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Research article

Urine output for predicting in-hospital mortality of intensive care patients with cardiogenic shock

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ABSTRACT

Background: The role of urine output (UO) in the first 24 h of admission in the clinical management of cardiogenic shock (CS) patients has not been elucidated.
Methods: This study retrospectively analyzed intensive care CS patients in the MIMIC-IV database. Binomial logistic regression analysis was conducted to evaluate whether UO was an independent risk factor for in-hospital mortality in CS patients. The performance of UO in predicting mortality was evaluated by the receiver operating characteristic (ROC) curve and compared with the Oxford Acute Severity of Illness Score (OASIS). The clinical net benefit of UO in predicting mortality was determined using the decision curve analysis (DCA). Survival analysis was performed with Kaplan-Meier curves.
Results: After adjusting for confounding factors including diuretic use and acute kidney injury (AKI), UO remained an independent risk factor for in-hospital mortality in CS patients. The areas under the ROC curves (AUCs) of UO for predicting in-hospital mortality were 0.712 (UO, ml/day) and 0.701 (UO, ml/kg/h), which were comparable to OASIS (AUC = 0.695). In terms of clinical net benefit, UO was comparable to OASIS, with different degrees of benefit at different threshold probabilities. Survival analysis showed that the risk of in-hospital death in the low-UO (≤857 ml/day) group was 3.0143 times that of the high-UO (>857 ml/day) group.
Conclusions: UO in the first 24 h of admission is an independent risk factor for in-hospital mortality in intensive care CS patients and has moderate predictive value in predicting in-hospital mortality.

1. Introduction

Cardiogenic shock (CS) is caused by severe damage to cardiac function, resulting in reduced cardiac output, hypoxia, and end-organ hypoperfusion. Acute myocardial infarction accounts for more than 80% of the causes of CS [1,2]. The clinical manifestations of CS are hypotension that is difficult to control by volume resuscitation, as patients often have symptoms such as confusion, increased heart rate, rapid breathing, nausea, and vomiting. In recent years, the incidence of CS has increased, especially in females, Asian/Pacific Islanders, and patients older than 75 years [3]. Although advanced medical technologies such as extracorporeal membrane oxygenation (ECMO) have decreased the mortality rate of CS, the 6-month/1-year mortality in CS was still around 50% [4,5].

Death prediction has far-reaching significance for CS, especially short-term death prediction, which can assist medical staff in

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formulating an appropriate diagnosis and treatment plans promptly and greatly help reduce mortality. Some remarkable results have been achieved in short-term mortality prediction in CS. The CardShock risk score proposed by Harjola et al. [2], consisting of seven easily accessible variables (including age, blood lactate, confusion at presentation, etc.), quickly stratifies the risk of short-term mortality of CS, even if not caused by acute coronary syndrome (ACS). In addition, Jentzer et al. demonstrated that a new 5-stage CS classification scheme also provides reliable hospital mortality risk stratification [6]. However, due to their complexity or novelty, the above scoring systems have not yet been fully promoted in clinical applications.

Urine output (UO) is one of the critical factors in the hemodynamic management of CS, and a deep understanding of UO is necessary. Although rooted in the heart, CS has systemic effects, especially renal perfusion. In the early stage of CS, the patients may have decreased UO; in the middle stage of shock, there may even be anuria. Currently, the prognostic role of UO in CS is almost unexplored. A retrospective study has demonstrated that UO is an independent risk factor for septic shock patients, and the decrease in UO is associated with a significant increase in in-hospital mortality. Meanwhile, the ability of using UO alone to predict in-hospital mortality of septic shock patients is comparable to the Sequential Organ Failure Assessment (SOFA) score [7]. Zhang et al. found that UO on the admission of intensive care unit (ICU) is closely associated with in-hospital mortality in unselected critically ill patients, and is an independent predictor of in-hospital mortality independent of diuretic use [8]. Nevertheless, it is unknown whether UO can predict in-hospital mortality in CS and to what extent. Therefore, we designed this retrospective study to clarify the relationship between in-hospital mortality in intensive care CS patients and UO. It should be noted that, for the convenience of research, the UO mentioned in this study is the UO in the first 24 h of admission.

