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Clinical paper

Evidence-based crisis standards of care for out-of-hospital cardiac arrests in a pandemic

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Abstract

Background & purpose: Pandemics such as COVID-19 can lead to severe shortages in healthcare resources, requiring the development of evidence-based Crisis Standard of Care (CSC) protocols. A protocol that limits the resuscitation of out-of-hospital cardiac arrests (OHCA) to events that are more likely to result in a positive outcome can lower hospital burdens and reduce emergency medical services resources and infection risk, although it would come at the cost of lives lost that could otherwise be saved. Our primary objective was to evaluate candidate OHCA CSC protocols involving known predictors of survival and identify the protocol that results in the smallest resource burden, as measured by the number of hospitalizations required per favorable OHCA outcome achieved. Our secondary objective was to describe the effects of the CSC protocols in terms of health outcomes and other measures of resource burden.

Methods: We conducted a retrospective cohort study of adult patients in the Cardiac Arrest Registry to Enhance Survival (CARES) database. Non-traumatic OHCA events from 2018 were included (n = 79,533). Candidate CSC protocols involving combinations of known predictors of good survival for OHCA were applied to the existing dataset to measure the resulting numbers of resuscitation attempts, transportations to hospital, hospital admissions, and favorable neurological outcomes. These outcomes were also assessed under Standard Care, defined as no CSC protocol applied to the data.

Results: The CSC protocol with the smallest number of hospitalizations per survivor with a favorable neurological outcome was that an OHCA resuscitation should only be attempted if the arrest was witnessed by emergency medical services or the first monitored rhythm was shockable (number of hospitalizations: 2.26 [95% CI: 2.21−2.31] vs. 3.46 [95% CI: 3.39−3.53] under Standard Care). This rule resulted in significant reductions in resource utilization (46.1% of hospitalizations and 29.2% of resuscitation attempts compared to Standard Care) while still preserving 70.5% of the favorable neurological outcomes under Standard Care. For every favorable neurological outcome lost under this CSC protocol, 6.3 hospital beds were made free that could be used to treat other patients.

Conclusion: In a pandemic scenario, pre-hospital CSC protocols that might not otherwise be considered have the potential to greatly improve overall survival, and this study provides an evidence-based approach towards selecting such a protocol. As this study was performed using data generated before the COVID-19 pandemic, future studies incorporating pandemic-era data will further help develop evidence-based CSC protocols.

Keywords: Out-of-hospital cardiac arrest, CSC, COVID-19, Clinical decision rule, Cardiac arrest predictors, CARES database, EMS

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Introduction

Pandemics can lead to shortages in healthcare resources, requiring the development of evidence-based guidelines that optimize the delivery of care during challenging times. The United States has had more deaths from the COVID-19 pandemic than any other country in the world. COVID-19 is associated with a 20.7%−31.4% hospitalization rate, a 4.9−11.5% ICU admission rate and an 11-day median hospital stay, causing massive strains on health care systems.[1,2] In some areas, medical resources such as ventilators, beds, and personal protective equipment (PPE) have been overwhelmed.[3,4] When there is a pervasive shortage of critical health care resources, healthcare leaders are compelled to shift to Crisis Standards of Care (CSC) in order to use resources to save as many lives as possible. The Institute of Medicine outlined five key elements and their associated components that underlie all CSC protocols, which includes that they be evidence-based (Table 1).[5]

The treatment of Out-of-Hospital Cardiac Arrest (OHCA) is resource-intensive, with a minority of cases ending with good patient outcomes. Traditionally, clinical decision rules governing the initiation of resuscitation for OHCA when resources are not limited have been based on a presumed futility model. This model assumes that when treatment is provided to those that would not be resuscitated under a given rule, the resuscitation effort is ineffective with a minimal amount of error, typically involving a threshold of no more than 1% of lives lost. During a pandemic, when resources become severely limited, acceptance of a higher threshold may be necessary to guide decision making. Currently, there is no such evidence-based CSC to guide the initiation of resuscitation for OHCA during a pandemic. If such a CSC were developed, it could reduce unnecessary provider exposure to pathogens while also preserving healthcare resources for those who are most likely to benefit from them.

