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# Validation of a Clinical Decision Aid to Discontinue In-Hospital Cardiac Arrest Resuscitations

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CARDIOPULMONARY RESUSCITATION and advanced cardiac life support interventions are used to resuscitate patients having cardiac or respiratory arrest. Physicians and other health care workers follow algorithmic advanced cardiac life support guidelines from the American Heart Association<sup>1</sup> in an attempt to restore a spontaneous circulation in these patients. Despite these guidelines, decision making during resuscitation is difficult because cardiac arrest is a complex common pathway of a diverse collection of diseases.<sup>2</sup>

The decision to stop resuscitative efforts can be particularly difficult for physicians. In these situations, decision making must balance a “respect for human dignity” and clinical judgment.<sup>3</sup> Prognostic factors that portend a poor outcome following arrest may help the latter. Death following resuscitation has been associated with both prearrest factors (including hypotension,<sup>4</sup> renal failure,<sup>5,6</sup> pneumonia,<sup>4</sup> low functional status,<sup>4,7</sup> and metastatic cancer<sup>4,6</sup>) and intra-arrest factors (including prolonged

**Context** Most patients undergoing in-hospital cardiac resuscitation do not survive to hospital discharge. In a previous study, we developed a clinical decision aid for identifying all patients undergoing resuscitation who survived to hospital discharge.

**Objective** To validate our previously derived clinical decision aid.

**Design, Setting, and Participants** Data from a large registry of in-hospital resuscitations at a community teaching hospital in Georgia were analyzed to determine whether patients would be predicted to survive to hospital discharge (ie, whether their arrest was witnessed or their initial cardiac rhythm was either ventricular tachycardia or ventricular fibrillation or they regained a pulse during the first 10 minutes of chest compressions). Data from 2181 in-hospital cardiac resuscitation attempts in 1987-1996 involving 1884 pulseless patients were analyzed.

**Main Outcome Measure** Comparison of predictions based on the decision aid with whether patients were actually discharged alive from the hospital.

**Results** For 327 resuscitations (15.0%), the patient survived to hospital discharge. For 324 of these resuscitations, the patients were predicted to survive to hospital discharge (sensitivity=99.1%, 95% confidence interval, 97.1%-99.8%). In 269 resuscitations, patients did not satisfy the decision aid and were predicted to have no chance of being discharged from the hospital. Only 3 of these patients (1.1%) were discharged from the hospital (negative predictive value=98.9%), none of whom were able to live independently following discharge from the hospital.

**Conclusion** This decision aid can be used to help physicians identify patients who are extremely unlikely to benefit from continued resuscitative efforts.

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duration of resuscitation<sup>4,7,8</sup> and initial cardiac rhythms other than pulseless ventricular tachycardia or ventricular fibrillation<sup>7,9-11</sup>). However, decision aids that use these and other factors to determine a patient's prognosis following resuscitation are complicated and difficult to use at the bedside. They have operated poorly when validated in distinct populations<sup>12</sup> and have been unable to definitively identify patients with no hope of survival.<sup>13</sup> A simple decision aid that reliably identifies patients who—regardless of the cause of their arrest—have a poor outcome would be helpful.

This could help avoid the “tendency to try prolonged, excessive resuscitative efforts.”<sup>3</sup>

For this reason, we previously derived a simple clinical decision aid to

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identify all patients who were eventually discharged from hospital after their arrest.<sup>14</sup> Our goal, when deriving this decision aid, was to maximize sensitivity for identifying these patients. We studied 1077 adults undergoing in-hospital resuscitation who participated in 2 randomized clinical trials<sup>15,16</sup> involving 5 teaching hospitals. Using recursive partitioning, we found that all resuscitated patients who were eventually discharged from the hospital had a witnessed arrest, an initial cardiac rhythm of either ventricular tachycardia or ventricular fibrillation, or a pulse within the first 10 minutes of chest compressions. We proposed that physicians might safely withdraw resuscitative efforts on patients who did not satisfy the decision aid since none of these patients were discharged from the hospital.

In that report we stressed 2 issues. First, we emphasized that while 100% of the patients not satisfying the decision aid eventually died in hospital, the 95% confidence interval (CI) of this point estimate extended down to 97.1%. Second, we cautioned that validation of the decision aid in a separate patient population was required before the decision aid should be used clinically.<sup>14</sup> This was the objective of our current study.