2. Methods

2.1. Database

Data in an American population from the Medical Information Mart for Intensive Care-IV (MIMIC-IV, official website at https://mimic.mit.edu/) database were extracted. By integrating electronic medical records, MIMIC-IV contains information of patients who were admitted to the ICUs of the Beth Israel Deaconess Medical Center from 2008 to 2019. The database requires researchers to pass the "Protect Human Research Participants" exam (on the National Institutes of Health website) and sign a data use agreement before accessing data. The author Tianyang Hu (Record ID: 37474354), is a credentialed user of PhysioNet and obtained access to the database.

The design of our study conforms to the basic principles of Helsinki Declaration. MIMIC-IV database was deidentified, and patient identifiers (including their names, phone number, place of residence, and dates) were removed according to the HIPAA Safe Harbor provision [9]. Thus, this study does not require an ethical review or informed consent from the patients.

2.2. Study population

CS is a state of a marked reduction in cardiac output due to cardiac causes, resulting in tissue hypoperfusion and various clinical and biochemical changes. Clinical manifestations of CS include systolic blood pressure (SBP) $<$ 90 mmHg for 30 min after adequate rehydration, or vasopressor therapy is required to maintain SBP $>$ 90 mmHg and signs of hypoperfusion (oliguria $<$0.5 ml/kg/h in first 6 h, confusion or altered mental status, cold periphery, etc.) [2]. By searching for the International Classification of Disease (ICD) code, there are two main types of patients diagnosed as "cardiogenic shock" in the database: "cardiogenic shock" with ICD code "78551" (9th revision)/"R570" (10th revision), and "postprocedural cardiogenic shock, initial encounter" with ICD code "T8111XA" (10th revision). We excluded patients with repeat ICU admissions, $<$18 years of age, length of hospital stay $<$24 h, and missing data on UO or weight.

We have compiled the following data for the enrolled patients: age at admission, gender, length of hospital/ICU stay, UO and infusion on the first day of admission, weight, coexisting comorbidities (cardiac arrest, congestive heart failure/CHF, chronic pulmonary disease, diabetes, myocardial infarct, hypertension, and renal disease), laboratory tests on the first day of admission (blood count, hemoglobin, blood urea nitrogen, creatinine, and anion gap), vital signs (heart/respiratory rate, mean artery pressure/MAP, temperature, and saturation of peripheral oxygen) on the first day of admission, whether complicated with acute kidney injury (AKI), diuretics use, catecholamine (including epinephrine, norepinephrine, dopamine and dobutamine) use, whether performed with renal replacement therapy (RRT)/extracorporeal membrane oxygenation (ECMO) on the first day of admission, and whether died in hospital. If laboratory tests or vital signs were measured multiple times, take the average.

We additionally collected the Oxford Acute Severity of Illness Score (OASIS) of the enrolled patients, which was developed by Johnson et al. using machine learning methods in 2013 and consists of 10 variables (including age at admission, heart rate, MAP, temperature, Glasgow coma score, etc.) [10], one of which is UO (ml/day). There are many scoring systems with UO as a component, such as the Logistic Organ Dysfunction system (LODS) [11] and the Simplified Acute Physiology Score (SAPS II) [12]. Still, OASIS is relatively simple, and all variables are non-laboratory tests. Chen et al. demonstrated that OASIS was significantly related to in-hospital mortality in patients with sepsis and could serve as a preliminary prognostic indicator in these patients [13]. Wang et al. also determined that OASIS showed better discrimination and calibration than Acute Physiology and Chronic Health Evaluation II (APACHE II) and Simplified Acute Physiology Score (SAPS II) in predicting the 28-day mortality risk of AKI patients, and its calculation was simpler [14]. Therefore, we intend to further clarify the predictive value of UO in in-hospital mortality of intensive care patients with CS by comparing it with the predictive ability of OASIS.

