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Association between the mean perfusion pressure and the risk of acute kidney injury in critically ill patients with sepsis: a retrospective cohort study

Ling Li[1], Shuangwen Qin[1], Xiuhong Lu[1], Liuyun Huang[1], Mingjie Xie[1] and Debin Huang[1*]

Abstract

Background Mean perfusion pressure (MPP) has recently emerged as a potential biomarker for personalized management of tissue perfusion in critically ill patients. However, its association with the occurrence of acute kidney injury (AKI) in septic patients and the optimal MPP range remain uncertain. Therefore, this study aims to investigate the relationship between MPP and AKI in critically ill patients with sepsis.

Methods We identified 5867 patients with sepsis from the MIMIC-IV database who met the inclusion and exclusion criteria. The exposure variable was the first set of MPP measured within 24 h after ICU admission with invasive hemodynamic monitoring. The primary outcome was the incidence of AKI at 7 days following ICU admission according to the Kidney Disease: Improving Global Outcomes (KDIGO) guidelines. Secondary outcomes included in-hospital mortality, lengths of ICU, and hospital stay. Optimal cut-off point for MPP were determined using the Youden index, and multivariable logistic regression was employed to examine the association between MPP and AKI. Subgroup analyses were conducted to enhance result robustness. Kaplan-Meier survival analysis was utilized to evaluate in-hospital mortality rates categorized by MPP.

Results A total of 5,867 patients with sepsis were included in this study, and the overall incidence of AKI was 82.3%(4828/5867). Patients were categorized into low MPP (< 63 mmHg) and high MPP (≥ 63 mmHg) groups using the optimal ROC curve-derived cut-off point. The incidence of AKI in the low MPP group was higher than that in the high MPP group (87.6% vs. 78.3%, $P < 0.001$). Multivariable logistic regression analysis adjusted for confounding factors revealed that each 1 mmHg increase in MPP as a continuous variable was associated with a 2% decrease in AKI incidence within 7 days of ICU admission (OR:0.98, 95%CI:0.97–0.99, $P < 0.001$). When MPP was used as a categorical variable, patients in the high MPP group had a lower risk of AKI than those in the low MPP group (OR:0.71, 95%CI:0.61–0.83, $P = 0.001$). Subgroup analyses demonstrated a consistent association between MPP and AKI risk across all variables assessed (P for interaction all > 0.05). Kaplan-Meier curve analysis demonstrated a higher survival rate during hospitalization in the high MPP group compared to the low MPP group (Log-rank test, $P < 0.0001$).

*Correspondence:
Debin Huang
hdeb@sina.com

Full list of author information is available at the end of the article

Conclusions Lower levels of MPP are associated with an increased incidence of AKI at 7 days in critically ill patients with sepsis.

Keywords Sepsis, Mean perfusion pressure, Acute kidney injury, Critical care

Background

Sepsis is characterized by life-threatening organ dysfunction resulting from a dysregulated host response to infection, and it remains a significant cause of death among critically ill patients [1, 2]. According to surveys, the global incidence of sepsis cases reached 48.9 million in 2017, with an estimated 11 million sepsis-related deaths [3]. Approximately one-third of sepsis patients develop acute kidney injury (AKI), often referred to as sepsis-associated acute kidney injury (SA-AKI) [4, 5]. Numerous studies have demonstrated that SA-AKI carries a poor prognosis, with high mortality rates and an independent association with prolonged hospital stays [6–10]. Previous research indicates that renal injury within the initial 48 h may primarily be functional, stemming from renal vasoconstriction and reduced renal blood flow leading to ischemia [11–13]. Furthermore, the interaction between renal hemodynamic alterations and inflammation likely contributes to AKI occurrence [14]. Thus, early monitoring of renal hemodynamics is crucial for improving SA-AKI outcomes.

