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Clinical paper

A simple decision rule predicts futile resuscitation of out-of-hospital cardiac arrest

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Abstract

Aim: Resuscitation of cardiac arrest involves invasive and traumatic interventions and places a large burden on limited EMS resources. Our aim was to identify prehospital cardiac arrests for which resuscitation is extremely unlikely to result in survival to hospital discharge.

Methods: We performed a retrospective cohort analysis of all cardiac arrests in San Mateo County, California, for which paramedics were dispatched, from January 1, 2015 to December 31, 2018, using the Cardiac Arrest Registry to Enhance Survival (CARES) database. We described characteristics of patients, arrests, and EMS responses, and used recursive partitioning to develop decision rules to identify arrests unlikely to survive to hospital discharge, or to survive with good neurologic function.

Results: From 2015–2018, 1750 patients received EMS dispatch for cardiac arrest in San Mateo County. We excluded 44 patients for whom resuscitation was terminated due to DNR directives. Median age was 69 years (IQR 57–81), 563 (33.0%) patients were female, 816 (47.8%) had witnessed arrests, 651 (38.2%) received bystander CPR, 421 (24.7%) had an initial shockable rhythm, and 1178 (69.1%) arrested at home. A simple rule (non-shockable initial rhythm, unwitnessed arrest, and age 80 or greater) excludes 223 (13.1%) arrests, of whom none survived to hospital discharge.

Conclusion: A simple decision rule (non-shockable rhythm, unwitnessed arrest, age $\geq$ 80) identifies arrests for which resuscitation is futile. If validated, this rule could be applied by EMS policymakers to identify cardiac arrests for which the trauma and expense of resuscitation are extremely unlikely to result in survival.

Keywords: Out-of-Hospital cardiac arrest, EMS, Prehospital, Resuscitation

Introduction

Over 350,000 patients suffer out-of-hospital cardiac arrest (OHCA) each year in the United States, and emergency medical services (EMS) respond to more than 180,000 of these cases.[1] Resuscitation is attempted on about 60% of cases in which EMS is dispatched with resulting survival rates ranging from 3 to 20%.[2,3] Survival rates vary by region, prehospital and healthcare system, and by characteristics of patients and arrests.[4–6] Traditionally, EMS systems have defaulted to a maximalist resuscitative strategy for all arrests, barring a specific legal directive to the contrary, or obvious signs of death. More recently, researchers have sought to identify patients unlikely to benefit from ongoing resuscitation, in order to reduce the medical, ethical, and financial burdens of futile resuscitation attempts.[7,8]

The potential harms from engaging in futile resuscitations are numerous. Cardiac arrest resuscitation is an invasive procedure, which exposes providers to considerable risk.[9] Many patients achieving return of spontaneous circulation (ROSC) in the field are subsequently pronounced dead in the emergency department (ED) or

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intensive care unit (ICU). In these cases, patients and families are subjected to the trauma of resuscitation, and often to the expense of transport, hospital care, or ICU admission, regardless of the patient's prognosis. Increasing the time from arrest to death without meaningfully increasing likelihood of survival may harm the health and finances of family members. Furthermore, transporting a patient undergoing resuscitation for cardiac arrest can place providers, patients, and the public at risk. Transporting a patient with lights and sirens increases the risk of crashes that can injure or kill responders and bystanders.[9] The cost of managing an OHCA has been estimated at $118,939, regardless of outcome.[10] While this expense is warranted in patients who could potentially survive with a good neurological outcome, the burden on patients and families with no chance of neurologically intact survival is large.

The ethical principle of nonmaleficence proscribes engaging in procedures without a reasonable likelihood of benefit. Despite this, many widely accepted standards indicate resuscitation on any arrest patient who does not have a "do not resuscitate" (DNR) document, is not in rigor mortis, and is not demonstrating lividity, transection, decapitation, or decomposition.[11] Many EMS regions have protocols guiding termination of resuscitation (TOR) based on the Uniform Definition of Death Act, the Milwaukee Criteria, and the Houston Criteria. These protocols, validated in several large studies,[12,13] suggest TOR on patients with unwitnessed arrests, delayed CPR or defibrillation, and no ROSC after 30 min of asystole or pulseless electrical activity (PEA).[14]

TOR guidelines can help to minimize futile transport and escalation of care, but do not address the significant trauma, burden, and risks to first responders associated with the first 30 min or more of a futile resuscitation. There are currently no widely accepted guidelines to identify patients for whom any resuscitation would be futile.

