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## Clinical paper

# Prospective validation of the Good Outcome Following Attempted Resuscitation (GO-FAR) score for in-hospital cardiac arrest prognosis<sup>☆</sup>



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### Abstract

**Aim:** We aimed to prospectively validate the Good Outcome Following Attempted Resuscitation (GO-FAR) score, which predicts the likelihood of survival to discharge neurologically intact or with minimal deficits (conscious, alert, and able to work) after in-hospital cardiac arrest (IHCA).

**Methods:** Inpatients experiencing an index episode of IHCA between 2010 and 2016 in hospitals participating in the Get With the Guidelines<sup>®</sup> — Resuscitation (GWTG-R) Registry were included. The score's performance was prospectively validated in both all GWTG-R hospitals and in a subset of hospitals not part of the GWTG-R registry when the score was originally developed using prospective data. Score performance was stratified by hospital size, presence of residency training programs, and type of hospital ownership. Discrimination was measured by the c-statistic, calibration using a Hosmer-Lemeshow plot, and classification accuracy by the survival rates in each risk group.

**Results:** A total of 62,131 inpatients in 386 hospital were included. The GO-FAR score had similar discrimination (c-statistic 0.75, 95% CI 0.748–0.758), calibration, and classification accuracy as in the original study. Survival rates were somewhat higher due to a secular increase in survival of IHCA. In hospitals that were not part of the derivation population, the score performed as well as in the hospitals used to derive the score (c-statistic 0.75). The score performed similarly in hospitals of different sizes (c-statistic of 0.80 and 0.75 for hospital with  $\leq 100$  and  $> 100$  beds, respectively), with and without residency training programs (c-statistics of 0.76 and 0.75, respectively), and with different ownership structures (c-statistic of 0.79 for private, 0.74 for military government, and 0.76 for nonprofit hospital).

**Conclusions:** The GO-FAR score accurately classifies patients into risk groups based on their likelihood of survival to discharge with a good neurologic outcome following an episode of IHCA. Recalibration may be necessary using different point score cutoffs as IHCA survival increases.

**Keywords:** Resuscitation, Cardiac arrest, Cardiopulmonary arrest, Mortality, Clinical prediction rules, Prognosis

## Introduction

Each year in the United States 209,000 adults experience an episode of in-hospital cardiac arrest (IHCA),<sup>1</sup> with an annual incidence of 2.85

per 1000 hospital admissions.<sup>2</sup> Survival to discharge following IHCA increased between 2003 and 2011, with an overall rate of survival to discharge of 18.4%, and a 9.8% rate of survival to discharge with a good neurologic outcome or with minimal deficits.<sup>2–5</sup> Interestingly, there is an inverse relationship between a hospital's incidence of IHCA

<sup>☆</sup> Notation of prior abstract presentation: 2017 North American Primary Care Research Group Annual Meeting.

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<https://doi.org/10.1016/j.resuscitation.2019.05.002>

Received 1 November 2018; Received in revised form 28 April 2019; Accepted 1 May 2019

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and the survival rate.<sup>2,6</sup> One possible explanation is that more accurate identification of patients unlikely to benefit from cardiopulmonary resuscitation (CPR) leads to a higher survival rate, by focusing resuscitation efforts on patients most likely to benefit.<sup>2</sup> An accurate clinical decision rule to predict the outcome of IHCA could assist both patients and physicians regarding the decision to write a do-not-resuscitate (DNR) order. Such a rule answers the clinical question: if my patient experiences an IHCA, what is the likelihood of a favorable clinical outcome?

The Good Outcome Following Attempted Resuscitation (GO-FAR) score was developed to predict the likelihood of survival to discharge neurologically intact or with minimal deficits among hospitalized adults experiencing an episode of IHCA, using exclusively variables knowable prior to arrest. It was developed using data from 366 hospitals participating in the Get With the Guidelines Registry-Resuscitation (GWTG-R) dataset between 2007 and 2009.<sup>7</sup> Using the score, nearly a quarter of patients could be identified as having a very low or low likelihood of survival to discharge with a good neurologic outcome.<sup>7</sup> Of those patients, only 1.4% had a good outcome at discharge, defined as a Cerebral Performance Category score of 1.<sup>7</sup> The score discriminated well, with a c-statistic of 0.78 and excellent calibration.<sup>7</sup> Recently, the GO-FAR score was successfully validated in a population of 287 Swedish inpatients.<sup>8</sup>