Regulation of renal perfusion hemodynamics significantly influences renal function. Early experiments confirmed that renal blood flow autoregulation occurs within an arterial blood pressure range of 60–100 mmHg [15]. Factors such as inflammation, sepsis, and volume depletion can impair renal blood flow autoregulation, leading to marked fluctuations in glomerular filtration rate and contributing to AKI [5, 16, 17]. The Save Sepsis Campaign guidelines recommend maintaining a minimum mean arterial pressure (MAP) of ≥65 mmHg for adequate organ perfusion; however, MAP may not reliably reflect organ perfusion[[18]. Prior research indicates that elevated central venous pressure (CVP) independently correlates with a higher incidence of AKI, especially post-sepsis resuscitation, due to increased resistance to renal venous return and subsequent venous congestion [19–21]. Therefore, a management strategy of lower CVP in the clinic may contribute to the maintenance of renal perfusion. However, relying solely on MAP or CVP may be inadequate, requiring a comprehensive approach. Currently, there is a lack of methods for directly monitoring or predicting renal blood flow and renal perfusion pressure. Recent studies suggest using mean perfusion pressure (MPP), calculated as MPP = MAP − CVP, as an alternative to MAP and CVP for estimating renal perfusion pressure [22]. A previous study on post-cardiac surgery patients demonstrated an association between decreased MPP and AKI [23]. However, research on the predictive value of MPP for AKI in septic patients is limited, and the optimal range of MPP is still undetermined.

Therefore, we conducted a retrospective cohort study utilizing the Medical Information Mart for Intensive Care-IV (MIMIC-IV) database to investigate the association between MPP and AKI in septic patients, aiming to assess the predictive validity of MPP for AKI in critically ill patients with sepsis.

Methods

Data source

Participants in this study were obtained from the publicly available MIMIC-IV Database (v2.2), developed and maintained by the Laboratory of Computational Physiology at the Massachusetts Institute of Technology (MIT) (https://physionet.org/content/mimiciv/2.2/). The MIMIC-IV data is de-identified, thus exempting the need for informed consent or ethical approval. From 2008 to 2019, the database accumulated data from over 70,000 critically ill patients at Beth Israel Deaconess Medical Center (BIDMC). Data extraction was performed by the first author (Ling Li), who had full database access (certification number: 12187573). This study adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) declaration [24].

Study population

The MIMIC-IV database comprises data on 299,712 critically ill patients. We included patients over 18 years old who met the sepsis-3 criteria or had a sepsis diagnosis in the discharge diagnosis in the ICD code. Sepsis-3 is defined as an increase of ≥2 points in the sequential organ failure assessment (SOFA) score and suspected or confirmed infection [1]. We excluded patients with ICU stays < 24 h and those who had missing MAP and CVP data within the first 24 h of ICU admission. In addition, we also excluded patients with MAP and CVP measurements longer than 3 h. For patients with multiple ICU admissions, we only included the data from their first ICU admission. Ultimately, 5,867 patients with sepsis were included in the study.

Data extraction

Baseline patient information was extracted from the MIMIC-IV database using Structured Query Language (SQL). Vital signs included initial measurements of MAP, CVP, systolic blood pressure (SBP), and diastolic blood pressure (DBP) during the first 24 h of ICU stay. Laboratory tests covered first measurements of hemoglobin,

platelets, white blood cell count (WBC), red blood cell count (RBC), blood urea nitrogen (BUN), and creatinine at ICU admission. Comorbidities comprised myocardial infarction, congestive heart failure, chronic pulmonary disease, liver disease, diabetes, renal disease, malignant cancer, and hypertension. Treatment details encompassed mechanical ventilation, renal replacement therapy, and vasopressor use within the initial 24 h of ICU admission. The severity of illness at admission was assessed using SOFA [25] and simplified acute physiology score II (SAPS II).