## METHODS

This validation study was a secondary analysis of a resuscitation registry at the Medical Center of Central Georgia (MCCG) in Macon. The MCCG is a 550-bed community teaching hospital affiliated with the Mercer University School of Medicine. It is the major hospital for the metropolitan area as well as the tertiary center for the surrounding rural areas and has approximately 25 000 admissions per year.

Multidisciplinary teams consisting of nurses, residents, staff physicians, respiratory therapists, and pharmacists conducted the resuscitations. Staff physicians or senior medical residents directed the resuscitations using standard protocols published by the American Heart Association.<sup>3</sup> Team

members were all trained in basic life support and most were trained in advanced cardiac life support. All members underwent regular updates. During the study period, resuscitation was attempted for approximately 1.5% of admissions.

With the exception of arrests occurring in the neonatal intensive care unit or operating room, all in-hospital arrests occurring between 1987 and 1996 were entered into the registry. The resuscitation registry was reviewed and approved by the Institutional Review Board of Mercer University School of Medicine and MCCG. Resuscitation was defined, as has been suggested by the Utstein Conference,<sup>17</sup> as “any effort to reverse a clinical death in progress.” Code sheets were completed after each resuscitation attempt and were used to identify events. To ensure complete capture of resuscitations, the records of patients without a code sheet but whose hospital charges included cardioversion, defibrillation, or the administration of epinephrine were also reviewed to determine if a resuscitation attempt occurred. Data were entered into the registry by MCCG project staff and were checked prior to analysis. All data were cross-checked for accuracy through an extensive review of hospital records and death logs. Clinical categories, such as whether or not the arrest was witnessed and initial cardiac rhythm, used standardized definitions that had interrater  $\kappa$  values exceeding 0.9 before final classification of the data set was complete. Questionable cases were reviewed by 2 researchers (D.C.P., K.M.D.C.) for consensus definition in the final review. This was done before this study was conceived. A detailed description of the registry was previously published.<sup>11</sup>

All resuscitations in the registry were eligible for this study. Resuscitations were excluded if they were performed on patients younger than 16 years old or were performed on patients in the operating room at the time of the arrest. Our decision aid applies to patients who were pulseless at the start of the resuscitation. Therefore, resus-

citations were excluded if the initial rhythm was any other than pulseless ventricular tachycardia, ventricular fibrillation, pulseless electrical activity, or asystole. Resuscitations were also excluded if patients received no chest compressions, if information required by the decision aid was missing, or if time to initial chest compressions exceeded 15 minutes. Each of these exclusion criteria was used for patient selection in the decision aid derivation.<sup>14</sup>

To apply the decision aid, we determined the time from the start of chest compressions to the end of the resuscitation. This was the return of any spontaneous circulation lasting 2 or more minutes or the end of resuscitative efforts. The former criterion addressed a concern of our decision aid,<sup>2</sup> namely, that patients who regained a pulse for most of the resuscitation only to lose it before the 10-minute mark might have resuscitation stopped if the aid was applied. Patients who were directly seen to lose spontaneous circulation were classified as “witnessed.” Also, all patients who had an arrest while on a cardiac monitor, in the intensive or coronary care unit or in the cardiac catheterization laboratory, were classified as “witnessed arrests.” This was regardless of whether or not the patient was directly visualized to lose spontaneous circulation. Patients in the emergency department were included in the study only if they actually had an arrest after they arrived in the department. Finally, we applied the decision aid in this study in a more clinically intuitive order than that presented in the derivation study. This altered order does not affect the model’s statistical significance or operating characteristics.

A 2 × 2 contingency table comparing actual discharge status to that predicted by the decision aid was used to calculate the classification performance of the clinical decision aid with 95% CIs. We reviewed the medical record of all patients who did not satisfy the decision aid but survived more than 24 hours to determine their course in hospital. Analyses are by resuscitation.

## RESULTS

When this study was conducted, the registry recorded 3960 resuscitations. We excluded 1779 events for the following reasons: no chest compressions were given during the resuscitation (n=1147), the patient was not pulseless at the start of the resuscitation (n=254), the patient was younger than 16 years (n=85), the patient was in the operating room when the arrest was called (n=1), the time from arrest being called to the first chest compression exceeded 15 minutes (n=9), or information required to apply the decision aid was missing (n=283).