The goal of the current study was to prospectively validate the GO-FAR score. In the primary validation, this was done temporally (using data from the GWTG-R dataset gathered since 2010), in a new population (by examining performance separately in hospitals not part of the original dataset), and after excluding two predictors, “hypotension or hypoperfusion” and “respiratory insufficiency” which are usually only available closely to the time of cardiac arrest. In secondary validations, we also examined the performance in different types of hospitals, based on their size, type of ownership, and teaching status. We examined performance of the GO-FAR score separately in African-American patients, who have had lower reported rates of survival to discharge following IHCA.<sup>9,10</sup>

## Methods

The GO-FAR score consists of 13 variables, and is shown in Table 1 (detailed definitions are in e-Table 1). The outcome predicted by the GO-FAR score is the likelihood of survival to discharge following an episode of IHCA with a Cerebral Performance Category (CPC) score of 1, which means that patient is neurologically intact or with minimal deficits (conscious, alert, able to work). Patients with score  $\geq 24$ , 14 to 23,  $-5$  to 13, and  $-15$  to  $-6$  are classified into very low ( $<1\%$ ), low ( $1\%$ – $3\%$ ), average ( $>3\%$  to  $15\%$ ), and above average ( $>15\%$ ) risk groups of survival with CPC score of 1.<sup>7</sup>

In the current study, we used data from hospitals participating in the GWRG-R between January 1st 2010 and January 31st 2016 to prospectively validate the GO-FAR score. Detailed information about the GWRG-R dataset has been previously published.<sup>11</sup> We limited our analysis to adult inpatients experiencing an initial episode of IHCA. Patients who survived to discharge but lacked an assessment of CPC at discharge were excluded. Patients who were missing any of 13 predictor variables or survival status at discharge were also excluded. A comparison concluded that there were no clinically meaningful differences between included and excluded patients with regards to their age distribution, admitting diagnoses, or comorbidities (data available upon request). Since September

**Table 1 – The Good Outcome Following Attempted Resuscitation (GO-FAR) score in the original derivation population.<sup>7</sup>**

Predictors	GO-FAR score	
Neurologically intact or with minimal deficits at admission	–15	
Major trauma	10	
Acute stroke	8	
Metastatic or hematologic cancer	7	
Septicemia	7	
Medical noncardiac diagnosis	7	
Hepatic insufficiency	6	
Admit from skilled nursing facility	6	
Hypotension or hypoperfusion	5	
Renal insufficiency or dialysis	4	
Respiratory insufficiency	4	
Pneumonia	1	
Age, year		
70–74	2	
75–79	5	
80–84	6	
$\geq 85$	11	
Likelihood of survival with a good outcome (CPC = 1)	GO-FAR Score	Survivors with CPC = 1/ total patients at risk group (%)
Very low ( $<1\%$ )	$\geq 24$	13/2,049 (0.6)
Low ( $1\%$ – $3\%$ )	14 to 23	99/4,381 (2.3)
Average ( $>3\%$ – $15\%$ )	$-5$ to 13	1,122/12,084 (9.3)
Above average ( $>15\%$ )	$-15$ to $-6$	1,147/4,112 (27.9)

2012, the variable describing residence prior to admission (res\_pri) has no longer been collected by the GWRG-R. Thus, for episodes having the res\_pri variable, the GO-FAR score was calculated from all 13 variables. For episodes without this variable, the GO-FAR score was calculated from the remaining 12 variables. These results are reported separately.

A chi-square test was used to compare the survival rates of CPC score of 1 between sites, presence of res\_pri variable, hospital's characteristics, and race. For each validation, we reported the percentage of patients in each risk category and the percentage of survivors with a CPC score of 1 within each category (classification accuracy). The C statistic (also known as the area under the receiver operating characteristic curve) was used to evaluate discrimination. Finally, calibration was evaluated using calibration plots of observed vs expected survival and the Hosmer-Lemeshow statistic.

### Prospective validation

First, we examined the performance of the GO-FAR score for all patients in the GWTG-R registry experiencing IHCA between January 1st, 2010 and January 31st, 2016 (temporal validation). We also prospectively validated the GO-FAR score using data from 2010 till 2016 in a subset of hospitals that were not part of the original derivation population. Thus, we examined performance of the GO-FAR score in hospitals that were not used to develop the original score (validation in a new population). Two of the GO-FAR predictors, “hypotension or hypoperfusion” and “respiratory insufficiency” are recorded in the registry using the most recent value prior to cardiac arrest. As these predictors may change from the time of admission to the time of cardiac arrest, we also validated the score's performance without these predictors in the full cohort.