2.3. Statistical analysis

Use Kolmogorov-Smirnov test to check the normality of continuous variables. Continuous variables following normal distribution were described by mean ± standard deviation (M ± SD) and compared by independent sample *t*-test; If not, then described by median interquartile interval (IQR) and compared by Wilcoxon rank-sum test. Categorical variables were described by numbers (percentage) and compared using the Chi-square test. Binomial logistic regression was conducted to determine whether a variable was an independent risk factor for hospital death. In this process, variables ($p < 0.1$) in univariable analysis were selected for the multivariable analysis. The ROC curves of UO and OASIS were drawn separately, and the areas under the ROC curves (AUCs) were compared (Z test by Delong et al. [15]) to clarify their predictive value.

We additionally conducted a decision curve analysis (DCA) [16] to evaluate the clinical net benefits when UO and OASIS were used to predict the prognosis of the CS patients. The so-called "net benefit" refers to the difference between the relative hazard proportions of false positives and false negatives (weighted by the odds of the chosen high-risk specified threshold), as the difference between the expected benefit and harm. If there is a certain probability of the predicted outcome event occurring and urgent intervention measures are taken immediately (in the case of CS, patients should be under mechanical ventilation or even ECMO), then choosing the prognostic strategy with the largest area under the decision curve will obtain the most significant clinical net benefit.

In-hospital mortality could be considered a time-to-event variable, and patients are followed up throughout the hospitalization period. The failure event is death during the hospital stay, and patients should be censored if discharged alive [8]. Based on the above theory, we conducted an in-hospital survival analysis by the log-rank test. The optimal cut-off value of UO was determined from the ROC curve, UO was divided into two groups by this cut-off value, and the Kaplan-Meier survival curve was drawn.

Analyses were performed with MedCalc 19.6.1 or R 4.1.2 software, and $p < 0.05$ was considered statistically significant.

3. Results

3.1. Baseline characteristics

1499 patients (Fig. 1) were enrolled in our study (483 died, while 1016 survived in hospital, with an in-hospital mortality rate of 32.22%). UO in the death group was significantly lower than that in the survival group. The age at admission and OASIS score of the death group were higher, and the length of hospital/ICU stay of the death group were shorter than those in the survival group (all $p < 0.001$). Regarding comorbidities, we found that patients died in hospital were more likely to suffer from cardiac arrest and renal disease, but were less likely to suffer from CHF. No difference was observed in the proportion of patients with AKI and diuretic use between the two groups on the first day of admission; however, the percentage of patients who treated with RRT, epinephrine and norepinephrine in the death group was higher than in the survival group. Table 1 shows the baseline characteristics.

3.2. Binomial logistic regression analysis

After adjusting for potential confounding factors by multivariable regression analysis, we determined that UO (ml/kg/h, OR = 0.673, 95% CI = 0.546–0.830, $p < 0.001$) and OASIS (OR = 1.043, 95% CI = 1.027–1.060, $p < 0.001$) were both independent risk factors for in-hospital mortality of the CS patients (Table 2).

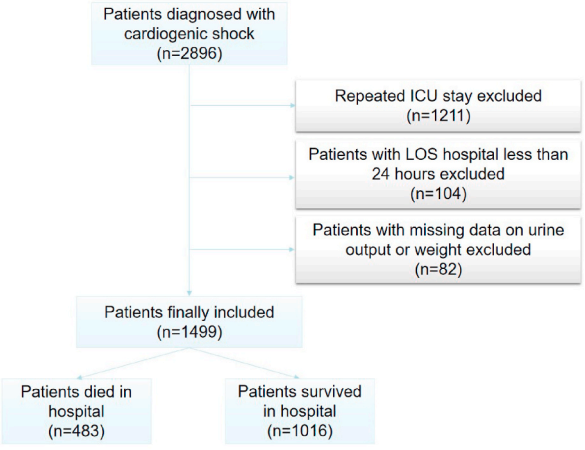

Fig. 1. Flowchart of study cohort. ICU=Intensive Care Unit, LOS = Length of Stay.