Our primary objective was to use recent non-pandemic data to evaluate potential CSC protocols for OHCA and identify the protocol that results in the smallest number of hospitalizations per neurologically favorable survivor. Our secondary objective was to describe the effects of the CSC protocols in terms of health outcomes and other measures of resource burden. This information could be utilized by policymakers during a pandemic to make better-informed guidelines.

Methods

Database

We conducted a retrospective cohort study of patients in the Cardiac Arrest Registry to Enhance Survival (CARES) database. CARES contains US OHCA data from 27 state-wide registries and communities in 16 additional states. The catchment area of CARES includes over 135 million people, 1800 Emergency Medical Services (EMS) agencies, and 2200 hospitals.[6,7] The database includes information on bystander response, who performed the initial defibrillation, the initial monitored rhythm, as well as EMS and hospital outcomes. Data from 2018 was extracted for the present study. This study protocol was reviewed and approved by the University at Buffalo's Institutional Review Board and the CARES Research Committee.

Table 1 – The Institute of Medicine's five key elements of crisis standards of care protocols.

A strong ethical grounding
Integrated and ongoing community and provider engagement, education, and communication
Assurances regarding legal authority and environment
Clear indicators, triggers, and lines of responsibility
Evidence-based clinical processes and operations

Selection of subjects

All patients in the database from January 1 through December 31, 2018 were eligible for inclusion. Patients were excluded if they were less than 18 years old, their presumed cardiac arrest etiology was trauma, a resuscitation was not attempted, or they had missing information for age, etiology, resuscitation attempt, arrest witnessed status, first monitored rhythm, or who initiated CPR.

Candidate CSC protocols

Various potential pre-hospital CSC protocols involving known predictors of OHCA survival were created *a priori*. Specifically, these protocols were defined using different combinations of Utstein elements that would be evident upon EMS arrival.[8] These elements included whether the arrest was witnessed by an EMS responder or a bystander, whether a bystander performed CPR, whether the first monitored arrest rhythm was shockable, and whether the first monitored rhythm was idioventricular/pulseless electrical activity (PEA). A total of 12 potential CSC protocols were created. The CSC were defined such that an OHCA should be subjected to a resuscitation attempt only if at least one Ustein element in the CSC was present. For example, the Ustein elements in CSC 1 were "witnessed by EMS" and "first monitored rhythm was shockable". Thus, under CSC1, an OHCA event should be subjected to a resuscitation attempt only if the event was witnessed by EMS or the first monitored rhythm was shockable.

We also evaluated previously published OHCA decision rules that have not allowed for a loss of >1% of those who otherwise would have survived with a favorable neurological outcome. Specifically, we evaluated the rule described by Shibahashi et al.[9] and Grunau et al.[10] (resuscitation terminated for patients aged > = 73 years old and had a non-shockable rhythm and had an unwitnessed cardiac arrest) and the rule described by Glober et al.[11] (resuscitation terminated for patients aged ≥80 years old and had a non-shockable rhythm and had an unwitnessed cardiac arrest).

Outcomes

Outcomes that were used to describe the effects of CSC protocols included: Cerebral Performance Category (CPC) of 1 (good cerebral performance) or 2 (moderate cerebral disability), CPC of 3 (severe cerebral disability) or 4 (coma, vegetative state), admission to hospital, transportation to hospital, resuscitation attempted, return of spontaneous circulation (ROSC), death in the field or resuscitation attempts were ceased due to the presence of a Do Not Resuscitate (DNR) order, pronounced dead in the emergency department (ED), and death in the hospital. A neurologically favorable outcome was any patient who achieved CPC 1−2.

Detailed definitions are provided in the Supplemental Materials.

