Neurological outcomes in adult drowning patients in China

Peisen Zhou, a Huaqing Xu, a Bingccan Li, a Chenbing Yang, a Zhiliang Zhou, b Jincun Shi, c Zhangping Li d

From the aDepartment of Emergency Medicine, The First Affiliated Hospital of Wenzhou Medical University, Zhejiang, China; bDepartment of Emergency Medicine, The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University, Zhejiang, China; cDepartment of Emergency Medicine, Wenzhou Central Hospital, Zhejiang, China; dThe Quzhou Affiliated Hospital of Wenzhou Medical University, Quzhou People's Hospital, Zhejiang, China

BACKGROUND: Drowning is the third leading cause of unintentional death worldwide. The epidemiological characteristics of adult drownings are rarely reported.

OBJECTIVE: Investigate factors associated with neurological prognosis in adult drowning inpatients.

DESIGN: Multicenter medical record review.

SETTING: Tertiary health care institutions.

PATIENTS AND METHODS: We collected demographic and clinical data on patients who drowned but survived between September 2006 and January 2020. Neurological prognosis was compared in patients with and without cardiac arrest.

MAIN OUTCOME MEASURES: Neurological outcomes.

SAMPLE SIZE AND CHARACTERISTICS: 142 patients with mean age of 50.6 (19.8) years, male/female ratio of 1.54:1.

RESULT: Forty-five patients (31.7%) received CPR, 90 patients (63.4%) experienced unconsciousness, and 59 patients (41.5%) received endotracheal intubation and mechanical ventilation. Multivariate logistic regression analysis showed that the initial blood lactic acid level (OR: 7.67, 95%CI: 1.23-47.82, P=.029) was associated with a poor neurological prognosis in patients without cardiac arrest. The incidence of ICU admission (OR: 16.604, 95%CI: 1.15-239.49, P=.039) was associated with a poor neurologic prognosis in patients with cardiac arrest.

CONCLUSIONS: For the drowning patients with cardiac arrest, ICU admission was associated with neurological function prognosis in these patients. Among the patients without cardiac arrest, the initial lactate value was associated with neurological function prognosis of these patients.

LIMITATIONS: Retrospective.

CONFLICT OF INTEREST: None.
Drowning is the experience of respiratory impairment from submersion/immersion in liquid. Drowning is the third leading cause of unintentional death worldwide. According to the Global Burden of Disease survey, approximately 60,000 people died from unintentional drowning in China in 2016, accounting for 21% of global drowning deaths. The primary outcome of drowning should be classified as death or survival, and neurological impairment is an important outcome scale for assessing the severity of drowning. One study showed that almost 30% of drowning patients required cardiopulmonary resuscitation (CPR). The survival rate of patients after CPR is low; only 10.6% of patients survive to hospital discharge, but the survival rate of drowning patients with cardiac arrest is better than that of other cardiac arrest patients.

The epidemiological characteristics of adult drowning are rarely reported so we retrospectively collected clinical data from three tertiary health care institutions and summarized and analyzed the clinical characteristics and predictors of neurological function prognosis.

PATIENTS AND METHODS
In accordance with the 2015 Revised Utstein-Style Recommended Guidelines for Uniform Reporting of Data from Drowning-Related Resuscitation, we collected data from three tertiary health care institutions for the period from September 2006 to January 2020 (The First Affiliated Hospital of Wenzhou Medical University, The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University, and Wenzhou Central Hospital). All data were collected from the medical record system and analyzed from the day of admission to the day of discharge. General clinical data, pre-existing illness, symptoms and signs, auxiliary examinations, diagnosis, treatment, and survival during hospitalization were analyzed. In terms of drowning-related characteristics, we collected the duration of drowning and wastewater drowning (wastewater specifically refers to rice field water, cement water or factory sewage). We collected data on age, sex, and preexisting illness. The Glasgow coma scale (GCS) score was determined after patients were admitted and discharged. We investigated the initial arterial oxygen saturation and pH. In addition, we collected levels of glucose, serum creatinine and lactic acid. We also checked for pneumonia by lung CT and investigated whether the patients were endotracheally intubated. For patients in the cardiac arrest group, bystander CPR, duration of CPR and restoration of spontaneous circulation (ROSC) after CPR were evaluated. The neurological function of drowning patients was assessed using the cerebral performance category (CPC) score. CPC scores of 1 and 2 represent good neurological outcomes, and CPC scores of 3 and 5 represent poor neurological outcomes.

Data were recorded and analyzed using IBM SPSS (Armonk, New York, United States: IBM Corp) version 21. Data were dichotomized into good and poor neurological outcomes. Normal distributions are presented as percentages and the mean (standard deviation). Data not normally distributed are presented as medians with ranges. We used the t test for continuous variables and the Fisher exact tests and chi-square tests for categorical variables. P values less than .05 were considered statistically significant. To evaluate factors associated with poor neurologic outcome, multivariate logistic regression analysis was performed. To maximize statistical power and minimize bias that might occur if some missing data were excluded from analyses, we used multiple imputation to impute missing values for levels of serum creatinine and pH.