Table 1
Demographic data of the patients.

Characteristics	Death (n = 483)	Survival (n = 1016)	*p*
Age, years	75 (66–83)	70 (60–79)	<0.001
Gender (male)	266 (55.1)	629 (61.9)	0.012
LOS ICU, days	3.9 (2.0–7.8)	4.7 (2.7–8.7)	<0.001
LOS hospital, days	6.7 (3.1–13.0)	12.1 (7.2–19.2)	<0.001
Coexisting comorbidities			
Myocardial infarct	254 (52.6)	496 (48.8)	0.173
Cardiac arrest	94 (19.5)	98 (9.6)	<0.001
Congestive heart failure	345 (71.4)	822 (80.9)	<0.001
Chronic pulmonary disease	156 (32.3)	284 (28.0)	0.084
Diabetes	185 (38.3)	351 (34.5)	0.156
Hypertension	119 (24.6)	285 (28.1)	0.164
Renal disease	199 (41.2)	311 (30.6)	<0.001
Laboratory tests			
White blood cell, 10^9/L	13.4 (10.0–17.8)	12.6 (9.4–16.4)	<0.001
Platelets, 10^9/L	186 (137–252)	192 (143–251)	0.304
Hemoglobin, g/dL	10.6 (9.1–12.2)	11.2 (9.6–12.9)	<0.001
BUN, mmol/L	35.5 (23.8–58.5)	27.0 (18.5–42.5)	<0.001
Creatinine, ng/dL	1.75 (1.23–2.55)	1.30 (1.00–1.95)	<0.001
Anion gap, mmol/L	18.0 (15.0–21.5)	15.5 (13.5–18.5)	<0.001
Vital signs			
Heart rate, bpm	88 (78–103)	86 (76–98)	0.004
MAP, mmHg	73 (67–78)	75 (70–81)	<0.001
Respiratory rate, cpm	21 (18–24)	20 (18–23)	<0.001
Temperature, °C	36.7 (36.3–37.0)	36.8 (36.5–37.1)	<0.001
SpO_2 (%)	96.9 (95.0–98.3)	97.0 (95.6–98.2)	0.128
OASIS, points	43 (36–49)	36 (28–42)	<0.001
Day 1 UO, ml	780 (302–1675)	1738 (946–2996)	<0.001
Day 1 UO, ml/kg/h	0.42 (0.15–0.85)	0.87 (0.50–1.52)	<0.001
Day 1 infusion, ml	12520 (6300–20750)	9500 (4827–18327)	<0.001
Day 1 AKI	112 (23.2)	208 (20.5)	0.230
Day 1 diuretic	221 (45.8)	538 (53.0)	0.009
Day 1 epinephrine	136 (28.2)	235 (23.1)	0.035
Day 1 norepinephrine	388 (80.3)	553 (54.4)	<0.001
Day 1 dopamine	74 (15.3)	156 (15.4)	0.987
Day 1 dobutamine	61 (12.6)	130 (12.8)	0.928
Day 1 ECMO	10 (2.1)	9 (0.9)	0.080
Day 1 RRT	128 (26.5)	113 (11.1)	<0.001

LOS = Length of Stay, ICU= Intensive Care Unit, BUN= Blood Urea Nitrogen, bpm = beat per minute, MAP = Mean Artery Pressure, cpm = count per minute, SpO_2=Saturation of Peripheral Oxygen, OASIS=Oxford Acute Severity of Illness Score, Day 1 UO=Urine Output in the first 24 h of admission, AKI=Acute Kidney Injury; ECMO = Extracorporeal Membrane Oxygenation, RRT = Renal Replacement Therapy.

