

2.6. Outcome measurement

The primary outcome was death before hospital admission (including death at the scene and death in the ED) and survival to hospital admission. The secondary outcome was 30-day survival and favorable neurological outcomes in cases who experienced survival to discharge after OHCA.

2.7. Statistical analyses

The sample size calculation was based on Hsu et al.'s study of TOR rules' external validity for predicting 30-day survival in OHCA patients using the PAROS populations, including Japan, Singapore, Thailand, United Arab Emirates, Korea, Malaysia, and Taiwan.

Two-sample ROC analysis was performed with the following parameters: two-sided test, alpha = 0.05, power = 0.8, ratio n2/n1 = 0.06, effect size = 0.2, and 20% missing data allowance. The analysis determined a required total sample size of 329 patients, comprising 21 patients in the survival to admission group and 308 in the non-survival group.

Statistical analyses were performed using STATA Version 16.1. Baseline characteristics were analyzed using descriptive statistics: categorical data with exact probability tests, normally distributed numerical data with two-sample independent t-tests (mean ± standard deviation (SD)), and non-normally distributed data with rank-sum tests (median, interquartile range (IQR)). TOR rules' accuracy was evaluated using receiver operating characteristic (ROC) curve analysis, presenting area under the ROC curve (AUC) values with 95% confidence intervals (CI). Diagnostic performance characteristics was assessed through sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and False positive rate (FPR), with 95%CI and p-values.

FPR was calculated as the proportion of patients who survived to hospital admission but would have been incorrectly identified for TOR based on each TOR rule. FPRs were analyzed at different resuscitation time points (5, 10, 15, 20, 25, 30, and >30 minutes) to evaluate how the predictive accuracy of each rule varied with prolonged resuscitation efforts.

3. Results

3.1. Baseline characteristics of studied patients

During the study period, 414 OHCA patients were identified. 283 cases were managed by the EMS of Ramathibodi Hospital and 131 cases were transported to the ED of Ramathibodi Hospital by other EMS providers. Excluding 35 cases, finally 379 cases were enrolled in the study (figure 1). There were 308 (81.24%) deaths before hospital admission, while 71 (18.73%) patients survived to hospital admission.

Baseline patient characteristics are shown in Table 1. The median age of patients was 62 (IQR: 49 - 78) years, 64.38% were male, and 78.36% experienced OHCA at house. Survivors were not significantly older than non-survivors (p = 0.119). Most patients (83.38%) presented with non-shockable rhythms, predominantly asystole. Of the 64.91% witnessed arrests, family members were primary witnesses (56.5%).

Transport platform arrests showed significantly higher survival (8.45% vs. 0.97%) than other locations (p = 002).

Bystander CPR was more frequent in non-survivors (75.32% vs. 46.48%, p<0.001). Prehospital defibrillation rates were similar between the groups (survivors 28.17%, non-survivors 27.60%, p=0.514), with comparable mean defibrillation numbers (3.91±0.42 vs 3.15±0.68, p=0.415). Prehospital ROSC was significantly higher in survivors (67.61% vs. 19.81%, p<0.001), though non-survivors experienced more prehospital re-arrest (42.62% vs. 16.67%, p=0.003). Median no-flow time (5 minutes, IQR: 0-20) and transport time (8 minutes, IQR: 5-12) were similar between groups. However, survivors showed significantly shorter low-flow time (16 vs. 25 minutes, p=0.001), response time (12 vs. 16 minutes, p<0.001), scene time (16 vs. 32 minutes, p<0.001), and total CPR time (19 vs. 36 minutes, p<0.001) compared to non-survivors.

3.2. Screening performance of TOR rules

Analysis of ten TOR rules among 379 cases revealed varying screening performance in predicting death before hospital admission (Table 2, figure 2).

The New TOR model I showed relatively high performance with sensitivity of 96.7% (95%CI: 93.0–98.8%), specificity of 33.2% (95%CI: 26.6–40.2%), PPV of 57.5% (95% CI: 51.5-63.1%), and area under the curve (AUC) of 0.74 (95% CI: 0.70-0.79).