RESULTS
During the 15-year period, 375 drowning patients were admitted to the hospital. Of these, 213 minors (age <18 years) and 20 incomplete medical records were excluded, leaving 142 patients in the analysis. The demographic characteristics were assessed for the 142 adult drowning patients; 86 (60.6%) were men, and 56 (39.4%) were women. The ages ranged from 18 to 92 years, and the mean age was 50.6 (19.8) years. The median duration of submersion was 6 minutes. The median date and time of hospital arrival were 3.3 hours. Ninety-one cases occurred in the summer or autumn (spring:summer:autumn:winter=25:36:55:32), and most occurred in rivers (sea water:river water:wastewater=19:93:32). The patients were divided into two groups according to the presence of cardiac arrest and then by neurological outcome (Figure 1).

Patients with good versus poor neurological outcome
Compared with patients with good neurological outcomes, patients with poor neurological outcomes exhibited significant differences in the incidence of cardiac arrest (P<.001), initial heart rate (P=.002), lowest body temperature within 96 hours of admission (P<.001), initial GCS score (P<.001), initial pH (P=.006), initial levels of glucose (P=.021), serum creatinine (P=.015), and lactic acid (P=.003), incidence of endotracheal intubation (P<.001), incidence of pneumonia (P=.003), incidence of hypotension during hospitalization (P<.001), usage of vasoactive agents (P<.001) and incidence of ICU admission (P<.001) (Table 1).
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Patients without cardiac arrest
Among the 97 patients without cardiac arrest, 90 had good neurological function outcomes, and 7 had poor neurological function outcomes (Table 2). Compared patients with good outcomes, patients with poor outcomes exhibited statistically significant differences in the incidence of wastewater drowning ($P=0.023$), initial heart rate ($P=0.016$), highest temperature within 96 h of admission ($P=0.014$), initial lactic acid level ($P=0.007$), incidence of acute respiratory distress syndrome (ARDS) ($P=0.032$), incidence of endotracheal intubation ($P=0.003$), incidence of hypotension during hospitalization ($P=0.005$), usage of vasoactive agents ($P<0.001$) and incidence of ICU admission ($P<0.023$). Seven patients without cardiac arrest had poor neurological outcomes; their median (range) age was 72 (42-90) years (Table 3). The body temperatures of five of these patients within 96 hours of admission were over 38°C. One patient with hypotension under vasoactive agents was considered for septic shock. Six patients received endotracheal intubation and mechanical ventilation after admission, and the arterial oxygen saturation of three of these patients was below 90%, even when gas exchange functioned. Five patients received glucocorticoids to reduce pulmonary injury.

Patients with cardiac arrest
Among the 45 patients with cardiac arrest, 28 had good neurological outcomes, and 17 had poor neurological outcomes (Table 4). Compared with patients with good neurological outcomes, patients with poor neurological outcomes exhibited statistically significant differences in duration of CPR ($P=0.015$), initial heart rate ($P=0.043$), lowest body temperature within 96 hours of admission ($P=0.002$), initial GCS score ($P=0.001$), initial pH ($P=0.007$), initial levels of glucose ($P=0.002$) and lactic acid ($P=0.047$), incidence of pneumonia ($P=0.015$), incidence of endotracheal intubation ($P=0.007$), incidence of hypotension during hospitalization ($P<0.001$), usage of vasoactive agents ($P<0.001$) and incidence of ICU admission ($P<0.001$). Seventeen patients had poor neurological outcomes. Nine patients were male, and the mean age was 52 years. The median duration of submersion was 12.5 minutes. Nine patients had ROSC after CPR in the field, and 8 patients had ROSC after CPR in the hospital. Sixteen patients were still unconscious after ROSC. Ten patients had hypotension during hospitalization, and three had hypotension under vasoactive agents. Four patients had an arterial oxygen saturation below 95%, even when they received endotracheal intubation and mechanical ventilation after admission. Four patients died during hospitalization (Table 5).

Multivariable analysis
Logistic regression analysis was performed to identify factors associated with neurological prognosis. Among all the patients, initial lactic acid level (OR: 1.389, 95%CI: 1.010-1.910, $P=0.043$) was associated with neurological prognosis. For patients without cardiac arrest, the initial lactic acid level (OR: 7.679, 95%CI: 1.233-47.826, $P=0.029$) was associated with neurological prognosis. For patients with cardiac arrest, the incidence of ICU admission (OR: 16.604, 95%CI: 1.151-239.486, $P=0.039$) was associated with neurological prognosis (Table 6).

DISCUSSION
According to a report by the World Health Organization, 0.7% of deaths worldwide, or more than half a million deaths a year, are caused by drowning. Drowning is a leading cause of death among young men 5-14 years of age. The limited published evidence on risk factors for drowning among children in China has been collected from several provinces. The epidemiological characteristics of adult drowning patients are rarely reported. Studies in other countries have reported roughly the same age and sex in adult drowning patients as we report in our study. The primary goal of treatment is to improve the survival rate and neurological outcome of drowning patients. Relevant studies suggest that the survival rate and neurological outcome of drowning patients may be related to various factors, such as duration underwater, drowning witnessed in the field, initial resuscitation in the field, response of emergency medical services, vital and neurological signs on admission, and comprehensive treatment after admission. The guidelines for

![Patient flow diagram](image)

Figure 1. Patient flow diagram.
Table 1. Neurological outcomes in all drowning patients (n=142).