In this study, we develop a simple decision rule that identifies futile resuscitations; that is, cardiac arrests that will not survive to hospital discharge, despite maximal resuscitative efforts. We study four years of cardiac arrest resuscitations from San Mateo County, California, and identify three criteria that collectively characterize resuscitations with no chance of survival. If validated, such a rule could reduce trauma to families and providers, while optimizing the allocation of limited prehospital resources.

Methods

We performed a retrospective cohort analysis of all OHCAs in San Mateo County, CA, for which paramedics were dispatched, from January 1, 2015 to December 31, 2018, using the Cardiac Arrest Registry to Enhance Survival (CARES) database. We described patient demographics (age, gender, race), arrest characteristics (witness to arrest, presence of bystander CPR, AED use, initial rhythm, arrest location), call times (first responder arrival, on-scene time, transport time, total response time), and survival (to ED, admission, and discharge).

We used recursive bipartite partitioning to develop the simplest decision rule (i.e., the rule with fewest elements) that achieves 100% specificity in identifying cardiac arrest patients who will not survive to hospital discharge, using data available from first contact with EMS (age, gender, race, bystander witnessed arrest, bystander CPR, shockable initial rhythm, location of arrest). We developed an alternative rule to identify patients who will not survive with good neurological status (cerebral performance category 1–2). We calculated test characteristics for both rules and described the characteristics of arrests identified by each rule. In auxiliary analyses, we evaluated both rules over the range of potential

Table 1 – Patient, arrest, and EMS response characteristics by outcome.

	All arrests (n = 1706)	Died in field (n = 737)	Died in ED (n = 533)	Died in hospital (n = 243)	Survived to discharge (n = 156)
Patient demographics					
Median age (IQR)	69 (57-81)	69 (58-83)	70 (58-83)	69 (58-80)	62 (51-73)
Female (%)	563 (33.0)	254 (34.5)	168 (31.5)	88 (36.2)	38 (24.4)
White (%)	785 (46.0)	333 (45.2)	249 (46.7)	121 (49.8)	68 (43.6)
Black (%)	70 (4.1)	35 (4.7)	19 (3.6)	12 (4.9)	4 (2.6)
Hispanic (%)	157 (9.2)	65 (8.8)	44 (8.3)	23 (9.5)	19 (12.2)
Asian (%)	247 (14.5)	95 (12.9)	89 (16.7)	36 (14.8)	19 (12.2)
Arrest characteristics					
Bystander witnessed (%)	816 (47.8)	188 (25.5)	330 (61.9)	154 (63.4)	124 (79.5)
Bystander CPR (%)	651 (38.2)	273 (37.0)	195 (36.6)	89 (36.6)	80 (51.3)
Shockable rhythm (%)	421 (24.7)	75 (10.2)	153 (28.7)	72 (29.6)	103 (66.0)
Arrest at home (%)	1178 (69.1)	562 (76.3)	359 (67.4)	168 (69.1)	70 (44.9)
AED shock prior to EMS arrival (%)	316 (18.5)	65 (8.8)	120 (22.5)	52 (21.4)	68 (43.6)
EMS response					
Median time to arrival (IQR)[a]	9.6 (7.3–12.2)	9.5 (7.1–12.1)	9.5 (7.4–11.9)	10.0 (7.8–13)	10.0 (7.4–13.2)
Median time on-scene (IQR)[b]	21.8 (15.0–30.0)	44.0 (35.0–55.0)	22.0 (16.0–30.0)	21.0 (15.9–27.2)	14.0 (10.5–20.0)
Median transport time (IQR)	10.8 (8.0–14.4)		10.6 (8.0–14.4)	11.0 (8.0–14.6)	10.7 (7.6–14.0)
Median total response time (IQR)[c]	42.8 (35.0–50.5)		44.0 (36.0–52.3)	43.5 (36.8–52.0)	37.2 (29.7–44.0)

[a] Minutes from call to first responder at patient side.
[b] Minutes from first responder arrival to ambulance leaving scene.
[c] Minutes from call to ED arrival for patients who were transported.

age thresholds, and described the characteristics of patients arresting at home and in public.