Exposure and outcomes

The exposure variable was MPP. We obtained the levels of MAP and CVP in the first 24 h after ICU admission in the first set of invasive hemodynamic monitoring, i.e., MPP=MAP-CVP [22]. The primary outcome was the occurrence of AKI at 7 days after ICU admission. According to the Kidney Disease: Improving Global Outcomes (KDIGO) guidelines [26], AKI was diagnosed if serum creatinine was ≥1.5 times baseline, increased by ≥0.3 mg/dL within 48 h, or urine output was <0.5 mL/(kg·h) for ≥6 h. The first serum creatinine measurement at ICU admission served as the baseline value [27]. Secondary outcomes included in-hospital mortality, length of ICU, and hospital stay.

Statistical analysis

Continuous variables were denoted as mean [standard deviation (SD)] or median [interquartile range (IQR)] and tested using the Student t-test for independent samples or the Mann-Whitney U test. Quantitative and percentage data were provided for categorical variables, and the $\chi 2$ or Fisher exact test was used to compare groups. We calculated the receiver operating characteristic (ROC) curve to determine the optimal cut-off point for MPP using the Youden index. Patients were then categorized into two groups: a high MPP(≥63mmHg) group and a low MPP(<63mmHg) group based on this cut-off point (Supplementary Material: Fig. S1). Univariate logistic regression analyses identified variables with $P<0.1$, which were included in multivariate logistic regression models to assess the association between MPP and AKI in septic patients. Models included unadjusted Model 1 (no adjustment for covariates), minimally adjusted Model 2 (adjusted only for sex and age), and fully adjusted Model 3 (adjusted for all covariates with $P<0.1$). Next, we conducted subgroup analyses to assess the consistency of MPP with the risk of occurring AKI in different populations and tested for interactions using the log-likelihood ratio test. In-hospital survival was evaluated using Kaplan–Meier survival curves for MPP groups and analyzed with the Log-Rank test.

Missing values for all variables were below 5% and were imputed using the mean or median. The Supplementary Material presents the missing rates for each variable (Table S1). Statistical analysis was conducted using R 4.3.2 (http://www.Rproject.org; The R Foundation) and Free Statistics software version 1.8 (https://www.clinicalscientists.cn/). A significance level of $P<0.05$ (two-tailed) was used for all analyses.

Results

The MIMIC-IV database includes data on 299,712 critically ill patients, 33,177 of whom were diagnosed with sepsis. According to the inclusion and exclusion criteria, our study included 5,867 patients with sepsis (Fig. 1). We used the Youden index of the ROC curve to determine that the optimal cut-off point for MPP is 63 mmHg. Then the study population was categorized into two groups based on the cut-off, i.e., the low MPP(<63mmHg) group and the high MPP(≥63mmHg) group (Supplementary Material: Fig. S1).

Baseline characteristics

In the entire cohort, the low MPP group comprised 2,535 patients with sepsis, while the high MPP group included 3,332. The median age was 68.0 (IQR 59.0, 77.0) years and 65.6% of patients were male. The incidence of AKI at 7days in the cohort was 82.3%. Patients in the high MPP group exhibited lower BUN, creatinine, SAPS II, and SOFA scores. Additionally, patients in the low MPP group were likely to be treated with mechanical ventilation, renal replacement therapy, and vasopressors, and more likely to have comorbidities of myocardial infarct, congestive heart failure, chronic pulmonary disease, liver disease, diabetes, and renal disease than the high MPP group (Table 1).

Primary outcome

We constructed three multivariate logistic regression models to assess the relationship between MPP and the incidence of AKI at 7 days in septic patients, and the results are shown in Table 2. In the unadjusted model 1, we found that for each 1 mmHg increase in MPP, the risk of AKI was reduced by 3% (OR: 0.97, 95% CI: 0.96–0.97, $P<0.001$). After fully adjusting for confounders (Model 3), the risk of AKI at 7 days decreased by 2% for each 1 mmHg increase in MPP (OR: 0.98, 95% CI: 0.97–0.99, $P<0.001$). To further explore sensitivity, MPP was categorized from a continuous to a categorical variable, with low MPP groups serving as the baseline reference. In Model 3, patients in the high MPP group exhibited lower AKI risk compared to those in the low MPP group (OR: 0.71, 95% CI: 0.61–0.83, $P=0.001$).