|                        | Neurological outcome good (n=118) | Neurological outcome poor (n=24) | P value |
|------------------------|-----------------------------------|----------------------------------|---------|
| Age (years)            | 49.8 (19.8)                       | 54.2 (19.6)                      | .323    |
| Male                   | 71 (60.2)                         | 15 (62.5)                        | .831    |
| Wastewater drowning    | 25 (21.2)                         | 7 (29.2)                         | .394    |
| Duration of drowning (min) | 5.5 (0.33, 240)                   | 10 (0.17, 60)                    | .917    |
| Cardiac arrest         | 28 (11.0)                         | 17 (70.8)                        | <.001   |
| Coma after drowning    | 72 (61.0)                         | 18 (75)                          | .195    |
| Initial blood pressure |                                  |                                  |         |
| Systolic (mmHg)        | 128.1 (25.4)                      | 116.8 (31.9)                     | .058    |
| Diastolic (mmHg)       | 745 (13.8)                        | 71.3 (19.0)                      | .343    |
| Initial heart rate (per min) | 89.6 (21.5)                    | 105.7 (25.0)                     | .002    |
| Initial respiratory rate (per min) | 22.7 (5.7)                      | 21.7 (9.8)                       | .493    |
| Initial 96 h highest temperature | 37.3 (2.8)                     | 37.6 (1.8)                       | .693    |
| Initial 96 h lowest temperature | 36.0 (0.6)                     | 35.6 (2.0)                       | <.001   |
| GCS on admission       | 6 (3, 15)                         | 3 (3, 15)                        | <.001   |
| Initial SaO₂ (%)       | 91.2 (9.0)                        | 87.0 (12.7)                      | .063    |
| Initial pH             | 7.4 (0.1)                         | 7.2 (0.2)                        | .006    |
| Initial glucose (mmol/L) | 8.5 (3.9)                         | 10.9 (4.4)                       | .021    |
| Initial serum creatinine (mmol/L) | 65.1 (6.9, 160)                   | 77 (32, 239.5)                   | .015    |
| Initial lactic acid (mmol/L) | 3.1 (0.7, 9)                       | 10.5 (1.6, 12)                   | .003    |
| Pneumonia              | 111 (94.1)                        | 18 (75)                          | .003    |
| ARDS                   | 20 (16.9)                         | 6 (25)                           | .352    |
| Endotracheal intubation| 37 (31.4)                         | 22 (91.7)                        | <.001   |
| Duration of intubation (days and range) | 3 (1, 9)                       | 2.5 (0.5, 48)                    | .353    |
| Hypotension            | 1 (0.8)                           | 12 (50)                          | <.001   |
| Vasoactive agents      | 5 (4.2)                           | 18 (75)                          | <.001   |
| ICU admission          | 24 (20.3)                         | 19 (79.25)                       | <.001   |

Data are expressed as mean (standard deviation) or number (%) unless noted otherwise. *SaO₂*: arterial oxygen saturation, *sCr*: serum creatinine, LA: lactic acid, ARDS: acute respiratory distress syndrome.

CPR suggest that submersion duration is associated with patient survival and neurological outcomes.17 Another study showed that all 56 patients with submersion durations less than 10 minutes survived, while none of the 7 patients with submersion durations more than 10 minutes survived.13 In this study, the median submersion duration was 10 minutes in the group with poor neurological outcomes and 5.5 minutes in the group with good neurological outcomes, which was roughly consistent with other studies.

Having witnesses in the field means earlier first aid and resuscitation. Several studies found having witnesses in the field was related to good neurological outcomes. Initial resuscitation includes establishment of an airway, artificial breathing (mouth-to-mouth breathing) and chest compression for circulation. In contrast to other causes of cardiac arrest, injury related to cardiac arrest by drowning is mainly due to insufficient oxygen. Tobin et al found that bystander CPR after drowning could improve the survival rate and neurological function prognosis of patients.19 In our study, 28 patients with good neurological outcomes underwent CPR in the field, while 17 patients with poor neurological outcomes underwent CPR in the field, showing a statistically significant difference. In patients with cardiac arrest, the median duration of CPR was 10 minutes in those with a good neurological prognosis, and the ROSC rate in the field was 53.6%, while the median duration of CPR was 25 minutes in patients with a poor neurological prognosis, and the ROSC rate in the field was 29.4%. For drowning patients with cardiac arrest, CPR in the field was not a factor affecting the prognosis, but the duration of CPR affected neurological prognosis. The duration of CPR suggested that the longer the duration of CPR, the more severe the illness and injury and the more likely it was that the patient would exhibit a poor neurological function outcome.

Gmec et al found that drowning patients had higher survival rates and were more likely to receive vasoactive agents than those with other causes of cardiac arrest.6 In our study, a total of 45 patients had cardiac arrest caused by drowning, 4 patients died before discharge, and 17 patients were discharged with poor outcomes of neurological function, which was significantly higher than the survival rate of cardiac arrest caused by other causes.