Statistical analyses

To evaluate our primary objective, we computed the number of admissions to hospital needed to achieve each favorable neurological outcome. This was defined as the number of patients admitted to the hospital divided by the number of patients achieving CPC 1–2. Secondarily, we also computed the number of transportations to hospital per favorable outcome (the number transported to the hospital divided by the number of patients achieving CPC 1–2) and the number of resuscitation attempts per favorable outcome (the total number of resuscitation attempts divided by the number of patients achieving CPC 1–2). These statistics were computed under each CSC protocol. R 3.4.0 (www.r-project.org) was used for analysis.

Results

Population description

We identified 79,533 adult patients who experienced non-traumatic OHCA and underwent resuscitation efforts (Fig. 1). Patient characteristics are included in the appendix (Table S1). The mean age of patients was 65.0 years (sd: 16.8) and 37.8% were female. The most common presumed arrest etiology was 'presumed cardiac etiology', representing 82.6% of all patients. A lay person initiated CPR in 39.9% of cases. The first monitored rhythm was shockable (ventricular fibrillation, ventricular tachycardia, or unknown shockable rhythm) in 18.7% of cases, and was idioventricular/PEA in 22.0% of cases (Table S1).

Current OHCA practice

Current OHCA practice without a pandemic CSC produced the 79,533 resuscitation attempts included in our total population (Table 2, Standard Care). These attempts resulted in 50,636 patients (63.7% of resuscitation attempts) being transported to the hospital, 22,415 (28.2%) being admitted to the hospital, and 6479 (8.1%) achieving a favorable neurological outcome of CPC 1–2; the remaining patients either died, had an unfavorable neurological outcome of CPC of 3–4, or were lost to follow-up.

CSC protocols

Potential pandemic CSC protocols were applied to the data to limit the types of OHCA cases that could be subjected to a resuscitation attempt (CSC 1 through CSC 12). The frequencies of outcomes under each CSC are shown in Table 2. For example, under these protocols, the number of resulting resuscitations ranged from 12.7% (CSC 2) to 78.0% (CSC 12) compared to Standard Care, while the number of patients achieving CPC 1–2 ranged from 21.9% (CSC 2) to 95.9% (CSC 12) of Standard Care.

CSC 1 (requiring that the first monitored rhythm was shockable or that the OHCA was witnessed by EMS) was the protocol that resulted in the smallest number of hospitalizations needed to achieve a positive outcome. Specifically, under CSC 1, 2.26 (95% CI: 2.21–2.31) hospital admissions were required to achieve one favorable neurological outcome, while under Standard Care, 3.46 (95% CI: 3.39–3.53) were required. CSC 1 also resulted in the smallest number of transportations to the hospital and the number of resuscitations per survivor with a favorable neurological outcome. For example, under CSC 1, 5.09 (95% CI: 4.96–5.22) resuscitation attempts were required to achieve one favorable neurological outcome, while under Standard Care, 12.28 (95% CI: 12.00–12.57) were required. Numbers needed to achieve a positive outcome under all considered decision rules are shown in Fig. 2.

CSC 1 led to large reductions in healthcare utilization relative to Standard Care. Specifically, CSC 1 resulted in 46.1% of the hospitalizations of Standard Care (12,088 beds freed), 39.7% of the transports to the hospital (30,520 fewer transportations), and 29.2% of the resuscitation attempts (56,319 fewer attempts) (Table 2). CSC 1 also led to 70.5% of neurologically favorable outcomes (1914 fewer patients with CPC 1–2). While other protocols resulted in larger reductions in hospital admissions or smaller reductions in favorable neurological outcomes, CSC 1 showed the greatest enrichment of neurologically favorable outcomes relative to the percentage of patients hospitalized (Fig. 3).

