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Original Article

Survival Prediction of Initial Blood pH for Nontraumatic Out-of-hospital Cardiac Arrest Patients in the Emergency Department☆

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SUMMARY

Background: Most nontraumatic out-of-hospital cardiac arrest (NTOHCA) patients who fail in prehospital resuscitation receive continued cardiopulmonary resuscitation in the emergency department (ED). Initial blood pH, which can be assessed rapidly in the ED, was examined to see whether it is a strong survival predictor for these patients.

Methods: A 1-year retrospective study included consecutive 225 NTOHCA patients at a medical center in northern Taiwan who presented through the emergency medical services system. On arrival at the ED, these patients received continued cardiopulmonary resuscitation, and their initial blood pH data were assessed.

Results: The pH value was positively correlated with variables such as return of spontaneous circulation, witnessed arrest, short prehospital time (≤20 minutes), and survival. The best cut-off value of initial blood pH, revealed by the receiver operating characteristic curve, was 7.068. The lowest pH value of the survivors was 6.856. The results of logistic regression model analysis shows that the odds ratios of survival was 10.0 (95% confidence interval [CI], 2.1–47.7) for patients with initial blood pH ≥ 7.068, 5.3 (95% CI, 1.48–18.9) for those with nonasystole rhythm, 4.0 (95% CI, 1.1–14.8) for those with prehospital time ≤20 minutes, and 9.1 (95% CI, 2.3–35.2) for those without $NaHCO_3$ administration during resuscitation, respectively.

Conclusion: A cut-off value of an initial blood pH of 7.068 can serve as a predictor for survival among NTOHCA patients. In addition, patients whose initial blood pH is lower than 6.85 in the ED may not survive until hospital discharge.

1. Introduction

Medical resources are always limited, and their use must be prudent. Gray et al.[1] reported that it was useless to resuscitate nontraumatic out-of-hospital cardiac arrest (NTOHCA) patients who failed to restore circulation by prehospital resuscitation in the past. Resuscitation of NTOHCA patients demands many medical resources in the emergency department (ED),[1,2] and may even compromise the medical services of other patients. Is it necessary to continue cardiopulmonary resuscitation (CPR) in the ED for patients who failed in prehospital resuscitation? If there were a rapid laboratory test that can predict the survival of these patients, we might quickly withdraw resuscitation from helpless and hopeless patients and explain the probable prognosis to their family.

During cardiac arrest and resuscitation, a critical decrease in tissue perfusion and CO_2 excretion can result in metabolic acidosis and respiratory acidosis.[3] Therefore, it is sensible that the decrease in blood pH is significantly correlated with cardiac arrest duration.[4,5] Because blood pH values usually can be reported within 2 minutes after blood gas samples have been obtained, we presume that it might be a rapid and useful tool for predicting survival outcome and helping to decide whether to continue resuscitation or not.

Although many studies have reported acid-base changes during CPR and focused on differences between arterial and mixed venous

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blood gases,[3,6–9] the studies do not discuss the relationship between blood pH and survival outcome. During CPR, the most preferred site for routine blood drawing is the femoral area because this site will not interrupt cardiac massage. However, it is impossible to differentiate an artery from a vein, even by palpable femoral pulsation.[10] During a closed chest cardiac massage, it is also difficult and time consuming to insert a central line just for mixed venous gas.

The purpose of our study was to determine whether the initial blood pH in the ED, whether an arterial or venous sample, was a strong predictor of survival among NTOHCA patients who had failed to respond to prehospital resuscitation.

2. Materials and Methods

2.1. Study subjects

During the 1-year period from January to December 2005, 330 consecutive NTOHCA patients presented at the ED of Mackay Memorial Hospital, including 268 patients sent through the emergency medical services (EMS) system. Of these patients from the EMS system, 225 failed prehospital resuscitation and received continued CPR in the ED. Forty-three patients did not undergo CPR because of evidence of irreversible death, a do not resuscitate notification from the family or no initial blood gas data. For this study, we excluded patients younger than 18 years, those whose cardiac arrests were caused by trauma, attempted suicide, drowning, and drug poisoning, and those who had regained pulse on arrival at the ED after prehospital resuscitation.