Once the patient has asphyxia or dyspnea, oxygenation should be improved. Popović et al study highlighted the impact of early endotracheal intubation on patient outcomes.20 In another study, mechanical ventilation was associated with neurological outcomes in patients without cardiac arrest.21 In our study, a to-
neurological outcomes of drowning patients without cardiac arrest (n=97).

|                          | Neurological outcome good (n=90) | Neurological outcome poor (n=7) | P value |
|--------------------------|---------------------------------|---------------------------------|---------|
| Age (year)               | 51.8 (19.8)                     | 64.0 (18.7)                     | .119    |
| Male                     | 53 (58.9)                       | 6 (85.7)                        | .318    |
| Wastewater drowning      | 19 (21.1)                       | 5 (71.4)                        | .023    |
| Duration of drowning (min)| 5 (0.33, 240)                   | 5 (1, 17)                       | .06     |
| Coma after drowning      | 44 (48.9)                       | 2 (28.6)                        | .52     |
| Initial BP               |                                 |                                 |         |
| Systolic pressure (mmHg) | 129.2 (25.6)                    | 125.1 (33.8)                    | .698    |
| Diastolic pressure (mmHg)| 74.8 (12.6)                     | 67.7 (16.6)                     | .192    |
| Initial heart rate (per min) | 90.1 (20.6)                   | 110.6 (29.7)                    | .016    |
| Initial respiratory rate (per min) | 23.0 (5.9)                 | 28.1 (13.0)                     | .114    |
| Initial 96 h highest temperature | 37.2 (3.2)                  | 38.8 (1.1)                      | .014    |
| Initial 96 h lowest temperature | 36.6 (0.7)                  | 37.2 (0.6)                      | .2      |
| Initial SaO2 (%)         | 91.5 (8.3)                      | 92.0 (7.8)                      | .893    |
| Initial pH               | 7.4 (0.1)                       | 7.3 (1.4)                       | .547    |
| Initial glucose (mmol/L) | 8.6 (3.9)                       | 7.0 (1.4)                       | .303    |
| Initial serum creatinine (mmol/L) | 68.8 (25.5)                | 83.7 (43.5)                     | .421    |
| Initial lactic acid (mmol/L) | 3.1 (0.7, 8.3)              | 6 (5.9, 12)                     | .007    |
| Pneumonia                | 84 (93.3)                       | 7 (100)                         | .999    |
| ARDS                     | 23 (25.6)                       | 5 (71.4)                        | .032    |
| Endotracheal intubation | 23 (25.6)                       | 6 (85.7)                        | .003    |
| Duration of intubation (days and range) | 3 (1, 9)               | 1 (0.5, 5)                      | .021    |
| Hypotension              | 0                               | 2 (28.6)                        | .005    |
| Vasoactive agents        | 4 (4.4)                         | 5 (71.4)                        | <.001   |
| ICU admission            | 19 (21.1)                       | 5 (71.4)                        | .023    |

Data are expressed as mean (standard deviation) or number (%) unless noted otherwise. SaO2: arterial oxygen saturation, ARDS: acute respiratory distress syndrome.
Table 3. Drowning patients who did not suffer cardiac arrest and were discharged with poor neurological outcomes (n=7).

| Sex | Age (y) | Duration of drowning (min) | Mental status | Initial GCS | Lowest temperature (°C) | Highest temperature (°C) | Bacterial culture | Heart rate (/min) | Blood pressure (mmHg) | Respiratory rate (/min) | SaO₂ (%) |
|-----|---------|----------------------------|---------------|-------------|------------------------|-------------------------|---------------------|-----------------|----------------------|------------------------|----------|
| M   | 74      | Unknown                    | Coma          | 3           | 36.8                   | 39.3                    | +                   | 108             | 118/60               | 21                     | 96.3     |
| M   | 77      | Unknown                    | Normal        | 10          | 37.5                   | 39                      | +                   | 141             | 60/36                | 30                     | 86       |
| M   | 90      | 0.17                       | Coma          | Unknown     | 36.5                   | 38.6                    | +                   | 112             | 170/81               | 34                     | 96.8     |
| M   | 72      | Unknown                    | Normal        | Unknown     | 36.6                   | 38.8                    | -                   | 77              | 131/66               | 124                    | 96.7     |
| F   | 42      | 5                          | Normal        | Unknown     | 36.9                   | 37.3                    | -                   | 84              | 131/74               | 23                     | 89.9     |
| M   | 46      | 1                          | Normal        | Unknown     | 37.7                   | 37.7                    | -                   | 94              | 146/87               | 12                     | 100      |
| M   | 47      | Unknown                    | Normal        | Unknown     | 38.2                   | 40.8                    | -                   | 158             | 120/70               | 53                     | 78       |

GCS: Glasgow coma scale. SaO₂: arterial oxygen saturation.