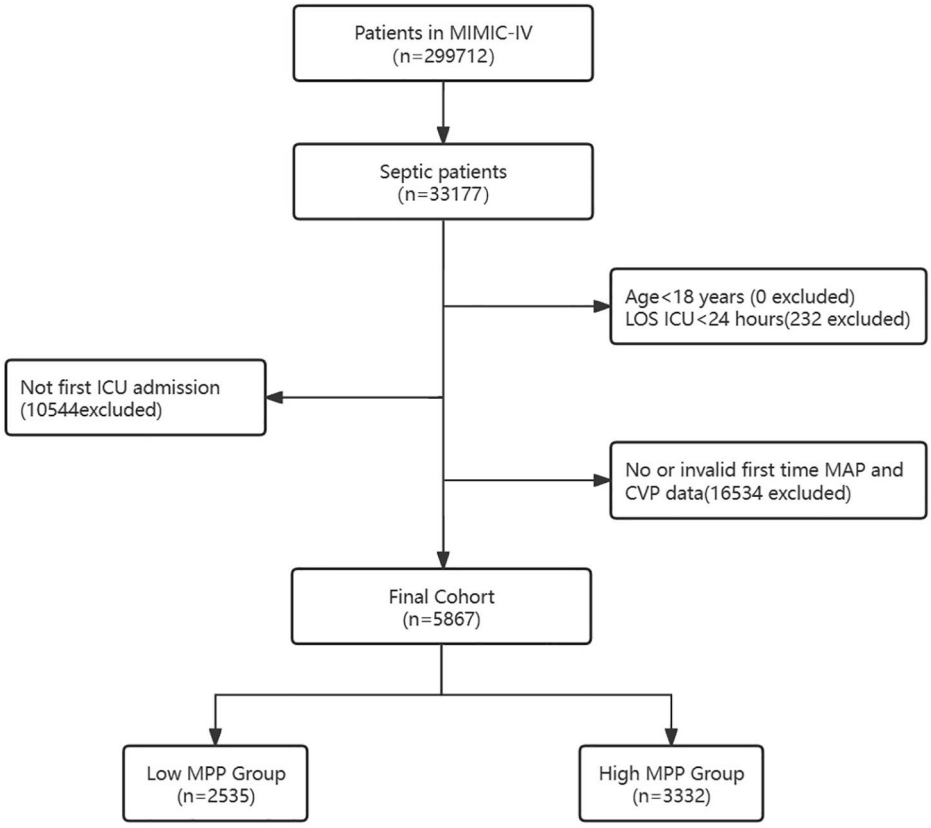

Fig. 1 Flowchart of the study population

Subgroup analyses

We conducted subgroup analyses to investigate the trend of association between MPP and the risk of 7 days AKI occurrence across different demographic subgroups(Fig. 2). Our results indicate that we did not observe any significant association between MPP and the risk of 7-day AKI occurrence, irrespective of patient age, sex, or presence of comorbidities such as myocardial infarct, congestive heart failure, chronic pulmonary disease, liver disease, diabetes, renal disease, malignant cancer and hypertension (*P* for interaction > 0.05).

Secondary outcomes

The median length of ICU stay was 3.3 days (IQR: 1.9-7.0) in the low MPP group and 2.2 days (IQR 1.3–4.3) in the high MPP group. The median length of hospital stay was 8.8 days (IQR 5.7–14.6) in the low MPP group and 7.2 days (IQR 5.1–12.0) in the high MPP group. Patients in the low MPP group had significantly longer ICU stays and hospital stays compared to the high MPP group ($P<0.001$) (Table 1). Kaplan-Meier survival curves showed that patients with sepsis in the high MPP group were significantly more likely to survive hospitalization than those in the low MPP group (log-rank test: $P<0.0001$) (Fig. 3).