**Table 1.** Description of 2181 Attempted Resuscitations\*

Location	
Ward	958 (43.9)
Off ward	1223 (56.1)
Mean delay to start of CPR, min (range)	0 (0-14)
Arrest type	
Cardiac	663 (30.4)
Respiratory	17 (0.8)
Cardiorespiratory	1498 (68.7)
Unknown	3 (0.1)
Initial rhythm	
Pulseless VT or VF	481 (22.1)
Asystole	570 (26.1)
Pulseless electrical activity	1130 (51.8)
Arrest witnessed	1721 (78.9)
Return of spontaneous circulation	1064 (48.8)
Mean duration of arrest, min (range)	34 (0-225)
Discharged from hospital	327 (15.0)

\*Data are presented as number and percentage unless otherwise indicated. CPR indicates cardiopulmonary resuscitation; VT, ventricular tachycardia; and VF, ventricular fibrillation.

This left 2181 attempted resuscitations comprising 1884 patients. These patients had a mean age of 65 years (95% CI, 64.3-65.7) and 47.3% were female. Most arrests occurred off ward, had a cardiorespiratory cause, and were witnessed (TABLE 1). The predominant initial rhythms were asystole and pulseless electrical activity, and for 2094 (96.0%) resuscitations, chest compressions were delivered within 5 minutes of arrest. A spontaneous circulation was attained in almost half of resuscitations, and for 15.0% of resuscitations, patients survived to discharge from hospital.

The FIGURE illustrates how the decision aid identified patients who would be discharged from the hospital. Of the 327 resuscitations for which patients were discharged from hospital, 287 satisfied the first component of the decision aid ("arrest was witnessed"). Of the remaining 40 resuscitations, 10 satisfied the second component of the aid ("initial rhythm was ventricular tachycardia or ventricular fibrillation"). Twenty-seven of the remaining 30 resuscitations satisfied the final component of the decision aid ("pulse regained during the first 10 minutes of chest compressions").

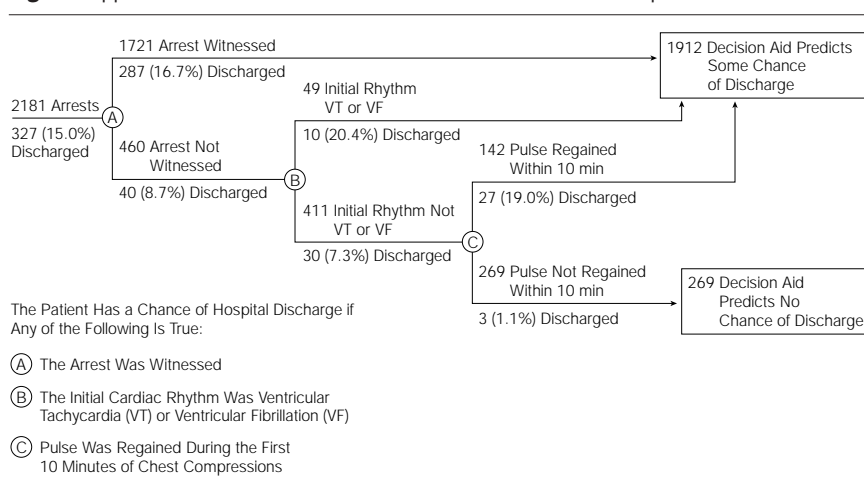
TABLE 2 presents the classification performance of the decision aid. Of the 327 resuscitations for which patients were discharged from hospital, all but 3 satisfied the decision aid, resulting in a sen-

sitivity of 99.1% (95% CI, 97.1%-99.8%). That is, the decision aid correctly identified all but 0.9% of those who were discharged from the hospital. The decision aid had a negative predictive value of 98.9% (95% CI, 96.5%-99.7%). That is, 1.1% of arrests that the decision aid predicted had no chance of survival were actually discharged from the hospital.

Likelihood ratios allow clinicians to measure the quantitative importance of test results.<sup>18</sup> The negative likelihood ratio of the decision aid was 0.064. To put this into perspective, assume that we could accurately determine the probability that hospitalized patients will survive to discharge if they required resuscitation. Also, assume that we have 3 patients whose probability of surviving to hospital discharge, in the event of an arrest, is 30%, 15%, and 5%. If these patients did not satisfy the decision aid during their resuscitations, their probabilities of surviving to discharge would decrease to 2.7%, 1.1%, and 0.3%, respectively.