All analyses were performed in *R* (version 3.4). The study was approved by the Stanford University Institutional Review Board (protocol 49,266).

Results

From 2015–2018, 1750 patients received EMS dispatch for cardiac arrest in San Mateo County. We excluded 44 patients on whom efforts were discontinued due to a "do not resuscitate" (DNR) directive. Median age was 69 years (IQR 57–81), 563 (33.0%) patients were female, 816 (47.8%) had witnessed arrests, 651 (38.2%) received bystander CPR, 421 (24.7%) had an initial shockable rhythm, and 1178 (69.1%) arrested at home. Patient, arrest, and EMS response characteristics are described in Table 1. Patients who survived to hospital discharge were younger, more likely to have witnessed arrests, bystander CPR, and shockable initial rhythms compared to the cohort as a whole (Table 1).

We used recursive partitioning to develop a decision rule that excludes any arrests surviving to hospital discharge, and found that three elements were collectively 100% specific for arrests that did not survive to discharge. Of 223 (13.1%) patients aged 80 or greater, with unwitnessed arrests and non-shockable initial rhythms, none survived to hospital discharge (Fig. 1). In our data, this rule was 100% specific and 14.4% sensitive for detection of arrests that would not survive to hospital discharge. Of these patients, 153 were pronounced dead in the field after resuscitation was attempted, 58 died in the ED, and 10 died during hospital admission.

A modified rule (age 80 or greater, non-shockable rhythm, arrest at home) excludes 296 (17.4%) of arrests, of whom none survived with good neurological outcomes (Fig. 2). This rule was 100% specific and 18.6% sensitive in our data for detection of arrests that would not survive with intact neurologic function. Patients arresting at home were older, less likely to have bystander witnessed arrests or to receive bystander CPR, less likely to have shockable initial rhythms or to receive AED shocks, and had longer times to EMS and ED arrival, compared to patients with arrests in other locations (Supplementary Table 1). Age was the least important predictor in both rules (Figs. 1–2). Supplemental Fig. 1 shows the sensitivity of both rules to the range of possible age thresholds.

Table 2 shows the characteristics of arrests meeting criteria for either decision rule. Patients meeting criteria for Rule 1 (age $\geq$ 80, non-shockable rhythm, unwitnessed arrest) had a median EMS response time (from 911 call to ED arrival, if transported) of 47.0 min, compared to 42.8 min for the general cohort. Patients meeting criteria for Rule 2 (age $\geq$ 80, non-shockable rhythm, arrest at home) had a median EMS response time of 43.3 min. Patients meeting criteria for either rule had a median age of 87 (compared to 69 for the general cohort), and were more likely to be female than the general cohort (Table 2).

Discussion

Cardiac arrest resuscitation is traumatic and costly, and identifying patients for whom resuscitation efforts are likely to be futile would benefit patients, families, providers, and EMS systems alike. Though we study arrests in a single EMS system, our arrest characteristics and outcomes are similar to those of multi-center studies.[15,16]

Our results complement a similar decision rule developed in Japan[17] and recently applied to a large database of Canadian OHCA.[18] That study identified similar predictors of futile resuscitation, though with a lower age threshold: age 73 or greater, non-shockable initial rhythm, and unwitnessed arrest.[17] As in the Canadian validation of these "Bokutoh" criteria, 1.2% of resuscitations deemed futile by these criteria in our data would in fact survive to hospital discharge. Unlike the Bokutoh criteria, which were selected from logistic regression coefficients, our use of recursive bipartite partitioning is better conceptually suited to the development of a binary decision rule, and transparently demonstrates the numbers of patients identified by sequential application of the criteria (i.e., non-shockable rhythm, unwitnessed arrest, age $\geq$ 80; Fig. 1). The higher age threshold identified by our model (80, compared to 73 in the Bokutoh criteria) increases specificity to 100% in our data, but awaits validation. Age is the least influential predictor of both Rule 1 and Rule 2, with very few survivors (Rule 1) or survivors with good neurologic outcome (Rule 2) at any age in the cohorts meeting the rules' other criteria. Supplementary Fig. 1 shows the sensitivity of both rules to the range