Discussion

Key findings

In this retrospective cohort study, we utilized data from the large-scale MIMIC-IV database to explore the association between MPP and the risk of AKI at 7 days in septic patients admitted to the ICU. The current study's findings suggested lower levels of MPP are associated with an increased incidence of AKI at 7 days in critically ill patients with sepsis. Notably, even after accounting for possible confounding variables, this association is still statistically significant. This association was constant across subgroup analyses and sensitivity analyses, demonstrating the robustness of the finding. Additionally, the current study also highlights the significant association of MPP with in-hospital mortality, length of ICU, and hospital stay among critically ill patients with sepsis.

Relation with previous evidence

It has been shown that hemodynamic instability may lead to circulatory compromise and renal insufficiency and that maintaining large-vessel hydrostatic pressure parameters such as MAP and CVP at a certain level maintains renal perfusion and reduces the risk of AKI [10, 15, 28]. Two prior retrospective studies investigated the impact of MPP on AKI in critically ill patients [17, 29]. Among

Table 1 Baseline characteristics according to MPP groups

Variables	Total ($n=5867$)	Low MPP ($n=2535$)	High MPP ($n=3332$)	*P*-value
Age, years	68.0 (59.0, 77.0)	71.0 (61.0, 79.0)	66.0 (57.0, 74.0)	< 0.001
Male, n(%)	3849 (65.6)	1586 (62.6)	2263 (67.9)	< 0.001
MPP, mmHg	64.0 (59.0, 69.0)	58.0 (54.0, 61.0)	68.0 (65.0, 72.0)	< 0.001
MAP, mmHg	75.0 (72.0, 79.0)	71.0 (68.0, 74.0)	78.0 (75.0, 82.0)	< 0.001
CVP, mmHg	11.0 (8.0, 14.0)	14.0 (11.0, 17.0)	9.0 (7.0, 12.0)	< 0.001
SBP, mmHg	112.0 (101.0, 126.0)	108.0 (97.0, 120.0)	116.0 (104.0, 129.0)	< 0.001
DBP, mmHg	60.0 (52.0, 68.0)	55.0 (49.0, 63.0)	63.0 (55.0, 71.0)	< 0.001
SAPS II	39.0 (31.0, 49.0)	42.0 (34.0, 54.0)	36.0 (29.0, 45.0)	< 0.001
SOFA	4.0 (2.0, 5.0)	4.0 (3.0, 6.0)	3.0 (2.0, 5.0)	< 0.001
Laboratory tests				
Hemoglobin, g/dL	10.1 (8.7, 11.9)	10.0 (8.6, 11.7)	10.3 (8.9, 12.0)	< 0.001
Platelets, 10^9/L	162.0 (122.5, 217.0)	164.0 (124.0, 221.5)	160.0 (122.0, 214.0)	0.053
WBC,10^9/L	11.8 (8.4, 16.0)	12.2 (8.6, 16.6)	11.7 (8.2, 15.7)	< 0.001
RBC,10^9/L	3.4 (2.9, 4.0)	3.3 (2.8, 3.9)	3.4 (2.9, 4.0)	< 0.001
BUN, mg/dL	18.0 (14.0, 25.0)	20.0 (15.0, 30.0)	17.0 (13.0, 22.0)	< 0.001
Creatinine, mg/dL	0.9 (0.7, 1.3)	1.0 (0.8, 1.5)	0.9 (0.7, 1.2)	< 0.001
Comorbidities, n(%)				
Myocardial infarct	1281 (21.8)	620 (21.5)	661 (19.8)	0.055
Congestive heart failure	1606 (27.4)	870 (34.3)	736 (22.1)	< 0.001
Chronic pulmonary disease	1434 (24.4)	735 (29)	699 (27)	0.061
Liver disease	622 (10.6)	284 (11.2)	338 (10.1)	0.192
Diabetes	1494 (25.5)	713 (28.1)	781 (23.4)	< 0.001
Renal disease	1002 (17.1)	535 (21.1)	467 (14)	< 0.001
Malignant cancer	413 (7.0)	163 (6.4)	250 (7.5)	0.111
Hypertension	3198 (54.5)	1313 (51.8)	1885 (56.6)	< 0.001
Treatments, n(%)				
Mechanical ventilation	4342 (74.0)	2031 (80.1)	2311 (69.4)	< 0.001
Renal replacement therapy	508 (8.7)	307 (12.1)	201 (6)	< 0.001
Vasopressors	4928 (84.0)	2369 (93.5)	2559 (76.8)	< 0.001
AKI in 7 days				
AKI, n(%)	4828 (82.3)	2220 (87.6)	2608 (78.3)	< 0.001
Stage 1	1294 (22.1)	478 (18.9)	816 (24.5)	
Stage 2	2411 (41.1)	1070 (42.2)	1341 (40.2)	
Stage 2	1123 (19.1)	672 (26.5)	451 (13.5)	
In-hospital mortality, n(%)	560 (9.5)	345 (13.6)	215 (6.5)	< 0.001
LOS ICU, Median(IQR)	2.5 (1.4, 5.4)	3.3 (1.9, 7.0)	2.2 (1.3, 4.3)	< 0.001
LOS hospital, Median(IQR)	7.9 (5.2, 13.0)	8.8 (5.7, 14.6)	7.2 (5.1, 12.0)	< 0.001