Table 3 (cont.) Drowning patients who did not suffer cardiac arrest and were discharged with poor neurological outcomes (n=7).

| Sex | Age (y) | Pupil size (mm) | Pupil light reflex | Hypotension ≥2 | Pneumonia | Pulmonary edema | Intubation | Glucocorticoid | Hospital stay (d) | GCS at discharge |
|-----|---------|-----------------|--------------------|----------------|-----------|----------------|------------|----------------|------------------|------------------|
| M   | 74      | 3/3             | Unknown            | -              | +         | -              | -          | -              | 8                | Unknown          |
| M   | 77      | 2/2             | Unknown            | -              | +         | -              | +          | +              | 12               | 4                |
| M   | 90      | 2.5/2.5         | Unknown            | -              | -         | -              | +          | +              | 6                | 3                |
| M   | 72      | 2/2             | +/+                | -              | +         | +              | +          | +              | 32               | 6                |
| F   | 42      | 3/3             | +/+                | +              | +         | -              | +          | +              | 2                | Dead             |
| M   | 46      | Unknown         | +/+                | -              | +         | -              | +          | -              | 1                | 3                |
| M   | 47      | Unknown         | +/-                | +              | +         | -              | +          | +              | 3                | 3                |
Table 4. Neurological outcomes in patients with cardiac arrest (n=45).

|                      | Neurological outcome good (n=28) | Neurological outcome poor (n=17) | P value |
|----------------------|----------------------------------|---------------------------------|---------|
| Age (year)           | 43.4 (18.7)                      | 50.2 (19.0)                     | .25     |
| Sex                  |                                  |                                 |         |
| Male                 | 18 (64.3)                        | 9 (52.9)                        | .337    |
| Duration of drowning (min) | 6 (1, 60)                     | 10 (2, 60)                      | .256    |
| Cardiac arrest       |                                  |                                 |         |
| CPR                  | 24 (85.7)                        | 13 (76.5)                       | .701    |
| Duration of CPR (min) | 10 (2, 30)                      | 25 (3, 60)                      | .015    |
| ROSC in the field    | 15 (53.6)                        | 5 (29.4)                        | .114    |
| Coma after drowning  | 28 (100)                         | 16 (94.1)                       | .378    |
| Initial blood pressure |                                 |                                 |         |
| Systolic pressure (mmHg) | 124.8 (24.8)                  | 113.3 (31.5)                    | .18     |
| Diastolic pressure (mmHg) | 73.3 (14.4)                   | 72.8 (20.2)                     | .924    |
| Initial heart rate (per min) | 88.2 (24.5)                  | 103.6 (24.5)                    | .043    |
| Initial respiratory rate (per min) | 21.8 (4.6)                  | 19.0 (6.9)                      | .116    |
| Initial 96 h lowest temperature | 36.7 (0.8)                  | 34.9 (2.0)                      | .002    |
| GCS on admission     | 10.9 (4.4)                       | 4.4 (3.4)                       | .001    |
| Initial SaO₂ (%)     | 90.4 (11.0)                      | 84.8 (14.0)                     | .161    |
| Initial pH           | 7.3 (0.1)                        | 7.1 (0.3)                       | .007    |
| Initial glucose (mmol/L) | 8.2 (3.8)                     | 12.6 (4.2)                      | .002    |
| Initial serum creatinine (mmol/L) | 70 (33.2, 145)               | 84 (32, 239.5)                  | .098    |
| Initial lactic acid (mmol/L) | 3 (1.3, 9)                     | 12 (1.6, 12)                    | .047    |
| Pneumonia            | 27 (96.4)                        | 11 (64.7)                       | .015    |
| ARDS                 | 9 (32.1)                         | 8 (47.1)                        | .317    |
| Endotracheal intubation | 14 (50)                        | 16 (94.1)                       | .007    |
| Duration of intubation (day) | 3.5 (1, 7)                   | 3 (1, 48)                       | .757    |
| Hypotension          | 1 (3.6)                          | 10 (58.8)                       | <.001   |
| Vasoactive agents    | 1 (3.6)                          | 13 (76.5)                       | <.001   |
| ICU admission        | 5 (17.9)                         | 14 (82.4)                       | <.001   |

Data are expressed as mean (standard deviation) or number (%).
SaO₂: arterial oxygen saturation, ROSC: restoration of spontaneous circulation, ARDS: acute respiratory distress syndrome.
Table 5. Drowning patients with cardiac arrest who were discharged with poor neurological outcomes (n=17).