We determined the outcome of the 3 people whom the aid predicted had no chance of being discharged from the hospital. The first patient was a 76-year-old man with dementia, hypertension, and chronic obstructive pulmonary disease who was transferred to another hospital following resuscitation to continue inpatient medical therapy. When he was discharged he was in a very poor condition and required tracheostomy, gastrostomy, foley catheter, and rectal tube. These, however, were at least partially required for an obstructive oropharyngeal carcinoma as opposed to ischemic cerebral damage. He died 2 months following discharge from the hospital. The second patient was a 43-year-old man with chronic obstructive pulmonary disease and alcoholic cardiomyopathy. Although he had minimal ischemic damage from the arrest, he was discharged to a nursing home residence because of problems caring for himself. The final patient was a 65-year-old previously well woman who had an arrest following back surgery. She had no ischemic injury but required nursing home placement because of complications of her back surgery.

**Figure.** Application of the Decision Aid to the Validation Set of Attempted Resuscitations



Of the 269 resuscitations in which patients were predicted to have no chance of surviving to hospital discharge, the mean resuscitation duration was 22.6 minutes (SD, 11.1 minutes; range, 10-72 minutes). In 53 of these resuscitations (19.7%), patients achieved a spontaneous circulation and were transferred to the intensive care unit. Twenty-six of these patients remained alive for at least 24 hours but died later during the hospitalization. These 26 patients survived a mean of 8.5 days following the resuscitation (range, 1-29 days; total, 213 days). Of the 20 patients whose chart was available, 15 (75%) never regained consciousness. For 9 (45%) of these 20 patients, a decision was made to withdraw active care.

## COMMENT

Using one of the world's largest continuous registries of hospital resuscitations, we found that a simple clinical decision aid performed well to identify patients with any chance of discharge from hospital following resuscitation. All but 3 patients (1.1%) who did not meet criteria for the decision aid died following their arrest. We believe that this decision aid can be used with other clinical factors to help physicians identify patients who are extremely unlikely to benefit from ongoing resuscitation efforts.

Our aid meets the most important methodological standards for decision aids.<sup>19-21</sup> The outcome predicted by the aid is important and objective. The aid is clinically sensible since each component (ie, witnessed arrest,<sup>8</sup> initial ventricular tachycardia or ventricular fibrillation,<sup>7</sup> and duration of resuscitative efforts<sup>4,7,8,22</sup>) has been associated with survival in other studies. The potential effects of using the decision aid—in terms of avoided intensive care unit days—have been estimated in both the derivation<sup>14</sup> as well as this study. Most important, the aid has been validated on a distinct population, a standard met by fewer than half of all decision aids published between 1991 and 1994 in 4 major medical journals.<sup>10</sup> We hope that this aid will be tested further in

**Table 2.** Decision Aid Performance for Identifying Patients Who Are Discharged From Hospital Following Attempted Resuscitation\*

Decision Aid Predicted Some Chance of Discharge From Hospital	Discharged From Hospital		Total
	Yes	No	
Yes	324	1588	1912
No	3	266	269
Sensitivity	= 99.1% (95% CI, 97.1%-99.8%)		
Specificity	= 14.4% (95% CI, 12.4%-16.0%)		
Positive Predictive Value	= 17.0% (95% CI, 15.3%-18.7%)		
Negative Predictive Value	= 98.9% (95% CI, 96.5%-99.7%)		

\*The clinical decision aid predicted some chance of discharge from hospital if the arrest was witnessed or the initial cardiac rhythm was ventricular tachycardia or ventricular fibrillation or the pulse was regained during the first 10 minutes of chest compressions. These patients are represented in the top row of the table above. CI indicates confidence interval.

other patient populations, preferably in a prospective fashion, to further ensure its validity.

Two factors regarding the decision aid require more detailed discussion. First, this study showed that the decision aid is very robust since it was valid in a separate patient group despite large differences between the derivation and validation populations. Compared with the derivation group,<sup>14</sup> patients in this study were significantly younger (mean age, 65 vs 68 years,  $P < .001$ ), and were less likely to have had an arrest on the ward (43.9% vs 55.2%). Outcomes for the validation group were much better with a significantly greater number of patients surviving to 1 hour (48.8% vs 33%,  $P = .0001$ ) and discharge (15.0% vs 9.6%,  $P < .001$ ). Most important, the patients used for the derivation and validation studies were from very different health care systems. The observation that our decision aid performed so well in such a different patient population should give physicians confidence to apply it to their own patients.