3.3. Comparison of ROC/DCA curves

The ROC curves (Fig. 2, Table 3) shows that the AUCs of UO (ml/day), UO (ml/kg/h), and OASIS were 0.712, 0.701, and 0.695, respectively. No statistical differences were found in comparing the AUCs between UO and OASIS (for UO, ml/day, Z = 1.067, p = 0.2858; for UO, ml/kg/h, Z = 0.371, p = 0.7107). However, statistical analysis showed a difference between the two different expressions of UO (Z = 2.555, p = 0.0106). The specificity (78.35%) and Youden's index (0.3197) of UO (ml/day) were the highest.

As shown in Fig. 3, the OASIS represented by the solid black line has a certain degree of the clinical net benefit between the threshold probability 0.2–0.7; however, the net benefit between the threshold probability 0.4–0.5 is significantly less than that of UO. When the threshold probability is between 0.4 and 0.6, the DCA curves representing UO and OASIS cross each other, and each has its net benefit and advantage under different threshold probabilities. The UO (ml/day) represented by the solid red line is always slightly higher than the UO (ml/kg/h) represented by the solid blue line between 0.3 and 0.5, and its clinical net benefit has a slight advantage.

3.4. Comparison of Kaplan-Meier curves

We determined the optimal cut-off value for UO (857 ml/day) according to the ROC curve, based on which we divided the patients into two groups (high-UO group > 857 ml/day; low-UO group ≤ 857 ml/day) and plotted the Kaplan-Meier curves (Fig. 4). The mean survival time of the high-UO group was 91.087 days (95% CI = 75.549–106.625), while in the low-UO group was 32.793 days (95% CI = 25.918–39.668), with a statistically significant difference (p < 0.0001). Compared to the high-UO group, the hazard ratio (HR) of the low-UO group was 3.0143 (95% CI = 2.4824–3.6602).

Table 2
Results of the binomial Logistic regression analysis.

	Univariable		Multivariable	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Age	1.024 (1.016–1.033)	<0.001	1.018 (1.008–1.029)	<0.001
Gender (male)	0.754 (0.606–0.939)	0.012	0.867 (0.667–1.127)	0.287
MI	1.163 (0.936–1.444)	0.173		
Cardiac arrest	2.246 (1.666–3.076)	<0.001	2.220 (1.548–3.185)	<0.001
CHF	0.590 (0.459–0.759)	<0.001	0.479 (0.352–0.652)	<0.001
CPD	1.230 (0.972–1.555)	0.084	1.307 (0.996–1.715)	0.054
Diabetes	1.176 (0.940–1.472)	0.156		
Hypertension	0.839 (0.654–1.075)	0.164		
Renal disease	1.588 (1.268–1.989)	<0.001	1.205 (0.887–1.637)	0.232
BUN	1.014 (1.010–1.019)	<0.001	1.012 (1.005–1.019)	0.001
Creatinine	1.266 (1.162–1.380)	<0.001	0.799 (0.687–0.929)	0.003
Anion gap	1.139 (1.108–1.170)	<0.001	1.099 (1.060–1.139)	<0.001
Heart rate	1.009 (1.003–1.015)	0.004	1.008 (1.001–1.016)	0.028
MAP	0.965 (0.953–0.977)	<0.001	0.981 (0.966–0.995)	0.008
OASIS	1.078 (1.065–1.092)	<0.001	1.040 (1.023–1.057)	<0.001
[a]Day 1 UO	0.382 (0.315–0.464)	<0.001	0.668 (0.541–0.825)	<0.001
Day 1 infusion	1.000 (1.000–1.000)	<0.001	1.000 (1.000–1.000)	0.288
Day 1 diuretic	0.749 (0.603–0.931)	0.009	0.867 (0.661–1.138)	0.305
Day 1 CA	2.161 (1.616–2.889)	<0.001	1.299 (0.905–1.866)	0.157
Day 1 ECMO	2.366 (0.955–5.860)	0.063	1.476 (0.541–4.031)	0.447
Day 1 RRT	2.881 (2.175–3.817)	<0.001	2.021 (1.409–2.897)	<0.001

OR=Odds Ratio, CI=Confidence Interval, MI = Myocardial Infarct, CHF=Congestive Heart Failure, CPD=Chronic pulmonary disease, BUN=Blood Urea Nitrogen, MAP = Mean Artery Pressure, OASIS=Oxford Acute Severity of Illness Score, Day 1 UO=Urine Output in the first 24 h of admission, AKI=Acute Kidney Injury, CA=Catecholamine, ECMO = Extracorporeal Membrane Oxygenation, RRT = Renal Replacement Therapy.
[a] Only UO (ml/kg/h) was included in the logistic regression analysis due to the collinearity.