The KoCARC TOR rule III demonstrated sensitivity of 97.5% (95% CI: 91.4-99.7%), FPR of 2.8% (95% CI: 0.3-0.98%), and NPV of 97.2% (95% CI: 90.2-99.7%).

In contrast, despite sensitivity of 92.0% (95% CI: 87.1-95.4%), the AHA-BLS rule showed FPR of 21.1%, (95% CI: 12.0-32.0%). Overall AUC values ranged from 0.47 to 0.74, and FPR ranged from 2.8 to 23.9%, with most rules showing a trade-off between sensitivity and specificity.

3.3. FPR of TOR rules across resuscitation times

Analysis of the ten TOR rules showed varying FPRs across resuscitation time points from 5 to over 30 minutes.

At 5 minutes, six rules (Helsinki's, AHA-BLS, AHA-ALS, Goto's, Petrie's, and KoCARC I) showed an FPR of 1.41%, while three rules (Shibahashi's, KoCARC II, and KoCARC III) maintained 0% FPR. FPRs increased over time across all rules, with Helsinki's rule and AHA-BLS showing the highest rates at >30 minutes (23.94% and 21.13%, respectively). KoCARC III demonstrated the most consistent performance, maintaining the lowest FPR throughout and reaching only 2.82% at >30 minutes (Table 3, figure 2).

Among the 71 patients who survived to hospital discharge, the survival distribution across time intervals is shown in Table 3. Of these, 22 (30.99%) achieved 30-day survival and 10 (14.08%) had favorable neurological outcomes (cerebral performance category (CPC) ≤3). For 30-day survival, AHA-BLS and Helsinki's rules showed the highest false positives (5 and 4 cases, respectively), while Shibahashi's and KoCARC III demonstrated the fewest (1 case each). Regarding neurological outcomes, AHA-BLS had 3 false positives, while Shibahashi's and KoCARC III had none (Table 4).

4. Discussion

This study evaluated the performance of ten TOR rules in predicting death before hospital admission among Thai OHCA patients, revealing two key findings. First, the New TOR model I demonstrated relatively high overall performance (sensitivity 96.7%, specificity 33.2%, PPV 57.5%, AUC 0.74), while the KoCARC TOR rule III showed excellent sensitivity (97.5%), highest NPV (97.2%), and lowest FPR (2.8%). Second, the TOR rules showed varying FPRs. The AHA-BLS and Helsinki's rules had the highest FPRs (peaking at 12.68% and 14.08% at 30 minutes), while KoCARC III maintained 0% FPR throughout. Other rules showed intermediate performance, with AHA-ALS and Goto's rules stabilizing at 5.63% FPR between 20-25 minutes, and the new model maintaining 2.82% FPR between 15-30 minutes.

Our findings align with previous studies, particularly those from Asian populations, regarding high sensitivity, NPV, and acceptable AUC in predicting death (1, 12, 18, 19). However, our observed FPRs (2.8%-23.9%) were higher than Western studies reporting rates below 1%, though consistent with other Asian studies (20, 21). This difference may be attributed to our focus on survival to hospital admission rather than discharge as an endpoint. While patients surviving to admission may later die during hospitalization, affecting FPR rates, this earlier endpoint captures a different phase of outcomes potentially influenced by factors not considered in traditional TOR rules developed for long-term survival prediction.

Most TOR rules incorporate key predictive criteria: witness status, initial cardiac rhythm, prehospital defibrillation status, and prehospital ROSC (22, 23), with some also considering age and response time (20, 24, 25). Our population showed distinct characteristics from Western populations, notably that while bystander CPR was associated with non-survival, healthcare provider-performed CPR showed higher survival rates, emphasizing CPR quality importance. Bangkok's traffic congestion affects response times, and although bystander CPR rates were high, quality assessment was impossible during the no-flow time measurements. TOR rules incorporating asystole as a criterion demonstrated lower FPRs, consistent with established evidence linking asystole to poor prognosis (25-27). While high sensitivity and low FPR across all TOR rules indicate effective avoidance of inappropriate termination (12), lower specificity suggests a conservative approach aligned with the primary goal: avoiding termination in potential survivors.