Abbreviations: MPP mean perfusion pressure, MAP mean arterial pressure, CVP central venous pressure, SBP systolic blood pressure; DBP diastolic blood pressure, SAPS II simplified acute physiology score II, SOFA sequential organ failure assessment, WBC white blood cell, RBC red blood cell, BUN blood urea nitrogen, AKI acute kidney injury, LOS Length of stay

Table 2 Association between MPP and AKI at 7 days

Variable	total	Model 1		Model 2		Model 3	
		OR(95%CI)	*P*-value	OR(95%CI)	*P*-value	OR(95%CI)	*P*-value
MPP	5867	0.97(0.96 ~ 0.97)	< 0.001	0.97 (0.96 ~ 0.98)	< 0.001	0.98 (0.97 ~ 0.99)	< 0.001
MPP < 63	2535	1(Ref)		1(Ref)		1(Ref)	
MPP ≥ 63	3332	0.51(0.44 ~ 0.59)	< 0.001	0.54 (0.47 ~ 0.63)	< 0.001	0.71 (0.61 ~ 0.83)	0.001

Model 1: unadjusted

Model 2: adjusted for age, and gender

Model 3: adjusted for age, sex, Hemoglobin, BUN, Creatinine, Myocardial infarction, Congestive heart failure, Chronic pulmonary disease, liver disease, Diabetes, Renal disease, Mechanical ventilation, RRT, Vasopressors, SAPS II, SOFA.