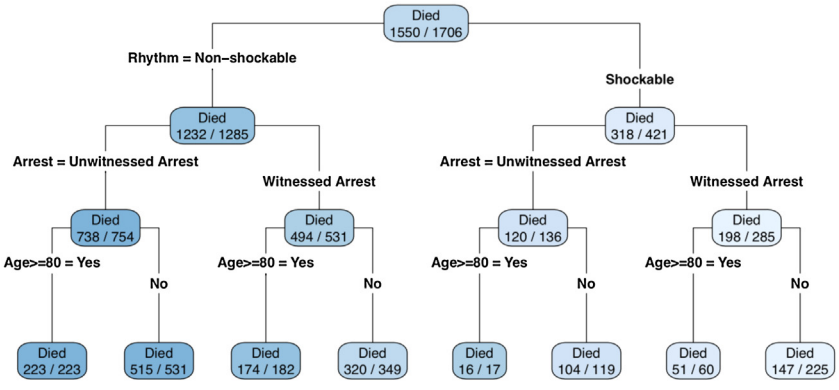

Fig. 1 – Simplified decision tree for OHCA survival (Rule 1). **Cells indicate the fraction of OHCA patients who do not survive to hospital discharge. The partitioning algorithm splits the data sequentially to identify the simplest combination of decisions that is 100% specific for death. The leftmost path in the figure depicts our decision rule for futile resuscitations (non-shockable rhythm, unwitnessed arrest, and age $\geq$ 80), which identifies 223 patients (13.1%), of whom none survive to hospital discharge.**

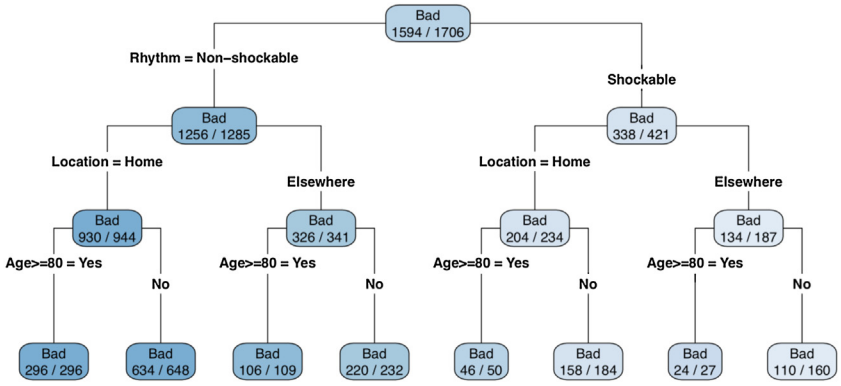

Fig. 2 – Simplified decision tree for OHCA neurologic outcome (Rule 2). **Cells indicate the fraction of OHCA patients who do not survive to hospital discharge with good neurologic status. The partitioning algorithm splits the data sequentially to identify the simplest combination of decisions that is 100% specific for bad neurologic outcome. The leftmost path in the figure depicts our alternative decision rule for futile resuscitations (non-shockable rhythm, arrest at home, and age ≥ 80), which identifies 296 patients (17.4%), of whom none survive with a good neurological outcome.**

Table 2 – Patient, arrest, and EMS response characteristics by inclusion in decision rules.

	All arrests (n = 1706)	Rule 1[a] (n = 223)	Rule 2[b] (n = 296)
Patient demographics			
Median age (IQR)	69 (57-81)	87 (83-91)	87 (83-91)
Female (%)	563 (33.0)	110 (49.3)	138 (46.6)
White (%)	785 (46.0)	92 (41.3)	131 (44.3)
Black (%)	70 (4.1)	6 (2.7)	11 (3.7)
Hispanic (%)	157 (9.2)	14 (6.3)	25 (8.4)
Asian (%)	247 (14.5)	43 (19.3)	53 (17.9)
Arrest characteristics			
Bystander witnessed (%)	816 (47.8)		134 (45.3)
Bystander CPR (%)	651 (38.2)	81 (36.3)	79 (26.7)
Shockable rhythm (%)	421 (24.7)		
Arrest at home (%)	1178 (69.1)	162 (72.6)	
AED shock prior to EMS arrival (%)	316 (18.5)		
EMS response			
Median time to arrival (IQR)[c]	9.6 (7.3–12.2)	9.5 (7.0–12.2)	9.3 (7.0–12.0)
Median time on-scene (IQR)[d]	21.8 (15.0–30.0)	28.0 (21.0–34.8)	24.0 (17.7–31.0)
Median transport time (IQR)	10.8 (8.0–14.4)	11.1 (8.7–15.0)	11.0 (8.8–14.5)
Median total response time (IQR)[e]	42.8 (35.0–50.5)	47.0 (38.9–54.1)	43.3 (37.6–53.0)