Previously described OHCA decision rules that required a threshold of no more than 1% of favorable outcomes lost were confirmed to preserve approximately 99% of the favorable outcomes compared to Standard Care (Table S3). However, these rules resulted

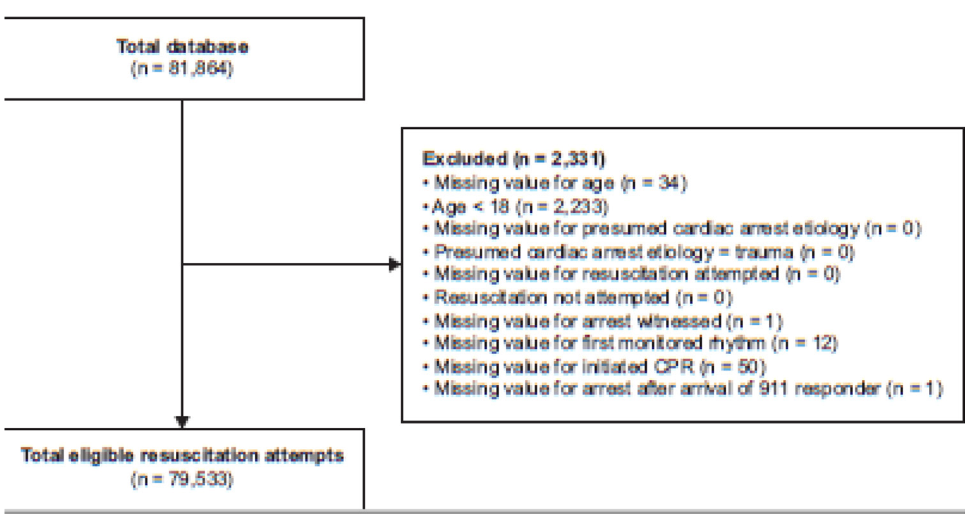

Fig. 1 – Population selection.

Table 2 – Outcome counts by decision rule.

Decision rule	Standard Care	CSC 1	CSC 2	CSC 3	CSC 4	CSC 5	CSC 6	CSC 7	CSC 8	CSC 9	CSC 10	CSC 11	CSC 12
Witnessed by EMS	–	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Witnessed by bystander	–	–	–	Or Yes	–	Or Yes	Or Yes	–	Or Yes	–	Or Yes	–	Or Yes
Bystander CPR	–	–	–	–	Or Yes	–	Or Yes	Or Yes	Or Yes	–	–	Or Yes	Or Yes
First monitored rhythm shockable	–	Or Yes	–	–	–	Or Yes	–	Or Yes	Or Yes	Or Yes	Or Yes	Or Yes	Or Yes
First monitored rhythm idioventricular/PEA	–	–	–	–	–	–	–	–	–	Or Yes	Or Yes	Or Yes	Or Yes
Total resuscitation attempts	79,533 (100%)	23,214 (29.2%)	10,081 (12.7%)	40,053 (50.4%)	41,797 (52.6%)	44,254 (55.6%)	56,139 (70.6%)	47,911 (60.2%)	58,543 (73.6%)	35,844 (45.1%)	49,786 (62.6%)	55,096 (69.3%)	62,017 (78.0%)
No ROSC	54,580 (100%)	12,739 (23.3%)	5812 (10.6%)	23,255 (42.6%)	27,319 (50.1%)	25,985 (47.6%)	36,064 (66.1%)	30,824 (56.5%)	37,640 (69.0%)	20,350 (37.3%)	29,544 (54.1%)	35,227 (64.5%)	39,899 (73.1%)
Dead in field or efforts ceased due to DNR	28,897 (100%)	3098 (10.7%)	929 (3.2%)	8569 (29.7%)	13,556 (46.9%)	9533 (33.0%)	17,398 (60.2%)	14,642 (50.7%)	17,909 (62.0%)	6294 (21.8%)	11,191 (38.7%)	16,482 (57.0%)	18,931 (65.5%)