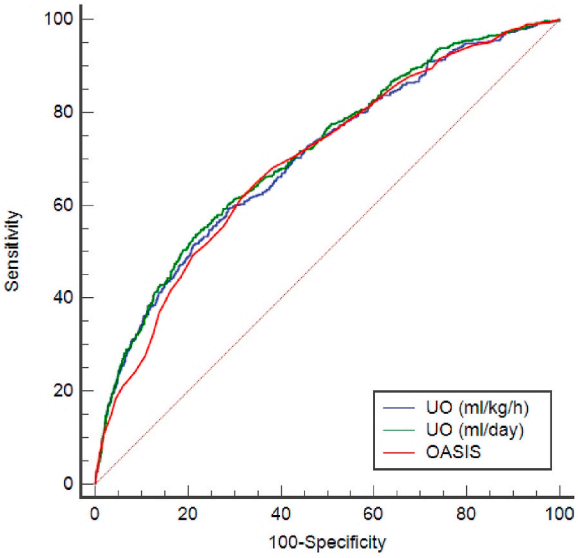

Fig. 2. ROC curves of UO and OASIS. UO=Urine Output in the first day of admission, OASIS= Oxford Acute Severity of Illness Score.

Table 3
Comparison of ROC curves.

Factor	AUC	95%CI	Optimal cut-off	Sensitivity	Specificity	Youden's index
UO (ml/day)	0.712	0.677–0.724	857	53.62	78.35	0.3197
UO (ml/kg/h)	0.701	0.688–0.735	0.55	59.21	71.36	0.3057
OASIS	0.695	0.671–0.719	39	64.60	65.55	0.3015

UO=Urine Output in the first day of admission, OASIS= Oxford Acute Severity of Illness Score.

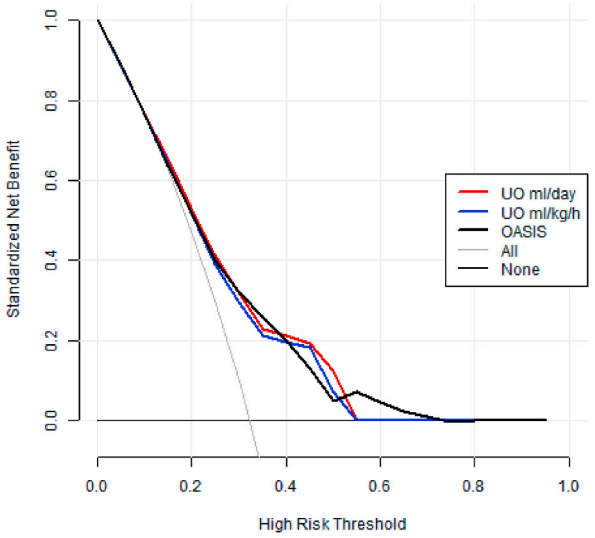

Fig. 3. DCA curves of UO and OASIS. UO=Urine Output in the first day of admission, OASIS= Oxford Acute Severity of Illness Score.