### Validation in subgroups

Performance of the GO-FAR score was evaluated in hospital subgroups by hospital size, teaching status, and the type of ownership. Hospital size was categorized into a hospital with 100 or fewer beds versus more than 100 beds. Teaching status was yes if a hospital had any residency training programs, and ownership was classified into three groups: military or government, nonprofit, and private hospitals. We also compared the performance of the GO-FAR score in African-American patients, and with and without the availability of the residence prior to admission variable.

All analyses were conducted with the Stata version 14.0 (StataCorp, College Station, TX). The Institutional Review Board at the University of Georgia reviewed the protocol and classified the study as “not human research”.

## Results

A total of 62,131 adult inpatients with IHCA in 386 hospitals were included in this validation (e-Figure 1). The mean age of patients in the GWTG-R experiencing IHCA between 2010 and 2016 was 65.3 years old, and 58.3% were male. The percentage of white, black, and other races were 70.0%, 23.2%, and 6.8%, respectively. Among the 386 hospitals in this analysis, 228 participated in GWTG-R before 2010; the data from those sites from 2007 to 2009 was previously used to develop the GO-FAR score. Of the sites whose characteristics are known, 79.1% had more than 100 beds (250/316), 49.7% had a training program (178/358), 16.2% were military or government ownership type (59/365), and 70.1% were nonprofit ownership type (256/365). The bivariate analysis between patient characteristics and the likelihood of surviving to discharge with good neurologic function or minimal deficits is shown in e-Table 2. A comparison of patient characteristics between the old and new sites is shown in e-Table 3, and the percentage of patient at each GO-FAR score among the overall cohort is described in e-Figure 2.

The rates of survival to discharge with a CPC score of 1 stratified by key hospital variables and race are presented in Table 2. Of 62,131 included episodes, there were 14,488 survivors to discharge (23.3%), of whom 9347 had a CPC score of 1 on discharge (15.0%). This compares with an overall rate of survival to discharge with CPC score of 1 of 10.4% in the original derivation study. The overall rate of survival to discharge with a CPC score of 1 was significantly lower in the hospitals added to the GWTG-R registry since 2010 (14.3% vs 15.3%,  $p=0.008$ ), in hospitals with 100 or fewer beds (13.7% vs 15.2%,  $p=0.014$ ), in hospitals without a residency training program (13.6% vs 15.9%,  $p<0.001$ ), and in private hospitals than in military/government or non-profit hospitals (10.2% vs 15.0% vs 15.6%, respectively,  $p<0.001$ ). The survival rate with CPC score of 1 was lower in African American patients than non-African American patients (12.0% vs 16.0%,  $p<0.001$ ).

The classification accuracy and c-statistic of the GO-FAR score in different validation populations is described in Table 3. In the entire prospective dataset (2010–2016), the score identified 7.1% and 16.5% of patients as a very low and low likelihood of a good outcome, with 1.6% and 3.7% surviving with neurological intact or with a minimal deficit in those groups, respectively. ROC curves for new and old sites where the res\_pri (prior residence) variable was available are shown in Fig. 1a and b. Among the entire cohort, the area under the ROC curve or c-statistic was 0.75, slightly lower than that in the original derivation population (0.77). The score had good calibration (Fig. 2a and b). Although the score systematically underestimated the likelihood of survival with CPC score of 1, the predicted probabilities were still close to the observed probabilities in the groups of very low (0.8% vs 1.6%) and low (2.0% vs 3.7%) likelihood of survival with good outcome. Calibration was better when the res\_pri (prior residence) variable was available than when it was not (Hosmer-Lemeshow  $\chi^2_{10}$  statistic of 74.4,  $p<0.001$  versus a Hosmer-Lemeshow  $\chi^2_{10}$  statistics of 412.3,  $p<0.001$ , respectively). There were significant differences between predicted and observed probabilities of CPC score of 1; however, this might be because of the very large sample size in this analysis.