First, several rules showed increasing FPR that peaked at 30 minutes, indicating greater uncertainty in predictions during prolonged resuscitation. Second, some rules maintained conservative predictions with FPR remaining at or near zero throughout the 30-minute interval. Third, certain rules demonstrated balanced performance with consistent FPR over time. The overall trend of increasing FPR until 30 minutes contrasts with Grunau et al.'s findings of decreasing FPR over time (12). This difference may be explained by clear signs of poor prognosis in non-survivors during early resuscitation, resulting in initially lower FPRs.

The increasing FPR trend can be attributed to multiple factors. First, the study included patients who benefited from prolonged CPR.

Furthermore, some patients may survive hospital admission after prolonged resuscitation. They often have a poorer prognosis and may die during subsequent hospital treatment (28, 29), affecting FPR rates. When analyzing the performance of TOR rules in predicting long-term outcomes rather than immediate survival, the FPRs were lower. This pattern particularly affects the FPR of TOR rules, as most were originally developed and validated for predicting long-term survival rather than immediate survival to admission.

Our findings showed increasing FPRs during resuscitation and survival at each time point (5 to over 30 minutes), suggesting that early termination carries a significant risk of inappropriate TOR for potentially survivable cases. This aligns with AHA 2020 and NAEMSP guidelines (13, 30) and recommends the continuation of resuscitation efforts for at least 20 minutes. This suggests that adherence to current resuscitation timing guidelines remains crucial.

5. Limitations

Our study has several important limitations. First, this study involved a 10-year timespan during which the Thai EMS system underwent continuous development in protocols, equipment, and personnel training. Additionally, in Thailand, CLS and ALS teams from different organizations vary considerably in terms of number and qualification levels of EMS personnel, as well as available resources. These differences lead to variations in resuscitation management and treatment protocols that patients receive. These developments represent important confounding factors affecting survival outcomes of OHCA patients throughout the study period. Our external validation analysis didn't adjust for these confounding factors, potentially resulting in TOR rule performance metrics that may not accurately reflect their accuracy in the current context where treatment advancements may have improved patient survival rates. Therefore, caution should be exercised when applying these criteria to contemporary treatment protocols.

Second, the retrospective design resulted in some missing data. We employed complete case analysis, excluding records with missing values relevant to TOR rules or outcome variables. The most common missing data resulted from incomplete EMS documentation, particularly in earlier years of the study period, primarily affecting EMS time and distance variables (approximately 5% of cases). While this approach preserved data integrity by including only verified information, it potentially introduced selection bias if missing data was not randomly distributed across the study population. Additionally, the absence of a standardized protocol for TOR decisions introduced confounding bias in TOR. These limitations affect determination of the optimal timing for TOR.

Third, our endpoint of death before hospital admission represents a short-term outcome, differing from the long-term outcomes used in reference studies (1). While our sample size exceeded calculations, the study may be underpowered, and the lack of long-term follow-up limits our understanding of resuscitation effectiveness in achieving optimal neurological outcomes and quality of life (3).

Fourth, although patients were treated according to standard protocols, variations in equipment and procedures among different ALS and CLS units could not be fully assessed. Fifth, the dynamic nature of resuscitation response and limitations in recording electrocardiography (ECG) rhythm changes at different time points may affect the practical utility of our findings. Finally, generalizability is limited by Bangkok's unique healthcare characteristics. Our study population may not fully represent Bangkok's entire OHCA population due to the city's divided emergency service regions and nearest hospital transport policy, excluding cases far from Ramathibodi Hospital. The urban setting's specific characteristics (traffic patterns, hospital proximity, healthcare-seeking behaviors) may further limit applicability to other populations or healthcare systems.

To address these limitations, prospective multicenter studies across diverse Thai settings, both urban and rural, are required to evaluate TOR rules in different contexts. Standardized data collection forms for OHCA cases should be developed to facilitate consistent documentation across all EMS units. Implementing standardized training for EMS personnel on TOR would reduce practice variability. Additionally, the multicenter approach would increase sample size within shorter timeframes, reducing seasonal bias.