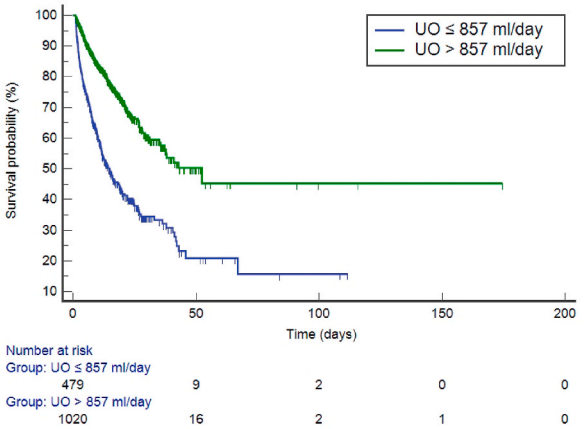

Fig. 4. Kaplan-Meier survival curves (log-rank $p < 0.0001$). UO=Urine Output in the first day of admission.

4. Discussion

Researchers have identified a range of factors related to in-hospital mortality in CS, including low body mass index (BMI), in-hospital cardiac arrest, vasopressor dosage, the mean of all mean arterial pressure values during the first 24 h (mMAP24), severe acidosis, etc. [17–19] Moreover, several researches have demonstrated the potential value of hemodynamic monitoring in reducing mortality [20–22]. However, few studies have paid attention to the role of UO in predicting mortality in unselected CS patients, which was one of the original motivations for this study. We firstly demonstrate that UO in the first day of admission is an independent risk factor for in-hospital mortality in intensive care patients with CS. Meanwhile, we found that the risk of in-hospital death in the low-UO group was about three times (HR = 3.0143) that of the high-UO group. In terms of predictive power, UO alone achieved a moderate predictive value (AUC > 0.70) in predicting in-hospital mortality. Compared with UO alone, we found no improvement in the predictive value of OASIS, nor did OASIS show an advantage in the clinical net benefit during DCA. The original intention of OASIS was to reduce variables as much as possible so that the scoring system could be more easily applied in clinical practice. As mentioned earlier, although OASIS performs well in short-term mortality prediction for many diseases, at least this study found that its performance to be suboptimal in predicting in-hospital mortality of CS. We believe that this is largely due to the dilution of the value of UO in the OASIS scoring system, as the grouping of UOs and the assignment of scores after grouping may not be reasonable. Or perhaps, OASIS is simply not suitable for predicting in-hospital mortality in CS. Different diseases may require individualized scoring systems, and it is unrealistic to expect a single scoring system to apply to multiple conditions simultaneously. Our study highlights the importance of UO and encourages researchers to focus on the role of UO in CS when developing better in-hospital mortality prediction scoring systems in the future.

The incidence of AKI in this study was 23.2% in the death group and 20.5% in the survival group, with no statistically difference. However, one study suggested that UO is an early and sensitive marker for AKI, as decreased UO may precede a creatinine-based diagnosis of AKI [23]. Meanwhile, oliguria may be a protective measure of the kidney against acute injury [24]. Therefore, we speculate that the proportion of AKI patients in the death group may be higher than 23.2%, which may be an essential factor for the higher mortality. Furthermore, in our study, the fluid infusion on the first day in the death group was significantly higher than the survival group (12520 ml/day vs. 9500 ml/day, $p < 0.001$). Resuscitation with large volume fluid has historically been considered the cornerstone of resuscitation in shock patients [25,26]. Still, fluid resuscitation is almost always related to some degree of fluid overload, which promotes tissue edema and can lead to progressive organ dysfunction [27,28]. In CS, the kidneys are more prone to hypoperfusion and dysfunction in a state of fluid overload, which further results in decreased UO. Teixeira et al. [25] found that fluid balance and UO were significant predictors of mortality in AKI patients and proposed that fluid overload is an intermediate pathway between lower UO and mortality. Due to obstruction of water and sodium excretion, fluid accumulation is an expected and logical complication of oliguric AKI [29]. Another study showed that an increase in fluid weight >10% in patients with AKI was related to higher mortality, which was proportional to the degree of fluid accumulation [30]. Overall, we believe that in patients with CS, decreased UO reflects the state of AKI and, to some extent, characterizes fluid overload and is directly associated with increased mortality.