All of the emergency physicians, staff, and nurses had passed the Advanced Cardiac Life Support 2000 guideline training course,[11] and all of the emergency medical technicians had participated in the basic life support and automatic electric defibrillator training program. The study was approved by the Mackay Memorial Hospital Institutional Review Board (MMH-I-S-341).

2.2. Definition and data collection

According to the Utstein style, signs of OHCA consist of unresponsiveness, absence of spontaneous respiration, and no palpable pulse.[12] The return of spontaneous circulation (ROSC) includes any spontaneous return of palpable pulse and does not require a specific duration of more than 5 minutes.[12] The response time was defined as the interval from the receipt of an emergency call to the arrival of emergency personnel at the scene, and the prehospital time defined as the interval from the emergency call to the patient reaching the ED.

According to Advanced Cardiovascular Life Support guidelines,[11] such procedures as chest compression, endotracheal intubation with ventilation, obtaining two large-bore intravenous lines via the upper limbs, and epinephrine administration, were performed before the initial blood gas was drawn. The initial blood gas data were obtained before the ROSC and within 5 minutes when patients arrived at the ED. The femoral area was the preferred site for obtaining a blood gas sample because that will not interrupt CPR action. The Bayer Rapidlab 855 Blood Gas Analyzer (Bayer Taiwan Co., Ltd. Taipei, Taiwan, ROC) was used to assess the blood gas measurements.

Patient information on age, gender, witness, response time, prehospital time, cardiac rhythm, blood gas (including pH, PCO_2, PO_2, and HCO_3), ROSC, and $NaHCO_3$ use was extracted from the EMS data set and medical charts. In the study, patients aged 65 years and over were categorized as the elderly group and those aged from 18 to 64 as the adult group.

2.3. Statistical analysis

Pearson χ^2 tests and Fisher exact tests were performed for categorical variables. Student t tests of independent sample were used for continuous variables. Logistic regression model analyses were performed to identify potential predictive factors for survival among NTOHCA patients. The receiver operator characteristic (ROC) curve was performed to determine the cut-off value of pH for survival prediction of NTOHCA patients. The p value of 0.05 was set as the level of statistical significance. All the above statistical analyses were conducted using SPSS software version 12.0 (SPSS Inc., Chicago, IL, USA). In addition, PRISM statistical software version 4.0 (GraphPad, San Diego, CA, USA) was applied to demonstrate the distribution of the initial blood pH of survivors and nonsurvivors, shown in Fig. 1.

3. Results

The survival rate in this study was 7.5%, and the median age was 72 years with a range of 21–95. There were 136 men and 89 women. The mean pH value of these patients was 6.99, with a range of 6.19–7.55. The mean responsive time was 5.6 minutes with a range of 0–48. The mean prehospital time was 25.2 minutes with a range of 5–66.

Table 1 presents the distributions of patient characteristics between the survivors and nonsurvivors. Compared with the nonsurvivors, the survivors tended to have higher pH values, lower PCO_2 values, shorter prehospital time, more witnessed arrests, more nonasystole presentations, and lower proportion of receiving $NaHCO_3$ administrations. No significant differences in the PO_2, HCO_3, age, response time, and gender were found between the two groups.

Table 2 presents initial blood pH value by selected characteristics. The pH value was significantly higher in ROSC patients, survivors, male gender, witnessed patients, those receiving $NaHCO_3$ administration, and those having short prehospital time ($\leq$20 minutes). There were no significant differences in the pH value with regard to age, asystole presentation, and response time.

