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The Scene Time Interval and Basic Life Support Termination of Resuscitation Rule in Adult Out-of-Hospital Cardiac Arrest

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We validated the basic life support termination of resuscitation (BLS TOR) rule retrospectively using Out-of-Hospital Cardiac Arrest (OHCA) data of metropolitan emergency medical service (EMS) in Korea. We also tested it by investigating the scene time interval for supplementing the BLS TOR rule. OHCA database of Seoul (January 2011 to December 2012) was used, which is composed of ambulance data and hospital medical record review. EMS-treated OHCA and 19 yr or older victims were enrolled, after excluding cases occurred in the ambulance and with incomplete information. The primary and secondary outcomes were hospital mortality and poor neurologic outcome. After calculating the sensitivity (SS), specificity (SP), and the positive and negative predictive values (PPV and NPV), tested the rule according to the scene time interval group for sensitivity analysis. Of total 4,835 analyzed patients, 3,361 (69.5%) cases met all 3 criteria of the BLS TOR rule. Of these, 3,224 (95.9%) were dead at discharge (SS,73.5%; SP,69.6%; PPV,95.9%; NPV, 21.3%) and 3,342 (99.4%) showed poor neurologic outcome at discharge (SS, 75.2%; SP, 89.9%; PPV, 99.4%; NPV, 11.5%). The cut-off scene time intervals for 100% SS and PPV were more than 20 min for survival to discharge and more than 14 min for good neurological recovery. The BLS TOR rule showed relatively lower SS and PPV in OHCA data in Seoul, Korea.

Keywords: Out-of-Hospital Cardiac Arrest; Cardiopulmonary Resuscitation; Decision Support Technique

INTRODUCTION

Despite many improvements in the emergency medical service (EMS) system and in the technique of cardiopulmonary resuscitation (CPR), survival rate of adult patients with out-of hospital cardiac arrests (OHCA) is still low. The survival rates are even lower for patients who have no response to basic life support (BLS) compared to the rest patients with OHCA (1, 2). However, for patients who are not likely to achieve return of spontaneous circulation (ROSC), the same amount of resources and time are used to transport these patients to the emergency department. A retrospective analysis of fatal ambulance crashes showed most crashes (202/339) and fatalities (233/405) occurred during emergency use, and most crashes resulted in at least one fatality (3). Fatal traffic accidents caused by rushing ambulances with lights and sirens hurt not only the patients and EMS personnel on board but also pedestrians and the passengers of other vehicles. Therefore, traffic accidents caused by unnecessary ambulance transport can be a potential danger to the community. To reduce the rate of hospital transport without compromising the care of potentially viable patients, many previous studies have tried to establish and validate termination of resuscitation (TOR) rules in pre-hospital OHCA situations.

The 2010 American Heart Association (AHA) resuscitation guidelines recommend that regional or local EMS authorities use the BLS TOR rule to develop protocols for the termination of resuscitative efforts by BLS providers for adult patients of cardiac arrest in areas where advanced life support (ALS) is not available or may be significantly delayed (Class I, LOE A) (4). To consider terminating BLS resuscitative attempts for adult OHCA patients, all 3 of following criteria must be present before moving the patient to the ambulance for transport: 1) arrest was not witnessed by an EMS provider or first responder; 2) there was no ROSC prior to transport; and 3) no automated electronic defibrillator (AED) shock was delivered. The recommendation was based on a clinical decision rule called the basic life support termination of resuscitation (BLS TOR) rule. The BLS TOR rule was derived by Verbeek et al. (5) through a retrospective review of case records from a large, urban EMS system where emergency medical technicians (EMTs) are trained to use an AED. The BLS TOR rule has been validated in the US, Canada, and Europe and was proven to generate high specificity and a positive predictive value (6-11). In one study, the BLS TOR rule proved to reduce the rate of hospital transport to 37% of cardiac

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arrests without compromising the care of potentially viable patients (12).