**Table 2 – The survival rate with neurologically intact or with minimal deficits by key characteristics.**

		Survivors with CPC score of 1 <sup>b</sup> /All patients within subgroup (%)		
		Total dataset 2010 to 2016 <sup>c</sup>	With “Residence prior to admit” variable <sup>d</sup>	Without “Residence prior to admit” variable <sup>d</sup>
Total		9,347/62,131 (15.0)	2,638/18,999 (13.9)	6,709/43,132 (15.6)
Site <sup>a</sup>	New sites	2,015/14,053 (14.3)	303/2,845 (10.7)	1,712/11,208 (15.3)
	Old sites	7,332/48,078 (15.3)	2,335/16,154 (14.5)	4,997/31,924 (15.7)
Hospital sizes	≤100 beds	495/3,613 (13.7)	110/1,009 (10.9)	385/2,604 (14.8)
	>100 beds	8,158/53,639 (15.2)	2,353/16,448 (14.3)	5,805/37,191 (15.6)
Having residents or interns	No	3,360/24,654 (13.6)	835/6,825 (12.2)	2,525/17,829 (14.2)
	Yes	5,640/35,499 (15.9)	1,764/11,783 (15.0)	3,876/23,716 (16.3)
Ownership type	Private	594/5,808 (10.2)	232/2,321 (10.0)	362/3,487 (10.4)
	Military or government	1,767/11,788 (15.0)	457/3,115 (14.7)	1,310/8,673 (15.1)
	Nonprofit	6,713/43,130 (15.6)	1,942/13,462 (14.4)	29,668/4,771 (16.1)
Race	African American	1,732/14,392 (12.0)	502/4,211 (11.9)	1,230/10,181 (12.1)
	Non-African American	7,613/47,723 (16.0)	2,136/14,788 (14.4)	5,477/32,935 (16.6)

<sup>a</sup> Old site = GWTG-R site before 2010, New site = GWTG-R site added since 2010.

<sup>b</sup> CPC score 1 = neurologically intact or with minimal deficit.

<sup>c</sup> The percentage of survivors with CPC score of 1 is significantly different between each pair of subgroups ( $p<0.001$ ), and for private versus military/government or nonprofit hospitals.

<sup>d</sup> The variable “Residence prior to admit” was used in the GO-FAR score, but was no longer collected as part of the standard GWTG-R registry dataset after September, 2012.

**Table 3 – Performance of GO-FAR score by the present of “Residence prior to admit” variable, site, hospital size, resident and intern status, and ownership type.**

	Risk groups								Area under ROC curve (95%CI)
	Very low (<1%)		Low (1% to 3%)		Average (3% to 15%)		Above average (>15%)		
	% patients in risk group	Survivors with CPC score of 1/All with this score (%)	% patients in risk group	Survivors with CPC score of 1/All with this score (%)	% patients in risk group	Survivors with CPC score of 1/All with this score (%)	% patients in risk group	Survivors with CPC score of 1/All with this score (%)	
Original dataset 2007–2009	9.4	37/4,799 (0.8)	19.0	194/9,725 (2.0)	53.6	2,531/27,464 (9.2)	18.1	2,568/9,253 (27.8)	0.77
All patients 2010–2016	7.1	72/4,385 (1.6)	16.5	380/10,272 (3.7)	52.0	4,023/32,326 (12.4)	24.4	4,872/15,148 (32.2)	0.75 (0.748–0.758)
Presence of “Residence prior to admit” variable <sup>a</sup>									
Yes	8.8	19/1,665 (1.1)	17.0	113/3,222 (3.5)	50.7	1,122/9,634 (11.7)	23.6	1,384/4,478 (30.9)	0.76 (0.751–0.769)
No	6.3	53/2,720 (2.0)	16.4	267/7,050 (3.8)	52.6	2,901/22,692 (12.8)	24.7	3,488/10,670 (32.7)	0.75 (0.744–.756)
Exclusion of ‘hypotension or hypoperfusion” and “respiratory insufficiency” from the GO-FAR score									
All patients 2010–2016	3.5	32/2162 (1.5)	12.1	205/7535 (2.7)	51.7	3308/32135 (10.3)	32.7	5802/20299 (28.6)	0.74 (0.739–0.749)
Site status									
New sites	5.8	13/818 (1.6)	14.8	67/2,079 (3.2)	53.4	828/7,510 (11.0)	25.9	1,107/3,646 (30.4)	0.75 (0.742–0.764)
Old sites	7.4	59/3,567 (1.7)	17.0	313/8,193 (3.8)	51.6	3,195/24,816 (12.9)	23.9	3,765/11,502 (32.7)	0.75 (0.748–0.759)
Hospital size									
≤100 beds	6.8	2/246 (0.8)	16.8	8/606 (1.3)	52.1	203/1,881 (10.8)	24.4	282/880 (32.1)	0.80 (0.777–0.816)
>100 beds	7.2	67/3,859 (1.7)	16.6	358/8,917 (4.0)	52.0	3,534/27,904 (12.7)	24.2	4,199/12,959 (32.4)	0.75 (0.744–0.754)
Having residents or interns									
No	6.9	24/1,707 (1.4)	16.5	122/4,074 (3.0)	53.2	1,466/13,111 (11.2)	23.4	1,748/5,762 (30.3)	0.76 (0.752–0.768)
Yes	7.2	45/2,571 (1.8)	16.8	248/5,946 (4.2)	51.2	2,406/18,166 (13.2)	24.8	2,941/8,816 (33.4)	0.75 (0.743–0.756)
Ownership type									
Private	6.9	3/399 (0.8)	18.5	8/1,076 (0.7)	52.2	262/3,029 (8.6)	22.4	321/1,034 (24.6)	0.79 (0.771–0.805)
Military/ government	5.6	12/660 (1.8)	16.0	79/1,885 (4.2)	54.0	784/6,362 (12.3)	24.4	892/2,881 (31.0)	0.74 (0.723–0.748)
Nonprofit	7.6	55/3,266 (1.7)	16.6	284/7,155 (4.0)	51.4	2,859/22,177 (12.9)	24.4	3,515/10,532 (33.4)	0.76 (0.749–0.761)
Race									
African American	8.7	17/1,247 (1.4)	18.8	96/2,710 (3.5)	51.7	839/7,438 (11.3)	20.8	780/2,997 (26.0)	0.74 (0.725–0.749)
Non-African American	6.6	55/3,138 (1.8)	15.8	284/7,562 (3.8)	52.1	3,184/24,888 (12.8)	25.5	4,092/12,151 (33.7)	0.76 (0.750–0.761)