As shown in Fig. 2, an ROC curve was constructed to estimate the best pH cut-off value to predict the survival of NTOHCA patients. When the pH value was 7.068, the largest area under the ROC

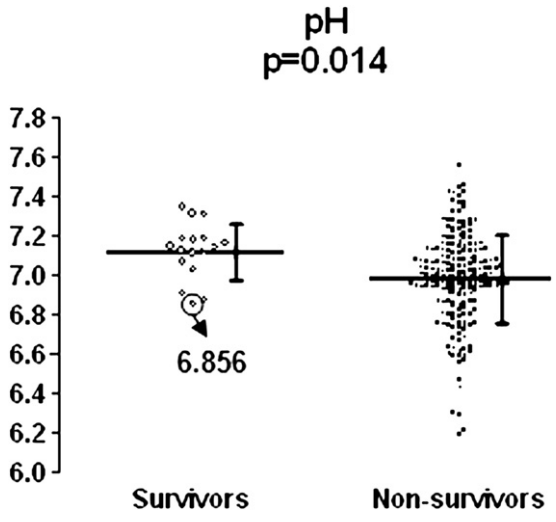

Fig. 1. pH distribution of survivors and nonsurvivors of nontraumatic out-of-hospital cardiac arrest patients. The lowest pH value of survivors was 6.856 mmHg.

Table 1
Comparison of patient characteristics between the survivors and nonsurvivors

Variable	Survivor ($n=17$)	Nonsurvivor ($n=208$)	p
pH (mean ± SD)	7.12 ± 0.14	6.98 ± 0.22	0.014
PCO_2 (mmHg) (mean ± SD)	57.44 ± 21.20	75.51 ± 42.76	0.005
PO_2 (mmHg) (mean ± SD)	64.35 ± 52.34	56.26 ± 75.73	0.666
HCO_3 (mmol/L) (mean ± SD)	17.61 ± 5.36	16.40 ± 7.30	0.505
Age (yr) (mean ± SD)	63.65 ± 18.50	68.07 ± 16.39	0.290
Response time (min) (mean ± SD)	3.94 ± 1.91	5.90 ± 5.12	0.131
Prehospital time (min) (mean ± SD)	18.31 ± 6.73	25.71 ± 9.11	0.002
Elderly (%)	9 (52.9)	138 (66.3)	0.264
Male (%)	8 (47.1)	128 (61.5)	0.240
Witnessed (%)	17 (100.0)	127 (61.1)	0.001
Asystole (%)	9 (52.9)	177 (85.1)	0.003
$NaHCO_3$ (%)	6 (35.3)	139 (66.8)	0.009
ROSC (%)	17 (100.0)	77 (37.0)	<0.001

Data are presented as mean ± SD or n(%). SD = standard deviation; ROSC = return of spontaneous circulation.

curve was 0.707 ($p=0.005$), with a sensitivity of 76.5% and a specificity of 68.3%. As shown in Fig. 1, among survivors, the lowest pH value was 6.856. When the PCO_2 value was 52.5, the largest area under the ROC curve was 0.386; however, the result was not statistically significant ($p=0.118$).

As shown in Table 3, the results of the logistic regression model analysis show that nonasystole rhythm (odds ratio [OR], 5.29 and 95% confidence interval [CI], 1.48−18.93), no use of $NaHCO_3$ (OR, 9.07 and 95% CI, 2.33−35.3), shorter prehospital time of ≤20 minutes (OR, 4.04 and 95% CI, 1.10−14.8), and higher pH value of ≥7.068 (OR, 10.0 and 95% CI, 2.10−47.7) were significantly

Table 2
Comparison of pH between different characteristics

Variable	pH (mmHg) Mean ± SD	p
ROSC		0.020
Yes ($n=94$)	7.03 ± 0.15	
No	6.96 ± 0.26	
Survivor		0.014
Yes ($n=17$)	7.12 ± 0.14	
No	6.98 ± 0.22	
Status		0.461
Elderly ($n=147$)	7.00 ± 0.21	
Adult	6.98 ± 0.24	
Sex		0.044
Male ($n=136$)	7.02 ± 0.20	
Female	6.95 ± 0.25	
Witnessed		< 0.001
Yes ($n=144$)	7.04 ± 0.18	
No	6.91 ± 0.26	
Asystole		0.103
Yes ($n=186$)	6.98 ± 0.23	
No	7.04 ± 0.19	
$NaHCO_3$		0.004
Yes ($n=145$)	7.02 ± 0.22	
No	6.94 ± 0.22	
Response time (min)		0.689
>10 ($n=21$)	6.97 ± 0.22	
≤10	6.99 ± 0.23	
Prehospital time (min)		0.032
>20 ($n=148$)	6.97 ± 0.22	
≤20	7.03 ± 0.23	

Data are presented as mean ± SD or n(%). SD = standard deviation; ROSC = return of spontaneous circulation.