Transported to hospital	50,636 (100%)	20,116 (39.7%)	9152 (18.1%)	31,484 (62.2%)	28,241 (55.8%)	34,721 (68.6%)	38,741 (76.5%)	33,269 (65.7%)	40,634 (80.2%)	29,550 (58.4%)	38,595 (76.2%)	38,614 (76.3%)	43,086 (85.1%)
Pronounced dead in the ED	28,095 (100%)	9731 (34.6%)	4946 (17.6%)	16,046 (57.1%)	14,938 (53.2%)	17,811 (63.4%)	20,526 (73.1%)	17,388 (61.9%)	21,592 (76.9%)	14,977 (53.3%)	20,009 (71.2%)	20,402 (72.6%)	22,994 (81.8%)
Admitted to hospital	22,415 (100%)	10,327 (46.1%)	4179 (18.6%)	15,354 (68.5%)	13,243 (59.1%)	16,821 (75.0%)	18,124 (80.9%)	15,802 (70.5%)	18,947 (84.5%)	14,489 (64.6%)	18,486 (82.5%)	18,116 (80.8%)	19,987 (89.2%)
Died in hospital or CPC3 -4	15,750 (100%)	5645 (35.8%)	2713 (17.2%)	9,977 (63.3%)	8631 (54.8%)	10,884 (69.1%)	12,161 (77.2%)	10,062 (63.9%)	12,705 (80.7%)	9091 (57.7%)	12,298 (78.1%)	12,003 (76.2%)	13,590 (86.3%)
Died in hospital	14,211 (100%)	4926 (34.7%)	2397 (16.9%)	8889 (62.6%)	7721 (54.3%)	9687 (68.2%)	10,890 (76.6%)	8950 (63.0%)	11,365 (80.0%)	8034 (56.5%)	10,961 (77.1%)	10,702 (75.3%)	12,162 (85.6%)
CPC 3-4	1,539 (100%)	719 (46.7%)	316 (20.5%)	1,088 (70.7%)	910 (59.1%)	1,197 (77.8%)	1,271 (82.6%)	1,112 (72.3%)	1,340 (87.1%)	1,057 (68.7%)	1,337 (86.9%)	1,301 (84.5%)	1,428 (92.8%)
CPC 1-2 (favorable neurological outcome)	6,479 (100%)	4,565 (70.5%)	1,416 (21.9%)	5,225 (80.6%)	4,468 (69.0%)	5,773 (89.1%)	5,790 (89.4%)	5,579 (86.1%)	6,066 (93.6%)	5,240 (80.9%)	6,010 (92.8%)	5,939 (91.7%)	6,215 (95.9%)
Lost to follow-up	312 (100%)	175 (56.1%)	77 (24.7%)	236 (75.6%)	204 (65.4%)	253 (81.1%)	264 (84.6%)	240 (76.9%)	271 (86.9%)	242 (77.6%)	278 (89.1%)	270 (86.5%)	287 (92.0%)