In this study, we adjusted for UO by actual body weight of the patients and found that the power of weight-adjusted UO to predict in-hospital mortality was not significantly different from that of unadjusted UO. The role of actual body weight in diagnosing AKI has been explained to some extent. Katayama et al. found that UO calculated from actual body weight resulted in a delayed diagnosis of AKI in underweight patients in a sepsis population [31], while Jiang et al. demonstrated that weight-adjusted UO by actual body weight may lead to overestimation of AKI and underestimation of UO [32]. In brief, the application value of body weight is limited in different clinical practices. Based on our study, the effect of actual body weight on UO may not be clinically relevant in CS, but the exact mechanism is unknown. It is worth mentioning that patients with CS in intensive care are very inconvenient to measure their body weight due to long-term bed rest, immobility, and even disturbance of consciousness. Therefore, the use of unadjusted UO for the management of CS patients in clinical practice may be a better strategy.

The sample size of the MIMIC-IV database is relatively large, and the conclusions drawn by this study are reasonably reliable. In this study, the number of the death and survival group was close to 1:2, and we did not use the propensity score matching (PSM) to conduct the so-called post hoc randomization analysis. Although some selection bias cannot be ruled out, our conclusions are more generalizable. Meanwhile, regarding comorbidities, we found that patients died were more likely to suffer from renal disease than those in the survival group, making renal disease a confounding factor that cannot be ignored. In the regression analysis, we adjusted for key confounding factors including renal disease, diuretic use, RRT treatment, and still confirmed that UO was an independent risk factor for hospital death. That is, the conclusions of this study are applicable to all types of CS. In addition, compared with some other laboratory tests, UO monitoring is simple to operate, and as one of the basic parameters of hemodynamics, its cost is low, and it has the potential to be applied in health institutions with limited medical resources for promotion. Even though UO can somewhat predict in-hospital mortality in CS patients, we do not advocate its use alone. We suggest that if the role of UO in CS can be thoroughly clarified, it may be a better strategy to use it as a factor to build a predictive model later.

The main limitation of our study is that we only collected the UO in the first 24 h. In patients with CS, monitoring of dynamic changes in UO may have more excellent value in predicting in-hospital mortality. In addition, this study is a retrospective analysis, thus, there is a certain selection bias, and we cannot accurately quantify the fluid intake indicators such as drinking water, nor can we obtain the exact cardiac function of the included patients, which inevitably affects the results. Meanwhile, the participants enrolled in our study were mainly white Americans (more than 60%), and whether these findings apply to other countries and races is still unknown. Finally, the primary diseases causing cardiogenic shock are diverse, and due to database limitations, we were unable to trace the exact etiology of the patients included in this study. Overall, this study has far-reaching significance for the volume management of CS, however, it is still necessary to conduct rigorous multicenter randomized controlled clinical trials to further confirm the actual value of UO for CS patients.

5. Conclusions

UO in the first 24 h of admission is an independent risk factor for in-hospital mortality in intensive care CS patients and has moderate predictive value in predicting in-hospital mortality. The prognostic value of UO in CS should be given full attention. Considering the retrospective nature of this study and the possible time lag between the UO in the first day of admission and the diagnosis of CS, the above viewpoints still need to be further investigated by rigorous prospective randomized controlled trials.

Authors contributions

Tianyang Hu and Rongzhong Huang: Conceived and designed the experiments; Wrote the paper.
Tianyang Hu: Performed the experiments; Analyzed and interpreted the data.
Rongzhong Huang: Contributed reagents, materials, analysis tools or data.

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Disclosure of relationships and activities

Not applicable.

Data availability

Data will be made available on request by contact with the corresponding author.

Ethics statement

The establishment of this database was approved by the Massachusetts Institute of Technology (Cambridge, MA) and Beth Israel Deaconess Medical Center (Boston, MA) (No. 27653720), and consent was obtained for the original data collection.

Additional information

The name of the repository that deposits the data of this study is the "Medical Information Mart for Intensive Care" database, which is available on the PhysioNet platform (official website at https://physionet.org/content/mimiciv/1.0/). The author, Tianyang Hu, was granted access to this database (Record ID: 37474354).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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