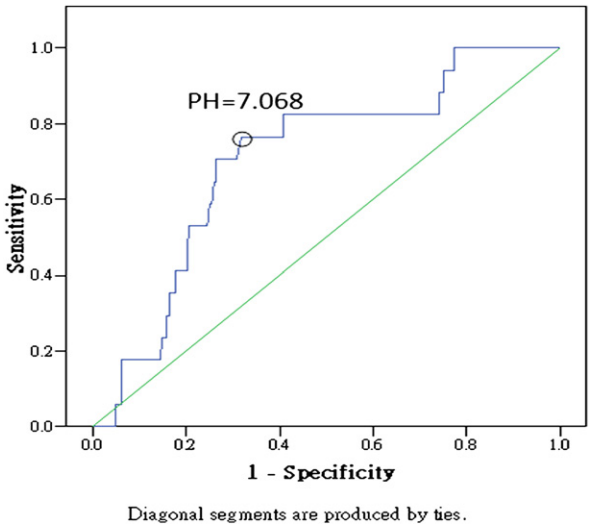

Fig. 2. Receiver operating characteristic curve of nontraumatic out-of-hospital cardiac arrest patients' pH measurements. Open circle was the optimum cut-off point.

associated with better survival outcome. Other variables such as gender, age, and PCO_2 value were not significantly associated with survival outcome.

4. Discussion

Emergency physicians often need to decide quickly and correctly whether resuscitation should be continued for NTOHCA patients who failed in prehospital resuscitation. With the exception of clear evidence of death, emergency physicians need to perform resuscitation immediately and soon discuss the latest conditions with family members to decide whether to continue CPR action. In clinical practice, the initial blood gas sample is usually drawn within 2 minutes after patient arrival at the ED, and the result is always reported within 5 minutes. Accordingly, the initial blood gas data may be a clinically useful reference for deciding whether resuscitation should be continued, as well as to predict the survival of these patients. In this study, we assumed that the decrease in pH value was associated with both prolonged unsuccessful resuscitation and poor outcomes of NTOHCA patients. As a result, the initial blood pH value in the NTOHCA patients at the ED was significantly higher in the survivors than the nonsurvivors. In addition, the pH value was significantly associated with important clinical predictors such as ROSC, witnessed and short prehospital time, but nonasystole rhythm, as showed in Table 2.

Ornato et al.[13] reported that NTOHCA patients who experienced the ROSC in the field were more likely to have had a normal pH compared with those who persisted in cardiac arrest on arrival at

Table 3
Comparison of survival rate between different characteristics by logistic regression (odds)

Variable	Odds ratio	95% confidence interval	p
Sex (female:male)	2.32	0.59−9.11	0.226
Age (adult:elderly)	3.87	1.00−15.06	0.051
PCO_2	1.00	0.98−1.02	0.745
Asystole (no:yes)	5.29	1.48−18.93	0.010
$NaHCO_3$ (no:yes)	9.07	2.33−35.26	0.001
Prehospital time > 20 (no:yes)	4.04	1.10−14.78	0.035
pH ≥ 7.068 (yes:no)	10.01	2.10−47.73	0.004

ED. Chazan and McKay[14] reported that patients with cardiac arrest at different locations of hospital had different initial blood pH values, and the mean pH for those at ED was 7.10. Compared with the finding by Chazan et al., the mean pH value (6.99) in the study was lower, implying that our patients may have longer resuscitation time. Steedman and Robertson[9] reported that all of the arterial and venous pH values after prolonged resuscitation decreased, and the differences between these values were not statistically significant.