East Asian EMS systems in Korea, Japan, and Taiwan have mostly a single-tier ambulance system, and only BLS can be provided to cardiac arrest patients before arriving to the hospital. EMTs are trained to provide BLS and use AEDs for rhythm analysis and defibrillation in the field. Unlike North America and Europe, EMTs provide CPR at the scene for a relatively short period of time and transport the patients with on-going CPR in a moving ambulance to the hospital according to their protocol. These systems do not allow EMTs to use the BLS TOR rule (13). The scene time interval (STI) is the critical period to provide high quality CPR, intubation, and fluid resuscitation in East Asian EMSs. If the STI is not enough to provide CPR before transporting patients to the emergency department (ED), the rule cannot be used or one should consider a modification of the rule components. Our purpose is to validate the BLS TOR rule retrospectively for predictive performance and perform the sensitivity analysis according to the STI.

MATERIALS AND METHODS

The study is one of Cardiac Arrest Registry and Encouragement of Excellent Resuscitation (CAREER) projects. CARRER project is a population-based emergency medical services intervention trial since 2011 in Seoul, Korea.

Study design and setting

This study was a retrospective validation of the BLS TOR rule. The setting of location was Seoul, the capital city of the Republic of Korea, with a population of approximately ten million people in 605 km^2, consisting mostly of urban areas. There are 114 ambulance stations and 23 EMS agencies. One ambulance has three crewmembers: a level-1 EMT, a level-2 EMT, and a driver. The EMS service level is equivalent to an intermediate level of service in North America. EMS personnel provide CPR at the scene according to the 2010 AHA CPR guidelines, with a 30:2 compression-to-ventilation ratio and advanced airway or bag-valve-mask ventilation. They are encouraged to provide four cycles of CPR and rhythm analysis and to transport the patient to an ED, continuing CPR during ambulance transport. A public access defibrillator program was approved in 2009, and the city started a program to set up AEDs in public places in 2009. However, few cases were defibrillated by laypersons in this study period.

Data source

The dataset included all registered OHCAs from January 1, 2011, to December 31, 2012. OHCA databases were composed of EMS data from ambulance run sheets, an EMS OHCA registry completed by the attending level-1 EMT, and the hospital medical record review containing the Utstein templates. Ambulance run sheets and EMS OHCA registry are filled after transporting patients to the ED and stored at the central server of the Seoul Metropolitan Fire Department (SMFD). We extracted the cases from the database at SMFD. Hospital records for all cases were reviewed by medical record reviewers after three months by the Korea Centers for Disease Control and Prevention (KCDC) for follow-up, including the etiology, co-morbidity, and outcomes, survival to discharge and the good neurological recovery using the cerebral performance category (CPC) (where 1 = good cerebral performance [conscious, alert, able to work and lead a normal life]; 2 = moderate cerebral disability [conscious and able to function independently—dress, travel, prepare food—but may have hemiplegia, seizures, or permanent memory or mental changes]; 3 = severe cerebral disability [conscious, dependent on others for daily support, functions only in an institution or at home with exceptional family support]; 4 = coma or vegetative state; and 5 = death).

Study population

EMS-treated and 19 yr old or older patients with presumed cardiac etiology were included. Patients who collapsed in the ambulance, patients with incomplete information in their registry regarding defibrillation provided by the EMS providers, presence of ROSC before ambulance transport and hospital outcomes were excluded.

Data variables

The variables collected were age, gender, response time between the initial call and the ambulance's arrival to the scene, scene time interval from arrival to departure to ED, number of witnesses, number of bystanders (EMS provider or lay person), bystander-administered CPR, use of EMS defibrillation, pre-hospital ROSC, and first ECG. The primary and secondary end-points were hospital mortality and poor neurological recovery (CPC 3, 4, or 5).

Statistical analysis

We retrospectively applied the BLS TOR rule to patients' data using AHA's three components, and calculated the predictive performance (percent and 95% confidence interval) of the rule, such as sensitivity (SS), specificity (SP), positive and negative predictive value (PPV and NPV) for hospital mortality and poor neurological recovery. We performed the sensitivity analysis on the performance value (SS, SP, PPV, and NPV) to find the cut-off value of STI for achieving 100% SP and 100% PPV for the study end-points.

Ethics statement

This study was approved by the institutional review board of Seoul National University Hospital (IRB No.1103-153-357). Informed consent was waived by the board because of the observational nature of the study.