"–" indicates that no requirement regarding the indicated criterion was imposed. Parentheses indicate row percentages (i.e. percentage of the respective outcome count under Standard Care).

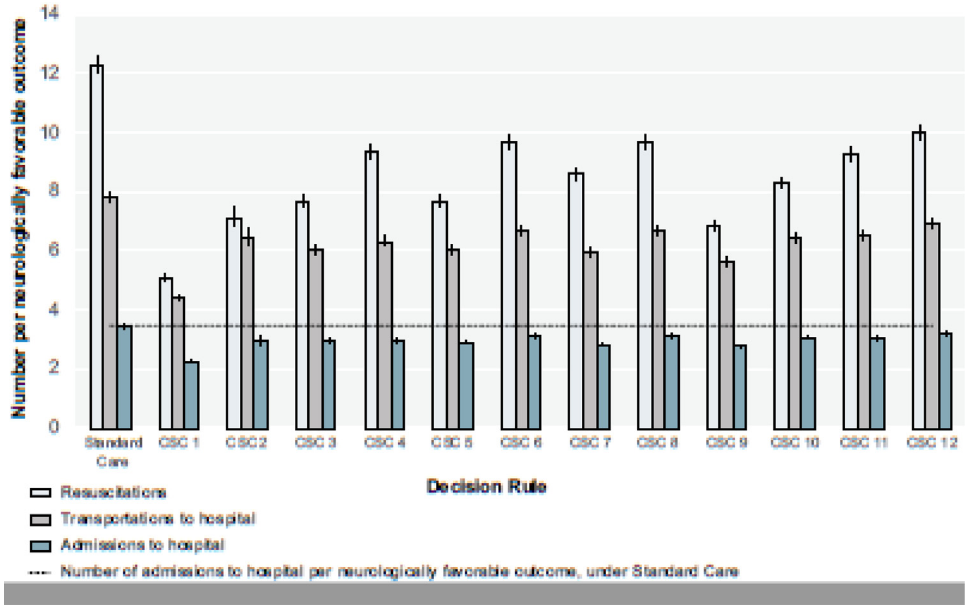

Fig. 2 – Effects of decision rules on the number of resuscitations, transportations to hospital, and admissions to hospital needed to achieve each favorable neurological outcome (CPC1-2).
This figure shows the number of resuscitations, transportations to hospital and admissions to hospital needed to achieve a favorable neurological outcome (CPC 1−2). For example, a number of hospitalizations per survivor of 5 would indicate that for every five patients admitted to the hospital, one patient has a favorable neurological outcome. The dashed line is a visual reference line indicating the number of admissions to hospital per survivor under Standard Care. Error bars indicate 95% confidence intervals. The numbers illustrated in this chart are provided in Table S2.

in modest reductions in resource utilization compared to the CSC protocols (Table S3).

Discussion

This study describes the impacts of potential pandemic CSC protocols for initiation of resuscitation for OHCA. Under normal circumstances, priority in the management of OHCA is given to maximizing favorable neurological survival. The resource burden required to achieve that outcome is typically a secondary consideration in resource-rich environments. Past studies examining the impacts of OHCA decision rules did not allow for a greater than 1% miss rate for neurologically intact survivors,[9−11] and they may already be implemented in some EMS systems across the country. In our study, these rules did not show as significant of a decrease in resuscitation attempts, transports to hospitals, and hospitalizations as compared to the CSC protocols we evaluated.

Given the severe stresses that COVID-19 has placed on healthcare systems around the globe, limits on resources may be unavoidable. In such situations, consideration must be given to the development of CSC protocols that more efficiently allocate scarce resources and maximize the number of overall lives saved, even though this may come at the expense of individual lives that could be saved under standard practice. In addition, particularly in an infectious disease pandemic where cardiac arrest resuscitation is highly likely to involve multiple personnel and may require procedures such as endotracheal intubation that increase exposure risk, each interaction increases the risk that an EMS or hospital care provider may become infected. This additional risk, which could contribute to the spread of disease and further deplete critical resources, must be considered against the potential for benefit.[4] Consistent with this, the American Heart Association released a statement on April 9th 2020 speaking to the importance of reducing provider risk and to consider the appropriateness of starting and continuing resuscitation regarding those suspected and confirmed COVID-19 patients.[12]

This study provides a model for evaluating the effects of different CSC cardiac arrest protocols, which aids in creating the evidence critical for the difficult decision-making that may be necessary during the COVID-19 pandemic and future healthcare crises. The CSC protocols we evaluated involved easily implementable decision points so that these protocols could be enacted quickly if needed. The healthcare system has already had to make decisions regarding allocation of resources and care in response to COVID-19. One such example is the distribution and use of ventilators in areas without enough equipment when compared to need. These triage decisions have the benefit of being made in a calculated fashion which include committees, calculation of a Sequential Organ Failure Assessment score, and repeated assessments.[13] In contrast, cardiac arrest care must be enacted quickly to provide the greatest likelihood of survival and as such, guidelines must be uncomplicated and easy to apply in stressful situations.

Our model specifically looked to maximize the number of hospital beds that could be made available by withholding pre-hospital resuscitations so that other patients with a higher likelihood of survival can be treated. As such, unlike previous studies, it considers decision rules that allow for greater than 1% loss of lives that otherwise would have survived with a good neurological outcome. While any loss of life is tragic, the proportionally larger number of beds freed could save an overall greater number of lives.