(continued on next page)

**Table 3 (continued)**

Risk groups	Area under ROC curve (95%CI)								
	Very low (<1%)		Low (1% to 3%)		Average (3% to 15%)		Above average (> 15%)		
	% patients in risk group	Survivors with CPC score of 1/All with this score (%)	% patients in risk group	Survivors with CPC score of 1/All with this score (%)	% patients in risk group	Survivors with CPC score of 1/All with this score (%)	% patients in risk group	Survivors with CPC score of 1/All with this score (%)	
Admission CPC									
CPC = 1	0.2	1/85 (1.2)	3.6	70/1,461 (4.8)	58.5	3,418/23,544 (14.5)	37.7	4,872/15,148 (32.2)	0.69 (0.680–0.692)
CPC = 2	19.9	37/2,167 (1.7)	41.0	164/4,473 (3.7)	39.1	246/4,266 (5.8)	–	–	0.64 (0.611–0.660)

<sup>a</sup> The variable "Residence prior to admit" was used in the GO-FAR score, but was no longer collected as part of the standard GWTG-R registry dataset after September 2012.

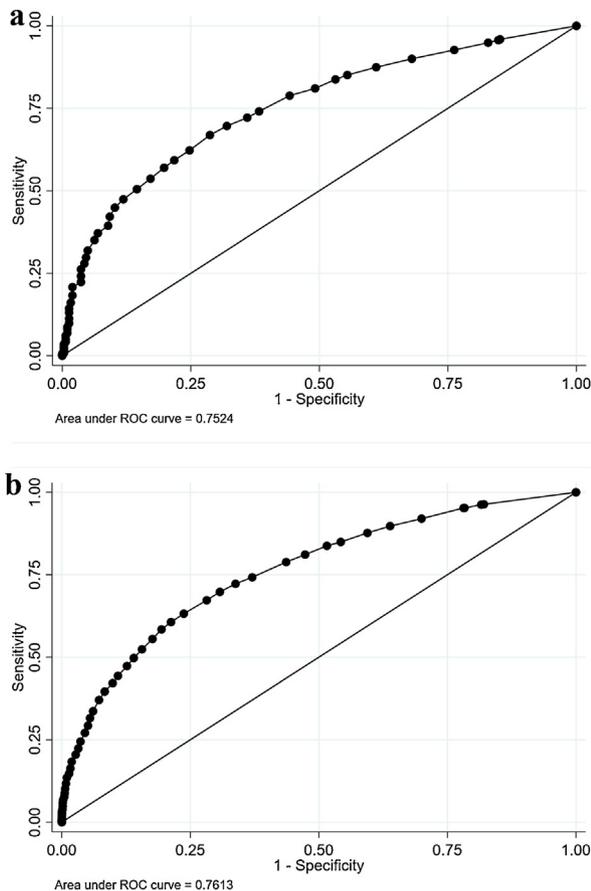
The GWTG-R registry records the most recent value prior to IHCA (within 4 h of resuscitation) for two variables ("hypotension or hypoperfusion" and "respiratory insufficiency"). Because this may differ from the value at the time of arrest, we recalculated the score after excluding these variables. The score's performance remained robust with c-statistic of 0.74 and the observed survivals of CPC score of 1 were within the predicted ranges, except the very low risk group (Table 3 and e-Figures 3–4).