RESULTS

Of the 7,458 OHCA patients, we enrolled 4,835 patients. The following were excluded: children (n = 168), non-cardiac etiology (n = 1,641), patients not treated by EMS (n = 316), occurred in ambulance (n = 283) and incomplete information (n = 242) (bystander to witness, n = 107), defibrillation by EMS provider (n = 21), prehospital ROSC (n = 109), and neurological recovery (n = 5) (Fig. 1). Among the enrolled 4,835 EMS-treated OHCA patients, 4,685 patients (96.9%) were not witnessed by emergency medical service personnel, 4,612 patients (95.4%) had no ROSC prior to transport, and 3,489 (72.2%) patients had no AED shock delivered (Table 1).

Overall, 3,361 (69.5%) patients met all 3 criteria of the BLS TOR rule, and resuscitative efforts for these patients might have been terminated before transport to the hospital if the BLS TOR rule was applied strictly. Of these, 3,224 (95.9%) were dead at discharge (SS, 73.5%; SP, 69.6%; PPV, 95.9%; NPV, 21.3%), and 3,342 (99.4%) showed poor neurologic recovery (SS, 75.2%; SP, 89.9%; PPV, 99.4%; NPV, 11.5%) (Table 2). The cut-off STIs for achieving 100% specificity and 100% positive predictive value for selecting patients were 20 min for hospital mortality with 48

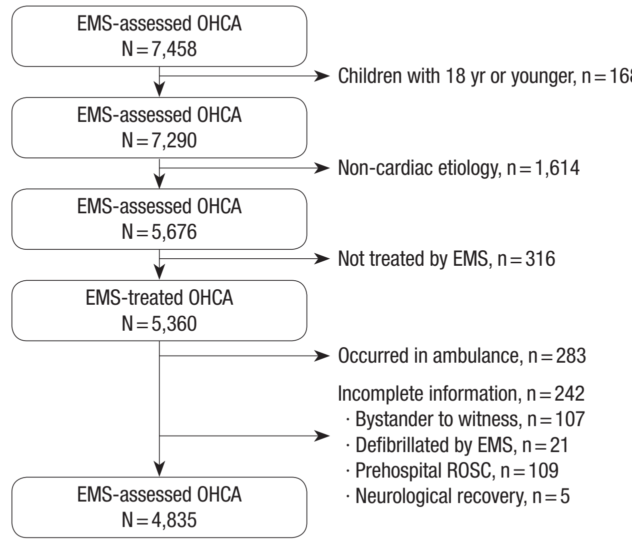

Fig. 1. Patient enrollment flow. EMS, emergency medical service; OHCA, out-of-hospital cardiac arrest; ROSC, return of spontaneous circulation.

Table 1. Demographic findings of study population

Variables		TOR (-)		TOR (+)		Total	
		No.	%	No.	%	No.	%
Total		1,474	100.0	3,361	100.0	4,835	100.0
Gender	Male	1,088	73.8	2,082	61.9	3,170	65.6
	Female	386	26.2	1,279	38.1	1,665	34.4
Age	Years (mean, standard deviation)	61.9	15.1	68.8	15.1	66.7	15.5
Response time interval	Minutes (mean, standard deviation)	6.6	4.3	6.4	3.1	6.5	3.5
Scene time interval	Minutes (mean, standard deviation)	7.6	4.4	7.6	4.6	7.6	4.3
Bystander CPR	Yes	767	52.0	1,963	58.4	2,730	56.5
	No	666	45.2	1,320	39.3	1,986	41.1
	Unknown	41	2.8	78	2.3	119	2.5
Place	Public	510	34.6	602	17.9	1,112	23.0
	Private	964	65.4	2,759	82.1	3,723	77.0
Witnessed	No	410	27.8	1,500	44.6	1,910	39.5
	Yes	936	63.5	1,460	43.4	2,396	49.6
	Unknown	128	8.7	401	11.9	529	10.9
Witnessed by EMS providers	Yes	110	7.5	40	1.2	150	3.1
	No	1,364	92.5	3,321	98.8	4,685	96.9
Prehospital ROSC	No	1,251	84.9	3,361	100.0	4,612	95.4
	Yes	223	15.1	0	0.0	223	4.6
Defibrillation by EMS provider	No	128	8.7	3,361	100.0	3,489	72.2
	Yes	1,346	91.3	0	0.0	1,346	27.8
First ECG	VF/VT	905	61.4	34	1.0	939	19.4
	PEA	96	6.5	428	12.7	524	10.8
	Asystole	372	25.2	2,528	75.2	2,900	60.0
	Nonspecific non shockable	30	2.0	111	3.3	141	2.9
	Unknown	71	4.8	260	7.7	331	6.8
Hospital outcome	Death	1,160	78.7	3,224	95.9	4,384	90.7
	Survival	314	21.3	137	4.1	451	9.3
Neurological recovery	Poor	1,304	88.5	3,342	99.4	4,646	96.1
	Good	170	11.5	19	0.6	189	3.9