| Sex | Age (y) | Duration of drowning (min) | CPR time | ROSC in the field | Hospitalization CPR | ROSC in the hospital | Mental status | Initial GCS | Lowest temperature (°C) | Heart rate (per min) | Blood pressure (mmHg) |
|-----|---------|---------------------------|----------|-------------------|---------------------|---------------------|---------------|-------------|-----------------------|---------------------|----------------------|
| M   | 82      | 2                         | 10       | +                 | -                   | -                   | Coma          | Unknown    | 36.2                  | 88                  | 123/76               |
| M   | 51      | 2                         | Unknown  | +                 | -                   | -                   | Coma          | 4           | 36.8                  | 78                  | 142/95               |
| M   | 36      | 20                        | 50       | -                 | +                   | -                   | Coma          | 3           | 35.3                  | 110                 | 80/60*               |
| M   | 50      | 2                         | 20       | -                 | +                   | +                   | Coma          | 3           | 34.2                  | 112                 | 132/86               |
| M   | 40      | 15                        | 30       | -                 | +                   | +                   | Coma          | 3           | 31.9                  | 91                  | 85/46*               |
| F   | 76      | 60                        | 60       | -                 | +                   | +                   | Coma          | 3           | 32.1                  | 101                 | 74/58*               |
| M   | 51      | 50                        | 30       | -                 | +                   | +                   | Coma          | 3           | 31.2                  | 86                  | 137/90*              |
| F   | 56      | 10                        | Unknown  | +                 | +                   | +                   | Coma          | 15          | 36.4                  | 91                  | 120/64               |
| M   | 30      | 10                        | 3        | +                 | +                   | -                   | Coma          | 4           | 37.6                  | 150                 | 109/74               |
| F   | 50      | Unknown                   | Unknown  | +                 | -                   | +                   | Coma          | 4           | 37                    | 129                 | 145/89               |
| F   | 20      | Unknown                   | Unknown  | -                 | +                   | -                   | Coma          | 3           | 33.8                  | 119                 | 65/36*               |
| M   | 57      | Unknown                   | Unknown  | +                 | -                   | -                   | Normal        | 3           | 36.4                  | 137                 | 137/93               |
| M   | 39      | 10                        | Unknown  | +                 | -                   | -                   | Coma          | 5           | 36.6                  | 110                 | 111/86               |
| F   | 27      | Unknown                   | Unknown  | +                 | -                   | +                   | Coma          | 3           | 35                    | 102                 | 127/100              |
| F   | 34      | 5                         | 20       | +                 | -                   | -                   | Coma          | 3           | 32.4                  | 119                 | 51/37*               |
| F   | 73      | 10                        | Unknown  | -                 | +                   | +                   | Coma          | 3           | 35                    | 84                  | 126/65               |
| F   | 81      | Unknown                   | Unknown  | -                 | +                   | -                   | Coma          | 4           | 36.2                  | 55                  | 162/83               |
Table 5 (cont.). Drowning patients with cardiac arrest who were discharged with poor neurological outcomes (n=17).

| Sex | Age (y) | Respiratory rate (/min) | SaO₂ (%) | Pupil size (mm) | Pupil light reflex | Hypotension ≥2 times | Complicating illness | Intubation | Glucocorticoid | Hospital stay (d) | GCS at discharge |
|-----|---------|-------------------------|----------|-----------------|-------------------|---------------------|---------------------|------------|----------------|------------------|------------------|
| M   | 51      | 23                      | 98b      | 4/4             | +/-               | +                   | HE, MODS            | +          | +              | 56               | 3                |
| M   | 56      | 27                      | 96.8     | 2/2             | +/-               | +                   | RF, PI              | +          | +              | 40               | Unknown          |
| F   | 30      | 15                      | 55b      | 3.5/3.5         | +/-               | -                   | PI                  | +          | +              | 15               | Unknown          |
| F   | 50      | 19                      | 88       | 5/5             | +/-               | +                   | ARDS, MODS          | +          | +              | 2                | Unknown          |
| F   | 20      | 15                      | Unknown  | Unknown         | +/-               | +                   | PI                  | +          | +              | 2                | Dead             |
| M   | 57      | 15                      | 64b      | 5/4             | +/-               | +                   | -                   | +          | +              | 3                | Unknown          |
| M   | 39      | 20                      | 72       | 3/3             | +/-               | -                   | PI                  | +          | +              | 20               | Unknown          |
| F   | 27      | 0                       | 95       | 5/5             | +/-               | +                   | PI                  | +          | +              | 2                | Dead             |
| F   | 34      | 24                      | 84       | 5/5             | +/-               | +                   | -                   | +          | +              | 1                | Unknown          |
| F   | 73      | 14                      | 98       | 4/4             | +/-               | -                   | PI                  | +          | +              | 3                | 4                |
| F   | 81      | 24                      | 99       | 3.5/2           | +/-               | -                   | -                   | +          | +              | 10               | 5                |

ARDS: Acute Respiratory Distress Syndrome, PI: pulmonary infections, RF: respiratory failure, HE: hypoxic encephalopathy, MODS: multiple organ dysfunction syndrome. *Maintain blood pressure by vasoactive agents. †Maintain arterial oxygen saturation by mask or mechanical ventilation.
Table 6. Factors associated with neurologic outcome in drowning patients (n=142).

|                        | OR   | 95% CI          | P value |
|------------------------|------|-----------------|---------|
| Initial lactic acid all patients (n=142) | 1.389 | 1.010-1.910     | .043    |
| Initial lactic acid without cardiac arrest (n=97) | 7.679 | 1.233-47.826    | .029    |
| ICU admission with cardiac arrest (n=45)          | 16.604 | 1.151-239.486  | .039    |

Dependent variable poor or good neurologic outcome. Model summary measures: deviance 13.162, Cox Snell .321, Nagelkerke .785, Overall \( \chi^2 \) 36.820, df 6, \( P < .001 \).

Lactic acid plays an important role in the severity and prognosis assessment of shock patients.\(^{26,27}\) The detection of lactic acid level is objective. Shapiro et al showed that blood lactic acid level could be a predictor of mortality in patients with emergency infections. Compared with the blood lactic acid level, dynamic monitoring of blood lactic acid was more significant and supported lactic acid as a promising risk-stratification tool.\(^{28}\) In our study, initial lactic acid level was associated with the prognosis of neurological function. Patients with poor neurological outcomes had a higher median lactate level than patients with good neurological outcomes.

This study has several limitations. First, the number of drowning patients was only 142, and some prognostic factors were not included. Second, we judged neurological outcome by CPC score, without long-term neurological outcome. In conclusion, for drowning patients with cardiac arrest, ICU admission was associated with the prognosis of neurological function. Among the patients without cardiac arrest, the initial lactic acid level was associated with the prognosis of neurological function.