In hospitals that were not part of the registry prior to 2010, and were thus not used to develop the GO-FAR score, the score also validated well. In these new sites, the c-statistic was 0.75 in either with or without res\_pri variable, the classification accuracy was a close match to that of the derivation population, and calibration was good (with res\_pri variable Hosmer-Lemeshow  $\chi^2_{10}$  statistic of 9.1,  $p=0.52$ ; without res\_pri variable Hosmer-Lemeshow  $\chi^2_{10}$  statistics of 51.1,  $p < 0.001$ , respectively). Again, with the presence of the res\_pri variable in the score, there was no significant difference between predicted and observed likelihood of survival with CPC score of 1 in the Hosmer-Lemeshow test. Calibration plots for the GO-FAR score by old or new site and the presence of the res\_pri variable are shown in e-Figures 5–8. The GO-FAR score performed with similar classification accuracy and discrimination in subgroups by hospital size (c-statistic of 0.80 in hospitals  $\leq 100$  beds and 0.75 in hospitals  $> 100$  beds), the presence of a training program (c-statistics of 0.76 and 0.75 in hospitals without and with residents or interns, respectively), type of ownership (c-statistics of 0.79, 0.74, and 0.76 in private, military/government, and nonprofit hospitals, respectively), and among patients of black and non-black race (c-statistics of 0.74 and 0.76, respectively). More detailed classification data can be found in e-Tables 4–11.

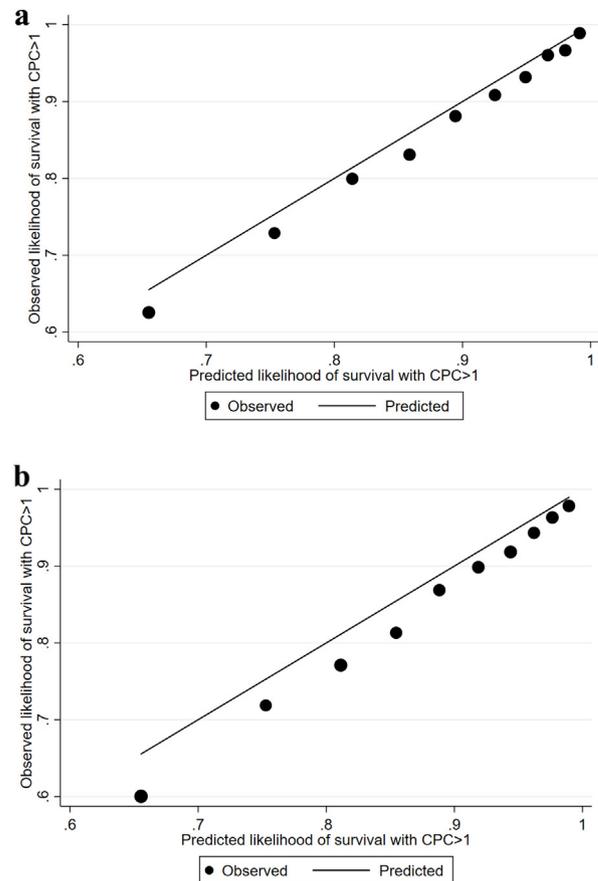
## Discussion

The GO-FAR score was successfully prospectively validated, including in hospitals that were not included in the derivation study. This relatively simple score accurately classifies patients into groups having a very low, low, average, and above average likelihood of survival to discharge neurologically intact or with minimal deficits following an episode of IHCA. In the very low risk group, the actual rate of survival with a good outcome was slightly higher than the predicted rate (1.6% vs <1%), which may in part be due to a temporal trend of increasing survival rates following IHCA. For the new sites that were not part of the original derivation study, the rates of survival with a good outcome among risk groups were very similar to the old sites. The C statistic of the score in the overall validation population was similar to that of the original study (0.75 vs 0.77).<sup>7</sup> The observed rates of good outcomes were somewhat higher than the expected rates in the Hosmer-Lemeshow calibration plots (Fig. 2a and b). This may be because of an overall increase in the rate of survival with a good outcome in more recent years (15% vs 10.4%). The reason for this increase in the rate of survival with a good outcome is not known, but may represent improvements in technology or greater use of do-not-resuscitate orders and palliative care in patients thought to have a poor prognosis. Thus, the score may require recalibration.