TOR, termination of resuscitation; CPR, cardiopulmonary resuscitation; EMS, emergency medical service; OHCA, out-of-hospital cardiac arrest; ROSC, return of spontaneous circulation; VF/VT, ventricular fibrillation/ ventricular tachycardia; PEA, pulseless electrical activity.

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Table 2. Sensitivity, specificity, positive predictive value, and negative predictive value of termination of resuscitation rule (TOR) for hospital mortality and poor neurological outcome at discharge

Outcomes	TOR (-)		TOR (+)		Total		SS	95% CI	SP	95% CI	PPV	95% CI	NPV	95% CI
	No.	%	No.	%	No.	%								
Total	1,474	100.0	3,361	100.0	4,835	100.0								
Hospital outcome														
Death	1,160	78.7	3,224	95.9	4,384	90.7	73.5	72.2-74.8	69.6	65.1-73.8	95.9	95.2-96.6	21.3	19.2-23.4
Survival	314	21.3	137	4.1	451	9.3								
Neurological outcome*														
Poor	1,304	88.5	3,342	99.4	4,646	96.1	75.2	73.8-76.4	89.9	84.7-93.8	99.4	99.1-99.7	11.5	9.9-13.3
Good	170	11.5	19	0.6	189	3.9								

95% CI, 95% confidence interval. *Good neurological outcome was classified by the cerebral performance category with good (1 and 2) and poor (3, 4, or 5). SS, sensitivity; SP, specificity; PPV, positive predictive value; NPV, negative predictive value.

Table 3. Sensitivity analysis for the cut-off scene time interval (STI) for including patients to test the predictive performance of termination of resuscitation (TOR)

STI (min)	Hospital mortality						Poor neurological recovery					
	TOR (+)*		SS (%)	SP (%)	PPV (%)	NPV (%)	TOR (+)*		SS (%)	SP (%)	PPV (%)	NPV (%)
	No.	%					No.	%				
0 ≤	3,361	69.5	73.5	69.6	95.9	21.3	3,361	76.6	71.9	89.9	99.4	11.5
1 ≤	3,341	69.1	73.1	69.6	95.9	21.0	3,341	76.2	71.5	89.9	99.4	11.4
2 ≤	3,278	67.8	71.9	71.8	96.1	20.8	3,278	74.8	70.2	91.0	99.5	11.0
3 ≤	3,127	64.7	68.6	73.4	96.2	19.4	3,127	71.3	67.0	92.1	99.5	10.2
4 ≤	2,907	60.1	63.9	76.3	96.3	17.8	2,907	66.3	62.3	93.1	99.6	9.1
5 ≤	2,614	54.1	57.6	79.8	96.5	16.2	2,614	59.6	56.0	94.2	99.6	8.0
6 ≤	2,171	44.9	47.9	84.3	96.7	14.3	2,171	49.5	46.6	96.8	99.7	6.9
7 ≤	1,807	37.4	40.0	88.5	97.1	13.2	1,807	41.2	38.8	96.8	99.7	6.0
8 ≤	1,462	30.2	32.3	90.2	97.0	12.1	1,462	33.3	31.3	96.8	99.6	5.4
9 ≤	1,177	24.3	26.2	93.3	97.5	11.5	1,177	26.8	25.2	97.9	99.7	5.1
10 ≤	929	19.2	20.7	94.9	97.5	11.0	929	21.2	19.9	98.4	99.7	4.8
11 ≤	674	13.9	15.0	96.2	97.5	10.4	674	15.4	14.5	98.9	99.7	4.5
12 ≤	510	10.5	11.3	97.1	97.5	10.1	510	11.6	11.0	99.5	99.8	4.3
13 ≤	375	7.8	8.3	97.8	97.3	9.9	375	8.6	8.0	99.5	99.7	4.2
14 ≤	276	5.7	6.1	98.2	97.1	9.7	276	6.3	5.9	100.0	100.0	4.1
15 ≤	219	4.5	4.9	98.7	97.3	9.6	219	5.0	4.7	100.0	100.0	4.1
16 ≤	147	3.0	3.3	99.3	98.0	9.6	147	3.4	3.2	100.0	100.0	4.0
17 ≤	112	2.3	2.5	99.6	98.2	9.5	112	2.6	2.4	100.0	100.0	4.0
18 ≤	85	1.8	1.9	99.8	98.8	9.5	85	1.9	1.8	100.0	100.0	4.0
19 ≤	60	1.2	1.3	99.8	98.3	9.4	60	1.4	1.3	100.0	100.0	4.0
20 ≤	48	1.0	1.1	100.0	100.0	9.4	48	1.1	1.0	100.0	100.0	3.9
21 ≤	35	0.7	0.8	100.0	100.0	9.4	35	0.8	0.8	100.0	100.0	3.9
22 ≤	27	0.6	0.6	100.0	100.0	9.4	27	0.6	0.6	100.0	100.0	3.9
23 ≤	22	0.5	0.5	100.0	100.0	9.4	22	0.5	0.5	100.0	100.0	3.9
24 ≤	16	0.3	0.4	100.0	100.0	9.4	16	0.4	0.3	100.0	100.0	3.9