6. Conclusions

Most TOR rules demonstrated good performance in predicting death before hospital admission with high sensitivity, NPV, and acceptable AUC. The KoCARC III showed the most conservative accuracy with good predictive performance and consistently low FPR throughout resuscitation for TOR decisions. However, the higher and increasing FPRs over time suggest that existing TOR rules may need modification for our local EMS system and population characteristics. With survival occurring at all time points and the risk of ending care prematurely in potentially survivable cases, we recommend continuing resuscitation efforts for at least 20 minutes before applying TOR rules. These findings should be interpreted with consideration of the limitations inherent to our retrospective design, potential confounding factors, and the need for further external validation in each specific setting before implementation of TOR in clinical practice.

7. Declarations

7.1. Acknowledgments

None.

7.2. Authors' contributions

All authors have substantially contributed to this work, from concept development through study design, data analysis, and interpretation. All authors participated in manuscript preparation, critically revised its content, approved the final version for publication, agreed on the journal selection, and took responsibility for all aspects of the work.

7.3. Funding sources

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7.4. Conflict of interest

The authors declare no conflicts of interest in the conduct of this research.

7.5. Using artificial intelligence chatbots

The authors confirm that no generative artificial intelligence (AI) or AI assistance tools were used in the writing or preparation of this manuscript.

7.6. Data availability

The data supporting this study's findings are available from the Electronic Medical Record (EMR), Faculty of Medicine Ramathibodi Hospital, Mahidol University. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the corresponding author with reasonable request and permission of the Faculty of Medicine Ramathibodi Hospital Ethics Committee.

7.7. Ethical considerations

This study was approved by the Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University (COA. MURA2024/322). The requirement for informed consent was waived due to the retrospective nature of the study and the use of de-identified patient data.

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Table 1: Characteristics of the OHCA study population were compared between the group of patients who died and the group who survived to hospital admission

Characteristics	Total (n= 379)	Survival to hospital admission		P-value
		No (n=308)	Yes (n=71)	
Gender				
Male	244 (64.38)	195 (63.31)	49 (69.01)	0.223
Age (year)				
Mean ± SD	62.50 ± 19.04	61.77 ±1.09	65.68 ± 2.15	0.119
Underlying				
Comorbidity	154 (40.63)	116 (37.66)	38 (53.52)	0.011
CAD	58 (15.30)	44 (14.29)	14 (19.72)	0.014
DM	99 (26.12)	74 (24.03)	25 (35.21)	0.009
HT	139 (36.68)	103 (33.44)	36 (50.70)	0.004
DLP	51 (13.46)	28 (9.09)	23 (32.39)	<0.001
CKD	31 (8.18)	18 (5.84)	13 (18.31)	<0.001
Old CVA	20 (5.28)	12 (3.90)	8 (11.27)	0.003
Shockable rhythm				
Yes	63 (16.62)	48 (15.58)	15 (21.13)	0.169
Initial rhythm				
VF	49 (12.93)	37 (12.01)	12 (16.90)	<0.001
pVT	3 (0.79)	2 (0.65)	1 (1.41)	
Asystole	238 (62.8)	214 (69.48)	24 (33.8)	
PEA	89 (23.48)	55 (17.86)	34 (47.89)	
Rhythm changes to shockable				
Yes	50 (17.61)	45 (18.22)	5 (13.51)	0.331
Rhythm changes to non-shockable				
Yes	43 (68.52)	36 (75.00)	7 (46.67)	0.043
Location of OHCA				
House	297 (78.36)	241 (78.25)	56 (78.87)	0.006
Public	35 (9.23)	28 (9.09)	7 (9.86)	
Traffic	26 (6.86)	25 (8.12)	1 (1.41)	
Transport platform	9 (2.37)	3 (0.97)	6 (8.45)	
Patient care	7 (1.85)	6 (1.95)	1 (1.41)	
Other	5 (1.32)	5 (1.62)	0 (0.00)	
Witness cardiac arrest				
Yes	246 (64.91)	195 (63.31)	51 (71.83)	0.111
Type of witness				
Family	139 (56.50)	111 (56.92)	28 (54.90)	<0.001
Lay rescuer	89 (36.18)	77 (39.49)	12 (23.53)	
Healthcare provider	16 (6.50)	6 (3.08)	10 (19.61)	
Other	2 (0.81)	1 (0.51)	1 (1.96)	
Bystander CPR				
Yes	265 (69.92)	232 (75.32)	33 (46.48)	<0.001
Times				
No-flow time	5 (0-20)	4 (0-19)	11 (0-20)	0.062
Low-flow time	20 (12-36)	25 (15.5-42)	16 (10-30)	0.001
Response time	15 (11-21)	16 (11-21)	12 (7-16)	<0.001
Scene time	32 (12-42)	32 (19.5-44)	16 (9-24)	<0.001
Transport time	8 (5-12)	8 (5-12)	8 (6-12)	0.373
CPR time				
Total	33 (18 – 48)	19 (10 - 34)	36 (22 - 52)	<0.001
< 20 min	111 (29.29)	73 (23.70)	38 (53.52)	
≥ 20 min	268 (70.71)	235 (76.30)	33 (46.48)	
Defibrillation				
Prehospital	105 (27.70)	85 (27.60)	20 (28.17)	0.514
Total	3.76 (0.36)	3.15 (0.68)	3.91 (0.42)	0.415