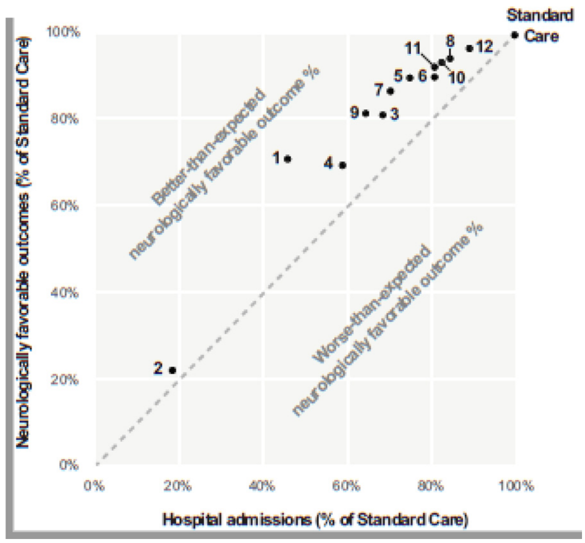

Fig. 3 – Neurologically favorable outcomes (CPC 1-2) vs. hospital admissions, relative to Standard Care.
This figure shows neurologically favorable outcomes and hospital admissions under each candidate CSC protocol, expressed as a percentage of these respective outcomes achieved under Standard Care. Numbers next to dots indicate CSC number. The diagonal line indicates the expected percentage of patients with a neurologically favorable outcome relative to the percentage of patients hospitalized, assuming no enrichment in favorable outcomes. Increasing vertical distance from this line indicates greater enrichment of neurologically favorable outcomes. The numbers illustrated in this chart are provided in Table 2.

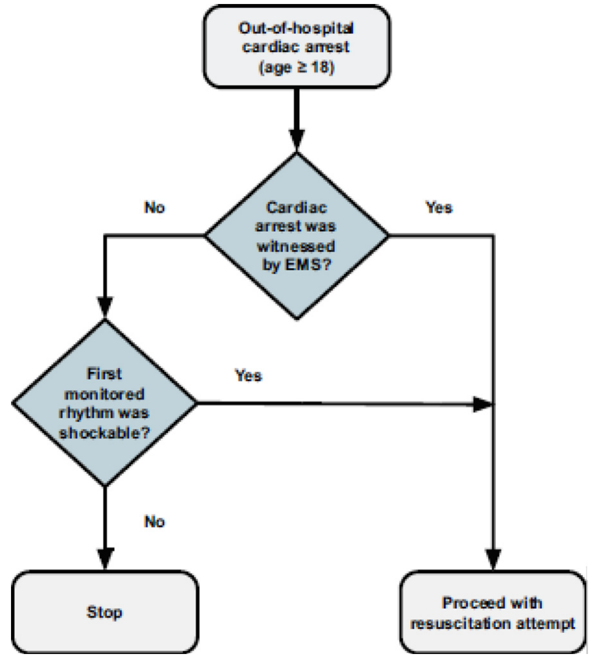

Fig. 4 – Crisis standard of care (CSC) protocol 1.

Our results identified CSC 1 (Fig. 4) as the protocol that resulted in the smallest number of hospitalizations needed to achieve a favorable OHCA outcome. In this scenario, where the arrest must be witnessed by EMS or the first monitored rhythm must be shockable in order to attempt a resuscitation, resulted in 12,088 hospital beds freed and 1914 lives lost from OHCA that could otherwise have been saved (i.e., 6.3 hospitals beds freed per OHCA life lost). If those 12,088 freed beds could be used to save more than 1914 lives (such as by using them to treat COVID-19 patients instead), then implementing this decision rule has the potential to improve overall survival in the population. Similarly, we observed that CSC 1 resulted in 56,319 fewer resuscitation attempts, which could also free up resources during times of constraint on EMS resources as well as reduce exposure to pandemic illness when personal protective equipment is limited. Both hospital teams and EMS systems must choose the CSC protocol that is most appropriate given their available resources as well as exposure risks and define their triggers for initiation clearly as outlined by the IOM guidelines. It is important to add that selection of a CSC must take in consideration the magnitude of resources in short supply and contrast that with allowable loss of those OHCA survivors who, under standard care, would have a good neurological outcome.