*The total number of patients (n = 4,835) was used to calculate TOR (%) as a denominator. SS, sensitivity; SP, specificity; PPV, positive predictive value; NPV, negative predictive value.

cases (1.0% of all patients) and 14 min for poor neurological recovery with 276 cases (6.3%), respectively (Table 3).

DISCUSSION

We validated the basic life support termination of resuscitation (BLS TOR) rule retrospectively using OHCA data of Seoul metropolitan EMS in Korea. We also tested it by investigating the scene time interval for supplementing the BLS TOR rule.

There were several previous studies suggesting the TOR rule in the BLS system, and a few guidelines for TOR have been proposed by researchers (5, 14, 15). Verbeek et al. (5) reviewed 700 cases in which the BLS defibrillator system was used and found that ROSC, defibrillation, and arrest witnessed by EMS to have the strongest association with survival. From these factors, they proposed the BLS TOR rule. Our study also showed significant differences between the following 3 factors and hospital mortality: witnessed by EMS provider ($P = 0.007$), pre-hospital ROSC ($P < 0.001$), and pre-hospital defibrillation ($P < 0.001$). Our study, however showed, when the BLS TOR rule was applied to the Seoul EMS data, the survival rate of OHCA patients who the BLS TOR rule suggested termination was 4.1% (Table 2). Generally, in clinical rule validation studies, 1% or less survival rate was suggested as reflective of medical futility (16). Because our validation results did not satisfy the medical futility limits, the BLS TOR rule should not be implemented without modification, or a new rule that has a better ability to predict performance should be developed.

Although the BLS TOR rule was validated in other countries and been proven to show high specificity and a positive predictive value (6-11), our study showed a much lower specificity and positive predictive value than other previous validation studies on the same BLS TOR rule. Compared to other previous validation studies with higher specificity, there was a much higher portion of patients who satisfied each criteria of the BLS TOR rule. The reason for this finding was not clear. One of the reasons could be the difference in EMS performance. One of the criteria of the BLS TOR rule is whether a patient had gained ROSC prior to transport. The original rule did not specify a time limit before achieving ROSC at the scene (scene time interval). Because of this vagueness, the TOR rule would produce different results because local EMS systems have different BLS protocols or algorithms for transporting OHCA patients. Therefore, the 2010 AHA guidelines expand on this and recommend applying the TOR rule after three full rounds of CPR and AED analysis (4). Regardless, we still found a low specificity (84.3%) and positive predictive value (96.7%) for hospital mortality when we tested the performance for patients excluding those with STI less than 6 min (Table 3), considering 1 cycle of CPR takes 2 min. For this cut-off STI, 1,190 (35.4%) patients would be excluded. This may imply that Korean EMS tends to be more focused on faster transfer to a designated ED rather than longer in-field procedures such as several cycles of CPR or defibrillation.