Data are presented as mean ± standard deviation (SD), median (IQR: interquartile range), or frequency (%).
CAD: Coronary artery disease; DM: Diabetes mellitus; HT: Hypertension; DLP: Dyslipidemia; CKD: Chronic kidney disease; CVA: Cerebrovascular accident; VF: Ventricular fibrillation; pVT: Pulseless ventricular tachycardia; PEA: Pulseless electrical activity; TOR: Termination of resuscitation; CPR: Cardiopulmonary resuscitation; OHCA: Out-of-hospital cardiac arrest.

Table 2: External validations of termination of resuscitation (TOR) rules for predicting death before hospital admission

TOR rules	Sensitivity	Specificity	FPR	PPV	NPV	AUC
AHA – BLS	92.0 (87.1-95.4)	29.2 (22.8-36.1)	21.1 (12.0-32.0)	55.8 (50.1-61.5)	78.9 (67.6-87.70	0.67 (0.62-0.73)
AHA – ALS	81.1 (64.8-92.0)	18.7 (14.7-23.3)	9.9 (4.0-19.0)	9.7 (6.7-13.6)	90.1 (80.7-95.9)	0.50 (0.46-0.54)
Goto's	89.9 (81.7-95.3)	21.4 (16.8-26.6)	12.7 (6.0-23.0)	26 (21.2-31.3)	87.3 (77.3-94.0)	0.57 (0.52-0.61)
Shibahashi's	88.0 (75.7-95.5)	19.8 (15.6-24.5)	8.5 (3.0-17.0)	14.3 (10.6-18.7)	91.5 (82.5-96.8)	0.53 (0.49-0.57)
Petrie's	71.0 (52.0-85.8)	17.8 (13.9-22.2)	12.7 (6.0-23.0)	7.1 (4.5-10.6)	87.3 (77.3-94)	0.47 (0.43-0.51)
Helsinki's	85.1 (77.2-91.1)	20.4 (15.7-25.7)	23.9 (15.0-36.0)	31.5 (23.6-37.0)	76.1 (64.5-85.4)	0.54 (0.48-0.59)
KoCARC I	96.7 (92.4-98.9)	28.8 (23.0-35.2)	7.0 (2.0-16.0)	47.1 (41.4-52.8)	93.0 (84.3-97.7)	0.70 (0.66-0.74)
KoCARC II	89.3 (81.7-94.5)	21.7 (17.0-27.1)	15.5 (8.0-26.0)	29.9 (24.8-35.3)	84.5 (74.0-92.0)	0.57 (0.52-0.62)
KoCARC III	97.5 (91.4-99.7)	23.2 (18.5-28.4)	2.8 (0.3-0.98)	25.6 (20.9-30.9)	97.2 (90.2-99.7)	0.61 (0.58-0.65)
New model I	96.7 (93.0-98.8)	33.2 (26.6-40.2)	8.5 (3.0-17.0)	57.5 (51.5-63.1)	91.5 (82.5-96.8)	0.74 (0.70-0.79)