Author contributions
ZPL, PSZ, HQX and CBY designed the study and drafted the manuscript; ZPL and PSZ helped interpret the results and write some discussion; BCL, CBY and HQX helped in the statistical analysis and result interpretation; ZLZ and JCS prepared the figures and interpret the results. ZPL and PSZ are identified as the guarantors of the paper, taking responsibility for the integrity of the work as a whole, from inception to published article.
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REFERENCES

1. Idris AH, Berg RA, Bierens J, Bossaert L, Branche CM, Gabrielli A, et al. Recommendations for uniform reporting of data from drowning: the “Utstein style”. Circulation. 2003;108:2565-74.
2. Peden M, K, Sharma K. The injury chart book: a graphical overview of the global burden of injuries. Geneva: World Health Organization, 2002. https://g.co/kgs/QD7TYv.
3. Global, regional, and national age-sex specific mortality for 244 causes of death, 1980-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet. 2017;390:1151-210.
4. Venema AM, Groothoff JW, Bierens JJ. The role of bystanders during rescue and resuscitation of drowning victims. Resuscitation. 2010;81:434-9.
5. Benjamin EJ, Blaha MJ, Chiuve SE, Cushman M, Das SR, Deo R, et al. Heart Disease and Stroke Statistics-2017 Update: A Report From the American Heart Association. Circulation. 2017;135:e146-e603.
6. Grmec S, Stmad M, Podgorsek D. Comparison of the characteristics and outcome among patients suffering from out-of-hospital primary cardiac arrest and drowning victims in cardiac arrest. Int J Emerg Med. 2009;2:7-12.
7. Idris AH, Bierens J, Perkins GD, Wenzel V, Nadkarni V, Morley P, et al. 2015 Revised Utstein-Style Recommended Guidelines for Uniform Reporting of Data From Drowning-Related Resuscitation: An ILCOR Advisory Statement. Circ Cardiovasc Qual Outcomes. 2017;10:7.
8. Mak M, Moulaert VR, Pijls RW, Verbunt JA. Measuring outcome after cardiac arrest: construct validity of Cerebral Performance Category. Resuscitation. 2016;100:6-10.
9. Lili X, Jian H, Liping L, Zhiyu L, Hua W. Epidemiology of Injury-Related Death in Children under 5 Years of Age in Hunan Province, China. 2009-2014. PLoS One. 2017;12:e0168524.
10. Fang Y, Dai L, Jaung MS, Chen X, Yu S, Xiang H. Child drowning deaths in Xiamen city and suburbs, People’s Republic of China, 2001 S. Inj Prev. 2007;13:339-43.
11. Wang L, Cheng X, Yin P, Cheng P, Liu Y, Schwebel DC, et al. Unintentional drowning mortality in China, 2006-2013. Inj Prev. 2019;25:47-51.
12. Youn CS, Choi SP, Yim HW, Park KN. Out-of-hospital cardiac arrest due to drowning: An Utstein Style report of 10 years of experience from St. Mary's Hospital. Resuscitation. 2009;80:778-83.
13. Lunetta P, Smith GS, Penttila A, Sajantila A. Unintentional drowning in Finland 1970-2000: a population-based study. Int J Epidemiol. 2004;33:1053-63.
14. Claesson A, Lindqvist J, Herlitz J. Cardiac arrest due to drowning—changes over time and factors of importance for survival. Resuscitation. 2014;85:644-8.
15. Panzino F, Quintillas JM, Luaces C, Pou J. [Unintentional drowning by immersion. Epidemiological profile of victims attended in 21 Spanish emergency departments]. An Pediatr (Barc). 2013;78:178-84.
16. Claesson A, Lindqvist J, Ortenwall P, Herlitz J. Characteristics of lifesaving from drowning. Anecdotal experience from St. Mary's Hospital. Resuscitation. 2014;85:644-8.
17. Merchant RM, Topjian AA, Panchal AR, Cheng A, Aziz K, Berg KM, Lavonas EJ, Magid DJ. Adult Basic and Advanced Life Support, Pediatric Basic and Advanced Life Support, Neonatal Life Support, Resuscitation Education Science, and Systems of Care Writing Groups. Part 1: Executive Summary: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2020;142(16_suppl_2):S337-S357.
18. Bierens JJ, van der Velde EA, van Berkel M, van Zanten JJ. Submersion in the Netherlands: prognostic indicators and results of resuscitation. Ann Emerg Med. 1999;10:1390-5.
19. Tobin JM, Ramos WD, Pu Y, Wernicki PG, Quan L, Rossano JW. Bystander CPR is associated with improved neurologically fa- vourable survival in cardiac arrest following drowning. Resuscitation. 2017;115:39-43.
20. Popović V, Gvozdenović L, Ivanov I, Milic S. [Out-of-hospital treatment in case of drowning]. Med Prigl. 2011;64:64-7.
21. van Berkel M, Bierens JJ, Lie RL, de Rooy TP, Kool LJ, van de Velde EA, et al. Pulmonary oedema, pneumonia and mortality in submersion victims; a retrospective study in 125 patients. Intensive Care Med. 1996;22:101-7.
22. Niskanen M, Kari A, Nikki P, Isalo E, Kaukinen L, Rauhala V, et al. Acute physiology and chronic health evaluation (APACHE II) and Glasgow coma scores as predictors of outcome from intensive care after cardiac arrest. Crit Care Med. 1991;19:1465-73.
23. Guenther U, Varelmann D, Putensen C, Wrigge H. Extended therapeutic hypothermia for several days during extracorporal membrane-oxygenation after drowning and cardiac arrest: Two cases of survival with no neurological sequelae. Resuscitation. 2009;80:379-81.
24. Bernard SA, Gray TW, Buist MD, Jones BM, Silvester W, Gutteridge G, et al. Treatment of comatose survivors of out-of-hospital cardiac arrest with induced hypothermia. N Engl J Med. 2002;346:557-63.
25. Cremer OI, Kalkman CJ. Cerebral pathophysiology and clinical neurology of hyperthermia in humans. Prog Brain Res. 2007;162:153-69.
26. Levereve XM. Energy metabolism in critically ill patients: lactate is a major oxidizable substrate. Curr Opin Clin Nutr Metab Care. 1999;2:165-9.
27. Yuan WH, Zeng LK, Cai BH, Liu XY, Weng S, Zhao LX, et al. [Value of arterial blood lactic acid in the evaluation of disease severity and prognosis in neonatal shock]. Zhongguo Dang Dai Er Ke Za Zhi. 2018;20:17-20.
28. Shapiro NI, Howell MD, Talmor D, Nathanson LA, Lisbon A, Wolfe R, et al. Serum lactate as a predictor of mortality in emergency department patients with infection. Ann Emerg Med. 2005;45:524-8.
Supplementary Table. Guidance for neurological outcomes in adult drowning in patients.