The score generally performed well in a range of hospital settings and populations. The discrimination and classification accuracy were good and similar regardless of hospital size, ownership, or the presence of training programs. It was also similar in African-Americans compared to non-African-Americans. Even after excluding the two predictors of "hypotension or hypoperfusion" and "respiratory insufficiency" which may change during hospitalization, the score still



**Fig. 1 – Receiver operating characteristic curve for (a) new sites added to GWTG-R since 2010 that had data regarding residence prior to admission, and (b) old sites participating in GWTG-R before 2010 that had data regarding residence prior to admission.**



**Fig. 2 – The Hosmer-Lemeshow graph for sites added to GWTG-R since 2010 and (a) patients with data regarding the residence prior to admission and (b) for patients without data regarding residence prior to admission.**

performed well. Of course, the preferred strategy to omitting these variables is to recalculate the full score if patients experience a significant change in these variables during their hospitalization. Overall, the GO-FAR score is robust and generalizes well in a range of settings and populations. It is more accurate when information about prior residence is available.

Previous scores such as the Pre-Arrest Morbidity score (PAM), the Prognosis After Resuscitation score (PAR), and the modified PAM index (MPI) were successfully developed, but have been found to lose their accuracy in the validation's studies.<sup>12–17</sup> The GO-FAR score is the first to predict not only survival, but survival with a good neurological outcome, and to do so without significant loss of accuracy in a prospective validation. The fact that the predictor variables are knowable prior to IHCA can provide patients and physicians with valid, reliable guidance regarding decisions about DNR orders.

Our study had several important strengths. First, we validated the GO-FAR score prospectively in a very large, diverse population. Second, the score performed as well or better in the subset of hospitals that were not used to derive the original rule. Third, the score performed well in various hospital and patient subgroups, suggesting that it is robust and broadly applicable. However, our study also had some limitations. First, the prior residence variable was not available after September 2012. Thus, the validation of the GO-FAR score for

episodes of IHCA without this variable may not fully reflect the score's accuracy. Another limitation is that some patients may find a CPC of 2 (moderate neurologic disability, requiring assistance with activities of daily living) to be an acceptable quality of life post-arrest, so a rule that only classifies CPC = 1 as a good outcome would not be helpful for their decision-making. For two of the variables used to develop the score, the most recent value prior to arrest was used ("hypotension or hypoperfusion" and "respiratory insufficiency"), so readers should update the risk prediction should the value of either of these variables change significantly from the time of admission. Finally, the score does not incorporate the location of the cardiac arrest (i.e. intensive care unit vs monitored bed vs unmonitored bed). An enhanced version of the score that updated information about patient location, hypotension or hypoperfusion, or respiratory insufficiency daily might have better accuracy.

Importantly, increasing rates of survival to discharge with a good neurologic outcome may necessitate recalibration of the score. Using the original cutoff of 24 or more points for "Very low likelihood of a good outcome" identified a group with a 1.6% likelihood of survival, compared with 0.8% in the original study. Increasing the cutoff to 26 or more points would classify 3380 patients in this group, of whom 52 survive (1.5%); increasing it to 28+ points would classify 2394 patients in this group, of whom 29 survive (1.2%). Readers can use eTable 10 in the Supplemental Materials for a more granular

look at survival for each point score. Finally, although the GO-FAR score performed well among the hospitals participating in the GWTG-R in this validation and in Swedish population,<sup>8</sup> there may still be some uncertainty of the score's performance in other populations.

Of course, the GO-FAR score should never be used in isolation, and should rather be one part of a shared decision that also involves a careful consideration of the patient's values and preferences. Any decision should incorporate new information and changes in the patient's condition. The score is not perfect, of course. Of 43,854 patients classified in the very low risk group and predicted to not have a good outcome, 72 (1.6%, 95% CI 1.3%–2.1%), will nonetheless have a good outcome. If the rule is widely applied in practice, and patients in the very low or low risk groups become less likely to undergo resuscitation, then over time this could artificially inflate the accuracy of the score.