Data are presented with 95% confidence interval. FPR: False positive rate; PPV: Positive predictive value; NPV: Negative predictive value; AUC: area under the receiver operating characteristic curve.

Table 3: False positive rates of termination of resuscitation rules at elapsed resuscitation time

CPR time (minute)	Deaths in Interval	Cumulative Deaths	Termination of resuscitation rules									
			AHA – BLS	AHA – ALS	Goto's	Shibahashi's	Petrie's	Helsinki's	KoCARC I	KoCARC II	KoCARC III	New model I
5	33 (10.71)	33 (10.71)	1.41 (0.04 - 7.6)	1.41 (0.04 - 7.6)	1.41 (0.04 - 7.6)	0 (0 - 5.06)	1.41 (0.04 - 7.6)	1.41 (0.04 - 7.6)	1.41 (0.04 - 7.6)	0 (0 - 5.06)	0 (0 - 5.06)	1.41 (0.04 - 7.6)
10	10 (3.25)	43 (13.96)	4.23 (0.88 - 11.9)	2.82 (0.34 - 9.81)	2.82 (0.34 - 9.81)	0 (0 - 5.06)	1.41 (0.04 - 7.6)	4.23 (0.88 - 11.9)	1.41 (0.04 - 7.6)	2.82 (0.34 - 9.81)	0 (0 - 5.06)	1.41 (0.04 - 7.6)
15	9 (2.92)	52 (16.88)	7.04 (2.33 - 15.7)	4.23 (0.88 - 11.9)	4.23 (0.88 - 11.9)	1.41 (0.04 - 7.6)	1.41 (0.04 - 7.6)	8.45 (3.16 - 17.5)	2.82 (0.34 - 9.81)	4.23 (0.88 - 11.9)	0 (0 - 5.06)	2.82 (0.34 - 9.81)
20	21 (6.82)	73 (23.70)	9.86 (4.06 - 19.3)	5.63 (1.56 - 13.8)	5.63 (1.56 - 13.8)	2.82 (0.34 - 9.81)	7.04 (2.33 - 15.7)	11.27 (4.99 - 21)	2.82 (0.34 - 9.81)	5.63 (1.56 - 13.8)	0 (0 - 5.06)	2.82 (0.34 - 9.81)
25	13 (4.22)	86 (27.92)	11.27 (4.99 - 21)	5.63 (1.56 - 13.8)	5.63 (1.56 - 13.8)	4.23 (0.88 - 11.9)	7.04 (2.33 - 15. 7)	12.68 (5.96 - 22.7)	2.82 (0.34 - 9.81)	7.04 (2.33 - 15.7)	0 (0 - 5.06)	2.82 (0.34 - 9.81)
30	36 (11.69)	122 (39.61)	12.68 (5.96 - 22.7)	5.63 (1.56 - 13.8)	7.04 (2.33-15.67)	4.23 (0.88-11.86)	8.45 (3.16-17.49)	14.08 (6.97-24.38)	2.82 (0.34 - 9.81)	8.45 (3.16-17.49)	0 (0 - 5.06)	2.82 (0.34 - 9.81)
>30	186 (60.39)	308 (100.00)	21.13 (12.33-32.4)	9.86 (4.06-19.26)	12.68 (5.96-22.7)	8.45 (3.16-17.49)	12.68 (5.96-22.7)	23.94 (14.61-35.5)	7.04 (2.33-15.67)	15.49 (8.00-26.03)	2.82 (0.34-9.81)	8.45 (3.16 - 17.5)

Data are presented as percentage with 95% confidence interval. CPR: Cardiopulmonary resuscitation.