During CPR, the most preferred site for routine blood drawing is the femoral area because this site is easy to approach and will not interrupt cardiac massage. Because Henneman et al.[10] found that the femoral vein often had greater palpable pulse than the femoral artery during cardiac massage however atherosclerotic changes in the elderly, arterial samples drawn from the site of femoral pulsations became unreliable. The authors suggested that femoral vessels should be cut down to distinguish an artery from a vein.

$NaHCO_3$ administration for resuscitation of NTOHCA patients is still a controversial issue.[3,15] Adequate alveolar ventilation is the mainstay of control of acid-base balance in cardiac arrest, there is consensus about abandoning the initial $NaHCO_3$ administration during CPR but only after prolonged resuscitation (>10 minutes)[16]. Our results demonstrated that $NaHCO_3$ administration may even be harmful to NTOHCA patients who failed to respond to prolonged prehospital resuscitation. It is interesting that patients who received $NaHCO_3$ administration had higher initial pH values than those who did not; however, the former had poorer survival rates than the latter. One possible explanation is that some patients received $NaHCO_3$ before the blood sample was drawn in the retrospective study. Further subgroup analysis shows that, in patients who received $NaHCO_3$, there were no significant differences in the pH value between survivors and nonsurvivors (7.18 ± 0.13 vs. 7.02 ± 0.22; $p = 0.065$); in those who did not receive $NaHCO_3$, survivors had higher pH values than nonsurvivors (7.08 ± 0.14 vs. 6.91 ± 0.22; $p = 0.016$).

In our study, response time was not a survival predictor for NTOHCA patients, although the survivors tended to have shorter response time; however, the prehospital time was significantly shorter in survivors than nonsurvivors. The quality of prehospital CPR[17] might not be good enough to contribute to the insignificant results of the responsive time; additionally, another possible explanation is our smaller sample size. Grmec et al.[18] reported that the response time was significantly shorter in survivors compared to nonsurvivors. However, the authors' mean response time (10.7 ± 4.4 and 5.9 ± 2.9 minutes for nonsurvivors and survivors, respectively) was longer as compared with our study (5.90 ± 5.12 and 3.94 ± 1.91 minutes for nonsurvivors and survivors, respectively). This contrast should result from the different distribution of the EMS system.

Age was not a factor for predicting the outcome of NTOHCA patients.[18–20] In this study, age was not a survival predictor, and the pH values were not statistically different for the adult and elderly groups. So it was valuable to resuscitate the elderly patients, the oldest patient of the survivors was 86 years old. Gender was not a survival predictor of NTOHCA patients.[18] In this study, compared with male patients, female patients had a similar survival outcome but significantly lower pH values and older ages (mean: 72.0 ± 14.3 vs. 64.9 ± 17.4 years, $p = 0.001$). Perhaps, women could tolerate acidosis caused by cardiac arrest better than men do.

The survival rate to hospital discharge in NTOHCA patients in this study was 7.5% and was similar to the 6.4% rate in North America and Europe,[21] So it was reasonable that our quality of resuscitation and medical care in NTOHCA patients was similar to these developed countries.

There were several limitations to this study. First, differentiating arterial from venous blood puncture at the femoral area during CPR was not performed in this study. Previous studies suggested that a $PO_2 \geq 50$ mmHg might be used as evidence of arterial sampling,[22] with a limitation to fluid-filled lungs.[23] However, inserting a central line during CPR to obtain a mixed venous blood in most resuscitation attempts is not recommended in clinical practice, since this procedure is time-consuming and interrupts the CPR action.[24] Second, a potential confounder such as bystander CPR was not measured; it might be an important predictor for survival among NTOHCA patients.[18,25] However, this was not obtained in the majority of our patients. Finally, this study may underestimate the survival rate of the NTOHCA population because the NTOHCA patients who regained spontaneous circulation due to prehospital resuscitation were excluded.

In conclusion, a cut-off value of initial blood pH at 7.068 can serve as a predictor for survival among NTOHCA patients. In addition, patients whose initial blood pH is less than 6.85 in the ED may not survive until discharge. Moreover, administration of $NaHCO_3$ to NTOHCA patients who failed in prehospital resuscitation is not beneficial and even harmful. Larger prospective studies will be necessary to confirm our study's results and extend them to larger populations.

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