## Conclusions

In conclusion, the GO-FAR score accurately classified patients according to their likelihood of experiencing a good outcome following attempted IHCA, defined as a CPC of 1. A substantial percentage of patients had a very low (1.6% in both overall and new sites) or low (3.7% overall and 3.2% in new sites) likelihood of a good outcome. Patients at high risk for a bad outcome should they experience IHCA should have the opportunity to decide whether CPR would be consistent with their values and preferences, as part of a shared decision about DNR orders.

## Contributions of authors

Dr. Ebell conceptualized the project and had overall responsibility, including drafting the manuscript. He is the guarantor for the paper. Thuy Thai, MPH was responsible for data analysis and contributed to writing the manuscript.

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## Conflict of interest

None.

## Source of funding

This was an unfunded study.

## 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.2019.05.002>.

## REFERENCES

1. Benjamin EJ, Virani SS, Callaway CW, et al. Heart disease and stroke statistics-2018 update: a report from the American Heart Association. *Circulation* 2018;137:e67–e492.
2. Kolte D, Khera S, Aronow WS, et al. Regional variation in the incidence and outcomes of in-hospital cardiac arrest in the United States. *Circulation* 2015;131:1415–25.
3. Mozaffarian D, Benjamin EJ, Go AS, et al. Heart disease and stroke statistics-2016 update: a report from the American Heart Association. *Circulation* 2016;133:e38–360.
4. Merchant RM. Public report cards for in-hospital cardiac arrest: empowering the public with location-specific data. *Circulation* 2015;131:1377–9.
5. Girotra S, Nallamothu BK, Spertus JA, et al. Trends in survival after in-hospital cardiac arrest. *New Engl J Med* 2012;367:1912–20.
6. Chen LM, Nallamothu BK, Spertus JA, Li Y, Chan PS. Association between a hospital's rate of cardiac arrest incidence and cardiac arrest survival. *JAMA Intern Med* 2013;173:1186–95.
7. Ebell MH, Jang W, Shen Y, Geocadin RG, the Get with the Guidelines–Resuscitation Investigators. Development and validation of the Good Outcome Following Attempted Resuscitation (GO-FAR) score to predict neurologically intact survival after in-hospital cardiopulmonary resuscitation. *JAMA Intern Med* 2013;173:1872–8.
8. Ohlsson MA, Kennedy LM, Ebell MH, Juhlin T, Melander O. Validation of the good outcome following attempted resuscitation score on in-hospital cardiac arrest in southern Sweden. *Int J Cardiol* 2016;221:294–7.
9. Ebell MH, Smith M, Kruse JA, Drader-Wilcox J, Novak J. Effect of race on survival following in-hospital cardiopulmonary resuscitation. *J Fam Pract* 1995;40:571–7.
10. Chan PS, Nichol G, Krumholz HM, et al. Racial differences in survival after in-hospital cardiac arrest. *JAMA* 2009;302:1195–201.
11. Peberdy MA, Kaye W, Ornato JP, et al. Cardiopulmonary resuscitation of adults in the hospital: a report of 14720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. *Resuscitation* 2003;58:297–308.
12. George [125\_TD\$DIFF]Jr AL, Folk 3rd BP, Crecelius PL, Campbell WB. Pre-arrest morbidity and other correlates of survival after in-hospital cardiopulmonary arrest. *Am J Med* 1989;87:28–34.
13. Ebell MH. Pre-arrest predictors of survival following in-hospital cardiopulmonary resuscitation: a meta-analysis. *J Fam Pract* 1992;34:551–8.
14. Dautzenberg PL, Broekman TC, Hoover C, Schonwetter RS, Duursma SA. Review: patient-related predictors of cardiopulmonary resuscitation of hospitalized patients. *Age Ageing* 1993;22:464–75.
15. Bowker L, Stewart K. Predicting unsuccessful cardiopulmonary resuscitation (CPR): a comparison of three morbidity scores. *Resuscitation* 1999;40:89–95.
16. Ohlsson MA, Kennedy LM, Juhlin T, Melander O. Evaluation of pre-arrest morbidity score and prognosis after resuscitation score and other clinical variables associated with in-hospital cardiac arrest in southern Sweden. *Resuscitation* 2014;85:1370–4.
17. Ebell MH, Afonso AM. Pre-arrest predictors of failure to survive after in-hospital cardiopulmonary resuscitation: a meta-analysis. *Fam Pract* 2011;28:505–15.