Adoption of any of the proposed CSC protocols in the present study may result in an ethical crisis for individual providers as well as the public, since each scenario reduces survival of OHCA relative to standard practice by limiting resuscitation attempts. Yet the potential for maximizing lives saved by "freeing up" hospital beds and allocating healthcare resources reflects the distributive justice principles that must be pursued when such resources are limited.[14] The Institute of Medicine names fairness as the first ethical operating principle during disasters,[15] and the attempt to save the most lives, even at the expense of some others, is consistent with fairness. It treats individuals equally according to their likelihood of benefitting from treatment and ignores morally irrelevant features such as age (considered as such), ability to pay, or expected quality of life. Distributing care according to who is most likely to survive is the value with the most consensus during a pandemic where resources are insufficient to treat everyone who might benefit.[3,4,16] Individuals who experience OHCA must be treated the same as those with COVID-19 and any other patients who need hospital beds in a time of scarcity[4]; the proposed CSC protocol meets this standard. Moreover, establishing a CSC protocol has the further ethical benefits of promoting transparency, of saving EMS providers from making difficult triage decisions on the front lines, and of preventing the need to face the difficult ethical decision to later withdraw a scarce resource in order to save others.

A limitation of this study is that it does not directly weigh the resource burden and survivability of OHCA against that of COVID-19 or any other potential pandemic or disaster. At the time of study, available COVID-19 survival and resource utilization data was inadequate and highly variable, making extrapolation unreliable and beyond the scope of the present study. Future studies may more readily evaluate healthcare burden when more reliable data regarding the epidemiology of COVID-19 in the US is available. The COVID-19 pandemic may lead to further shifts in cardiac arrest etiologies and bystander's willingness to perform CPR, which could further affect the model.

Information from this database may not be fully generalizable. The cardiac arrest data was captured prior to pandemic onset and thus is not representative of cardiac arrest care in a pandemic situation.

Additionally, the data reflects healthcare practice within certain regions of the United States, and is not a true nationwide study. CARES is an opt-in program which may lend itself to portraying better outcomes as those who contribute to the database are more likely to provide the most current and effective care.

Finally, reductions in healthcare utilization predicted by this model also assume compliance with the CSC protocol by the EMS personnel directly providing care. These models are built by taking a broad view on how we may best utilize our resources to care for the entire population, but EMS providers take care of one patient at a time, making these decisions emotionally distressing for providers and families. Thus, in development of CSC protocols, the other key elements, including education, engagement and communication with providers and the public, cannot be ignored. Implementation of any CSC protocol requires that leadership prepares providers and the public for the possible need for CSC, educates providers to communicate with families, and supports them when they face decisions that violate standards care.[17] For example, training prehospital providers using a structured communication model could improve confidence and competence regarding delivering a death notification.[18]

Conclusion

Using known predictors of OHCA survival, we described possible pre-hospital clinical decision rules that could be used as CSC protocols for OHCA, potentially increasing the total number of lives saved in a pandemic scenario. Further studies are needed to determine how such outcomes for a given CSC are impacted by a pandemic or other resource-poor situations. While a true cost-benefit analysis could not be completed due to variability in the current information regarding COVID-19, this study provides guidance for EMS advisors to better understand the consequences of implementing potential decision rules.

Conflicts of interest statement

Disclosure: Dr. Clemency is a speaker for Stryker.

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CRediT authorship contribution statement

Peter Natalzia: Conceptualization, Methodology, Formal analysis, Data curation, Writing - original draft, Visualization. **William Murk:** Conceptualization, Methodology, Formal analysis, Data curation, Writing - original draft, Visualization. **Jeffrey J. Thompson:** Conceptualization, Writing - original draft, Visualization. **Maia Dorsett:** Conceptualization, Writing - original draft, Visualization. **Jeremy T. Cushman:** Conceptualization, Writing - original draft, Visualization. **Philip Reed:** Conceptualization, Writing - original draft. **Brian M. Clemency:** Supervision, Conceptualization, Methodology, Formal analysis, Writing - original draft, Visualization.

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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.2020.07.021.

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