| Item description                                                                 | Explanation                                                                                                                                                                                                                                                                                                                                 | Other |
|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1. Report the background of drowning                                              | Drowning is the third leading cause of unintentional death worldwide and approximately 60,000 people died from unintentional drowning in China.                                                                                                                                                                                                 |       |
| 2. Report the difference of drowning patients with CPR and without CPR            | CPR accounts for 30% drowning patients and the survival rate was difference with other cardiac arrest.                                                                                                                                                                                                                                                                                          |       |
| 3. Report the patients                                                            | We collected demographic and clinical data on drowning patients between September 2006 and January 2020.                                                                                                                                                                                                                                                                                       |       |
| 4. Report the data we collected                                                   | All data were collected from the medical record system and analyzed from the day of admission to the day of discharge.                                                                                                                                                                                                                                                                         |       |
| 5. Report the statistical method                                                   | All data were recorded and analyzed using SPSS 21. We used t-tests for continuous variables and Fisher’s exact tests and chi-square tests for categorical variables.                                                                                                                                                                                                                          |       |
| 6. Report the result of general clinical data                                     | The demographic characteristics were assessed for the 142 adult drowning patients.                                                                                                                                                                                                                                                                                                                   |       |
| 7. Report the result of neurological outcome                                      | The factors influencing neurological outcome of 142 adult drowning patients.                                                                                                                                                                                                                                                                                                                      |       |
| 8. Report the result of drowning patients without cardiac arrest                  | The difference between good and poor neurological outcome of drowning patients without cardiac arrest.                                                                                                                                                                                                                                                                                           |       |
| 9. Report the result of drowning patients with cardiac arrest                     | The difference between good and poor neurological outcome of drowning patients with cardiac arrest.                                                                                                                                                                                                                                                                                               |       |
| 10. Report the result of logistic regression                                       | Logistic regression analysis was performed to identify predictive factors of neurological prognosis.                                                                                                                                                                                                                                                                                                   |       |
| 11. Report on treatment strategies for drowning patients                           | The primary goal of treatment is to improve the survival rate and neurological outcome of drowning patients.                                                                                                                                                                                                                                                                                   |       |
| 12. Report submersion duration was associated with patients’ survival             | The American Heart Association (AHA) 2020 guidelines for cardiopulmonary resuscitation suggest that submersion duration is associated with patient survival and neurological outcomes. This study was roughly consistent with other studies.                                                                                                                                       |       |
| 13. Report Initial resuscitation was associated with patients’ survival           | Initial resuscitation includes establishment of an airway, artificial breathing (mouth-to-mouth breathing) and chest compression for circulation.                                                                                                                                                                                                                                                      |       |
| 14. Report oxygenation was associated with patients’ survival                     | The GCS score, alert-verbal-painful-unresponsive (AVPU) score and Aristotle Basic Complexity (ABC) score are important factors in evaluating the neurological function of patients at admission.                                                                                                                                                                                                       |       |
| 15. Report neurological examination was associated with patients’ survival        | The lowest body temperature (36°C) within 96 h of admission affects the prognosis of neurological function. The highest temperature (38°C) within 96 h of admission was a predictive factor of the prognosis of neurological function.                                                                                                                                                                                       |       |
| 16. Report Lactic acid was associated with patients’ survival                     | Lactic acid is a byproduct of anaerobic metabolism and a marker of tissue hypoxia or shock. Lactic acid plays an important role in the severity and prognosis assessment of shock patients.                                                                                                                                                                                                            |       |