Unlike an STI of 20 min in the United States (17, 18), the 7 min of median STI (mean 7.6 min) in our TOR(+) group (median of 9 min of STI even though STI less than 6 min and unresponsive patients were excluded) was too short to achieve ROSC prior to transport or to pronounce death. Our study proposes that the TOR rule should be modified or revised to reflect these CPR protocols. We compare the study results with previous studies performed in Japan and Singapore in Appendix 1 (19, 20). Specificity of the BLS TOR rule in all 3 studies is lower than 0.9, which demonstrates a lower specificity result from previous validation studies performed in North America. A lower specificity of the BLS TOR rule in Asia could imply that the BLS TOR rule could misjudge possible survivors of OHCA or recommend TOR in these patients before they are transported to hospitals.

Our study had a number of limitations. First, our study was a retrospective validation of an existing rule. If we used the rule to validate prospectively, we may have obtained different results. However, it was too hard to validate this TOR rule in the EMS setting due to ethical issues. Second, we excluded a number of patients due to incomplete information which could lead to bias for performance. Third, although a recent study performed in Korea and Japan showed a positive association between intermediate STI from 8 to 16 min and good neurological outcomes after OHCA (21), inclusion of STI in TOR rule could be a controversy because there was only few study regarding relation between STI and patients' outcome. Moreover there is no specific comment in 2010 AHA guideline regarding optimal scene treatment time for EMS personnel providing CPR in the scene. Additionally our study used STI instead of the real treatment time interval, which could reflect the other time frame such as vertical response time. Therefore, the real treatment time interval would be shorter than STI.

In conclusion, the BLS TOR rule showed a relatively low specificity and positive predictive value when retrospectively validated with OHCA data from Seoul, Korea. With additional sensitivity analysis, an STI longer than 20 min for hospital mortality and 14 min for poor neurological recovery was derived to achieve 100% performance of each for a very select group of patients. Further efforts of modifying and validating BLS TOR rule to fit into Korean EMS system is needed in the future based on our study results.

DISCLOSURE

All authors have no potential conflicts of interest to disclose in this study.

AUTHOR CONTRIBUTION

Conceived and designed the experiments: SD Shin, TH Kim. Performed the experiments: TH Kim, YJ Kim, CH Kim. Analyzed the data: TH Kim, JE Kim. Contributed reagents/materials/analysis tools: CH Kim, YJ Kim. Wrote the first draft of the manuscript: TH Kim, SD Shin. Wrote the paper: TH Kim, YJ Kim, CH Kim, SD Shin. ICMJE criteria for authorship read and met: TH Kim, SD Shin. Agree with manuscript results and conclusions: TH Kim, SD Shin, YJ Kim, CH Kim, JE Kim.

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Appendix 1. Comparison of validation studies on basic life support (BLS) termination of resuscitation (TOR) rule in Asian countries for out-of-hospital cardiac arrest

Category	Korea*		Singapore†		Japan‡	
	No.	%	No.	%	No.	%
Sample size, total	4,835		2,269		151,152	
Survival, total	451	9.3	32	1.4	9,516	6.3
BLS TOR rule criteria						
Not witnessed by EMS personnel	4,685	96.9	2,034	89.7	135,273	89.5
No ROSC prior to transport	4,612	95.4	2,226	98.1	113,140	74.9
No AED used	3,489	72.2	1,761	77.6	116,375	77
BLS TOR rule (+)	3,361	69.5	1,559	68.7	113,140	74.9
Death	3,224		1,553		111,980	
Survival	137		6		1,160	
BLS TOR rule (-)	1,474	30.5	710	31.3	38,012	25.1
Death	1,160		684		29,656	
Survival	314		26		8,356	
Sensitivity		73.5		69.4		79.1
Specificity		69.6		81.3		87.8
Positive predictive value		95.9		99.6		99.0
Negative predictive value		21.3		3.7		22.0

*Korea, current study; †Ong ME, Tan EH, Ng FS, Yap S, Panchalingham A, Leong BS, Ong VY, Tiah L, Lim SH, Venkataraman A. Comparison of termination-of-resuscitation guidelines for out-of-hospital cardiac arrest in Singapore EMS. Resuscitation 2007; 75: 244-51. (Reference 19); ‡Kajino K, Kitamura T, Iwami T, Daya M, Ong ME, Hiraide A, Shimazu T, Kishi M, Yamayoshi S. Current termination of resuscitation (TOR) guidelines predict neurologically favorable outcome in Japan. Resuscitation 2013; 84: 54-9. (Reference 20). EMS, emergency medical service; ROSC, return of spontaneous circulation.

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