Second, although each component of the aid is very objective, it must be used with care since difficulties in measuring time, classifying cardiac rhythms, and determining the presence of a pulse during the resuscitation have been well documented in the medical literature. All patients who had an arrest in the intensive care unit or while on a monitor are considered witnessed arrests when applying this aid, even if they are not actually visualized to become unstable.

Similarly, physicians must be confident about the classification of the initial rhythm, and special care must be exercised to ensure that perfusing rhythms with hypotension are not classified as pulseless electrical activity. Also, physicians must ensure that resuscitative efforts have truly proceeded for a complete 10 minutes, without the return of a pulse that persisted for 2 or more minutes, before the last component of the aid is determined. Finally, this decision aid cannot be applied to out-of-hospital resuscitations without further research.

Although the resuscitations in this study spanned over 9 years, we do not believe that changes in resuscitation significantly affected our results. Between 1987 and 1996, the time period of the study, no pharmacological or mechanical intervention was introduced that reliably improved the patient outcomes following resuscitation. Although monitoring technology, such as telemetry, might have become more prevalent during the study, the decision aid would account for this since all such patients would be classified as having a witnessed arrest.

This study addresses several criticisms of our decision aid.<sup>2</sup> There was concern that patients who regained a pulse within the first 10 minutes of the resuscitation, only to lose it again at 10 minutes, would not satisfy the decision aid and would have resuscitative efforts withdrawn. Since the registry used for this study recorded when patients had any return of spontaneous

rhythm, we ensured that patients who regained a pulse for longer than 2 minutes within the first 10 minutes of resuscitation satisfied the decision aid. Second, the decision aid only identified 12% of the study group as patients with no chance of survival. However, this is comparable to other decision aids used to identify patients with poor outcomes postarrest such as the Pre-Arrest Morbidity score,<sup>12,23,24</sup> the Prognosis After Resuscitation score,<sup>12,23</sup> and the APACHE (Acute Physiology and Chronic Health Evaluation) III index,<sup>12</sup> each of which applied to between 5% and 20% of all resuscitations. Third, we were criticized for both ignoring prearrest patient factors that are associated with outcomes and attempting to derive a simple decision aid to be applied to such a diverse population of patients having a broad range of survival probabilities. As we demonstrated in this article, physicians could combine the negative likelihood ratio of the decision aid with estimated prearrest survival probabilities to improve prognostication.<sup>18</sup> However, we believe that freeing physicians from having to calculate a pretest

probability of survival based on various factors is a strength of the aid. Since many patients with a good prognosis have some return of spontaneous circulation within the first 10 minutes of the resuscitation, our aid innately accounts for these patients. Finally, we agree that any time patients are interactive with their environment after resuscitation—even if they end up dying later—is valuable. However, we do not feel that this advocates adopting a “never give up” mind-set during resuscitative efforts. Our data show that for each person who did not satisfy the decision aid but regained consciousness, approximately 15 people did not. In many of these cases, family members are put in the unenviable position of having to decide whether to withdraw care from a loved one. Given the stress that this causes,<sup>25,26</sup> it is arguably a high price to pay.

We believe that the decision aid validated in this study can be used by physicians to identify patients who are extremely unlikely to benefit from ongoing resuscitation efforts. Further validation of the aid in multiple sites with prospectively collected data would be wel-

come. In addition, this decision aid might also help patients be more directive regarding their resuscitation attempts. Our data could allow patients and physicians to precisely quantify when resuscitative efforts would be stopped, such as when our decision aid is not satisfied. Since patients are often afraid of being resuscitated only to remain on life support, our decision aid could be used to help patient decision making that might avoid such a situation.

**Author Contributions:** Study concept and design: van Walraven, Stiell, Parish, Forster.

**Acquisition of data:** Dane, Parish, Whaley, Durham, Chandra.

**Analysis and interpretation of data:** van Walraven, Dane, Parish.

**Drafting of the manuscript:** van Walraven, Durham, Forster.

**Critical revision of the manuscript for important intellectual content:** van Walraven, Stiell, Dane, Parish, Whaley, Durham, Chandra.

**Statistical expertise:** van Walraven, Stiell, Dane, Forster.

**Administrative, technical, or material support:** Dane, Parish, Whaley, Durham, Chandra.

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