[a] Age ≥ 80, non-shockable rhythm, unwitnessed arrest.
[b] Age ≥ 80, non-shockable rhythm, arrest at home.
[c] Minutes from call to first responder at patient side.
[d] Minutes from first responder arrival to ambulance leaving scene.
[e] Minutes from call to ED arrival for patients who were transported.

of possible age thresholds. Determination of age in the field can sometimes be challenging. If the age of the patient is unknown, we suggest that full resuscitation be pursued. Though a lower age threshold would prevent a larger number of resuscitations, the conceptual novelty of prospectively identifying and preempting futile resuscitations encourages, in our opinion, a maximally conservative initial strategy for which the conventionally accepted 1% false positive threshold cited in the Universal TOR Guidelines[19] may be too large, though the appropriate proportion of preempted resuscitations that could conceivably survive is an ethical and societal, rather than a scientific question.

Although we have developed two rules, one identifying arrests that will not survive to discharge, and a second identifying a slightly larger proportion of arrests that will not survive with good neurologic function, we favor the first, more conservative rule, at least for initial application, due to greater potential subjectivity surrounding neurologically compromised survival. We suggest the acronym "NUE" for this rule: Non-shockable initial rhythm, Unwitnessed, Eighty or older. With either rule, the single most discriminating characteristic is presence of a non-shockable initial rhythm (Figs. 1–2), meaning that, in practice, prehospital providers would initiate compressions immediately, apply the AED, and determine the initial rhythm before any determination of futility or decision to terminate resuscitation could be made.

Patients experiencing arrest at home had poorer outcomes than patients arresting elsewhere, due in part to the factors described in Supplementary Table 1 (older age, less bystander CPR, fewer shockable initial rhythms, and longer EMS response times). Additional, unmeasured factors contributing to the lower survival

rates of home arrests may include performance of CPR on suboptimal surfaces (such as on beds), and patient comorbidities that lead the patient to spend more time at home than in public.

Adopting a decision rule for prehospital TOR would increase the number of death declarations in the field. Research has shown that prehospital providers are generally comfortable and effective at terminating resuscitations, and conveying the news to family members,[20,21] with no adverse long-term emotional sequelae.[22] In some cases, family members express preference for prehospital rather than in-hospital TOR.[23] The majority of family members of patients who were pronounced dead in the prehospital setting reported that EMS providers informed the family in a gentle and professional manner.[24] Providers who were not comfortable delivering death notifications often cited lack of formal training.[25] To address the increased burden of prehospital death notification that would follow implementation of a prehospital TOR rule, medical directors could specifically train prehospital providers in delivering death notifications, as such training has been shown to increase provider comfort and improve family members' reception of bad news.[25]

Our study has limitations. Our sample is limited to a single county and does not permit a separate validation cohort. Future research can characterize the performance of our decision rules across multiple EMS systems, and with prospective data. We are also unable to evaluate the role of dispatch-directed CPR, which has been shown to result in better outcomes than no bystander CPR, but poorer outcomes than CPR by a trained bystander or EMS agent.[26–28] While application of our rule could improve the efficiency of prehospital resource utilization, the logistics of an increased number of patients pronounced dead in the field are likely to be complex. Reducing futile resuscitations could decrease fatigue and injuries, and increase the availability of ambulances for other emergency responses. In many EMS systems, however, patients who are pronounced dead in the field stay on site or in the ambulance until retrieved by the coroner, which can take several hours.

Conclusion

Our analysis suggests that cardiac arrests in patients with non-shockable rhythms, unwitnessed arrests, and age 80 or greater are unlikely to respond to resuscitation. These criteria, if validated, could serve as guidelines to prevent futile resuscitation attempts, which are associated with trauma to patients and families, and large burdens on EMS systems.

Conflicts of interest

None.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2019.06.011.

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