Table 4: Patient outcomes in survival to hospital discharge group (n=71)

30-day Outcome	N (%)	Missing	TOR rules positive									
			AHA-BLS	AHA-ALS	Goto's	Shibahashi's	Petrie's	Helsinki	KoCARC I	KoCARC II	KoCARC III	New model I
Survival	22(30.99)	3	5	3	3	1	2	4	2	4	1	2
CPC ≤ 3	10(14.08)	6	3	1	1	0	1	1	1	2	0	1

TOR: termination of resuscitation; CPC: Cerebral Performance Category.

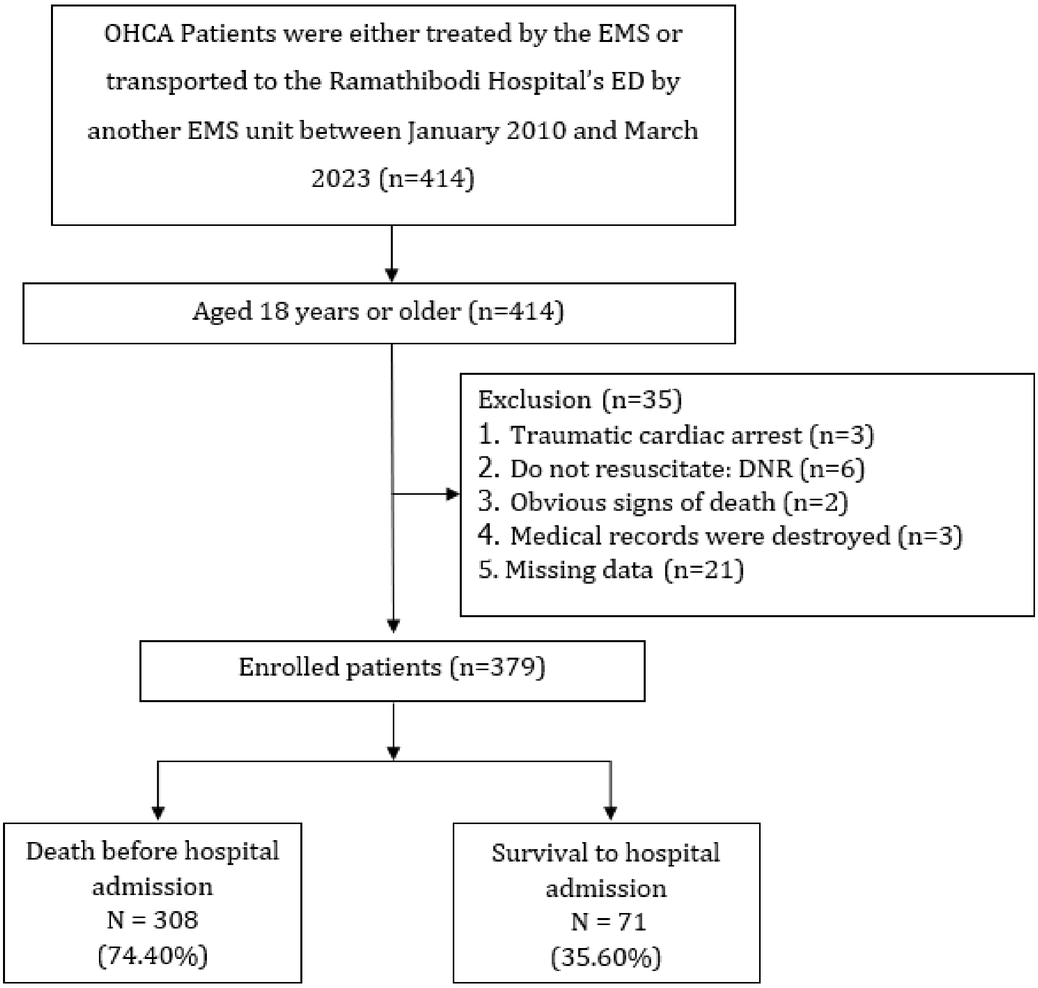

Figure 1: Flow diagram of the study. OHCA: Out-of-hospital cardiac arrest; EMS: Emergency medical service; ED: emergency department.

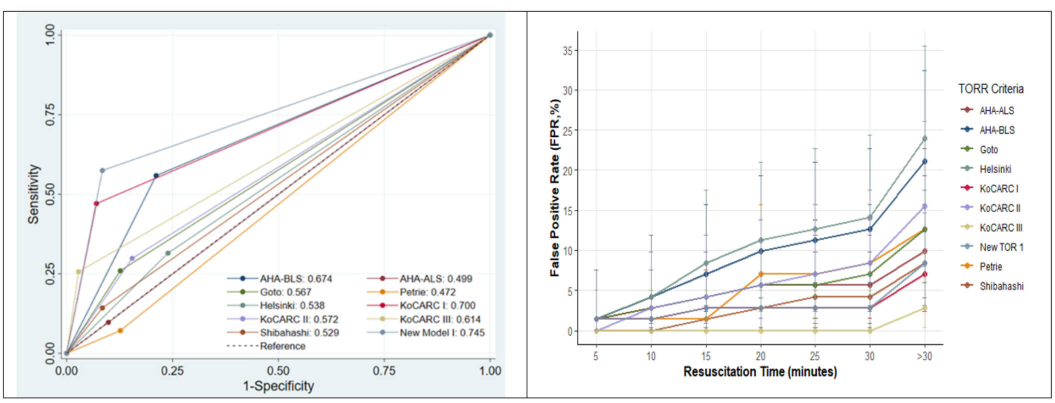

Figure 2: Area under the receiver operating characteristics curves for terminating resuscitation rules to predict death before hospital admission (left) and trend in the false positive rate with 95% confidence intervals at elapsed resuscitation time (right).

Supplementary table 1: External validations of termination of resuscitation (TOR) rules for predicting death before hospital admission

TOR rules	Witness status	Initial rhythm	Prehospital defibrillation	Prehospital ROSC	Others	Setting
AHA-BLSa	Unwitnessed by EMT		No defibrillation before transport	No ROSC before transport		Prehospital
AHA-ALSb	Unwitnessed by EMT or bystander		No defibrillation before transport	No ROSC before transport	No bystander CPR	Prehospital
Goto'sc	Unwitnessed by bystander	Non-shockable		No ROSC before transport		Emergency department
Shibahashi'sd	Unwitnessed by bystander	Non-shockable			Age > 73 yrs.	Prehospital
Petrie'se		Asystole			Response time > 8 min	Prehospital
Helsinki DNA0Rf	Unwitnessed by bystander	Asystole		No ROSC within 20 min by ALS	Or response time > 10 min	Prehospital
	Unwitnessed by bystander	PEA		No ROSC within 10 min by ALS		
	Unwitnessed by bystander	PEA		No ROSC within 20 min by ALS	Or response time > 15 min	
KoCARC Ig	Unwitnessed by EMT	Asystole	No defibrillation before transport	No ROSC before transport		Prehospital
KoCARC IIg	Unwitnessed by EMT		No defibrillation before transport	No ROSC before transport	Age > 60 yrs.	Prehospital
KoCARC IIIg	Unwitnessed by EMT	Asystole	No defibrillation before transport	No ROSC before transport	Age > 60 yrs.	Prehospital
New model 1h	Unwitnessed by bystander	Asystole		No ROSC before transport		Prehospital

BLS: Basic life support; ALS: Advanced life support; EMT: emergency medical technician; PEA: Pulseless electrical activity;
CPR: Cardiopulmonary resuscitation; TOR: Termination of resuscitation; ROSC, Return of spontaneous circulation.
a: Verbeek PR et al, 2002; b: Morison LJ et al, 2008; c: Goto V, 2013; d: Shibahashi K, 2018;
e: Perie DA, 2001; f: Väyrynen T, 2008; g: Yoon JC, 2019; h: Lee DE, 2019.