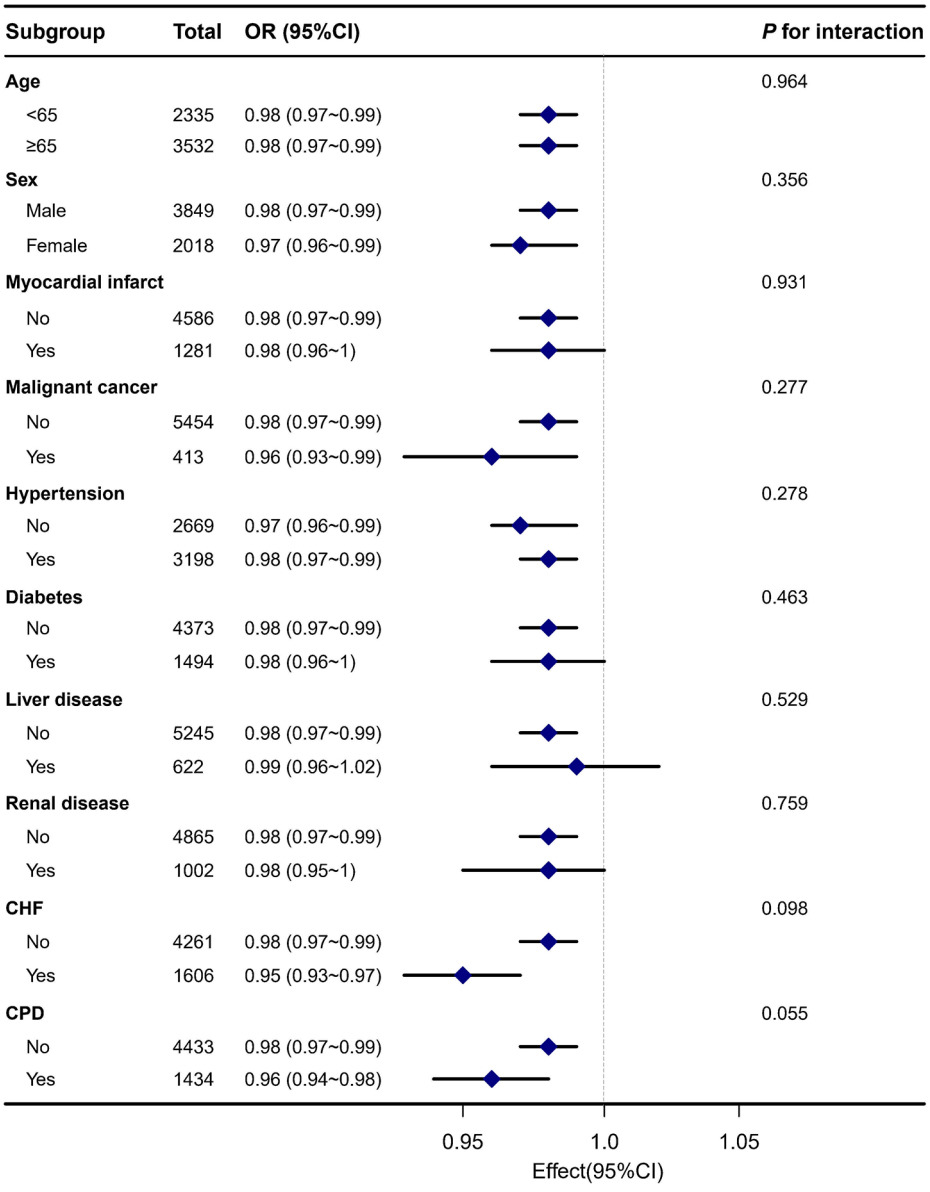

Fig. 2 Subgroup analyses. Abbreviations: CHF Congestive heart failure; CPD Chronic pulmonary disease

those, one large-scale retrospective investigation indicated that an increase in mean perfusion pressure variability (MPPV) in critically ill patients was related to an increased risk of eventual worsening in renal function after controlling for relevant variables [29]. Another study indicated that low MPP is a risk factor for the progression of AKI in critically ill patients, with MPP < 60 mmHg being independently associated with the progression from AKI I to AKI III [17]. Maintaining stable mean perfusion pressure may decrease the risk of renal function impairment. A retrospective observational study by Wong et al. suggested that patients with septic shock who developed severe AKI exhibited lower MPP levels during the initial 24 h of ICU admission in comparison to patients without severe AKI [30]. In a study by Saito et al. [15], post-cardiac surgery patients were analyzed and categorized based on AKI progression. The study found no significant differences in pressure indicators between the groups initially. However, retrograde calculation analysis revealed that the AKI progression group had a significantly higher MPP retrograde value compared to the non-progression group, indicating a relatively lower renal perfusion status. Furthermore, a multicenter retrospective cohort study by Kotani et al. also indicated that in post-cardiac surgery patients, lower MPP was associated with the progression of AKI [31]. The aforementioned studies emphasize the significance of individualized blood pressure management, considering underlying

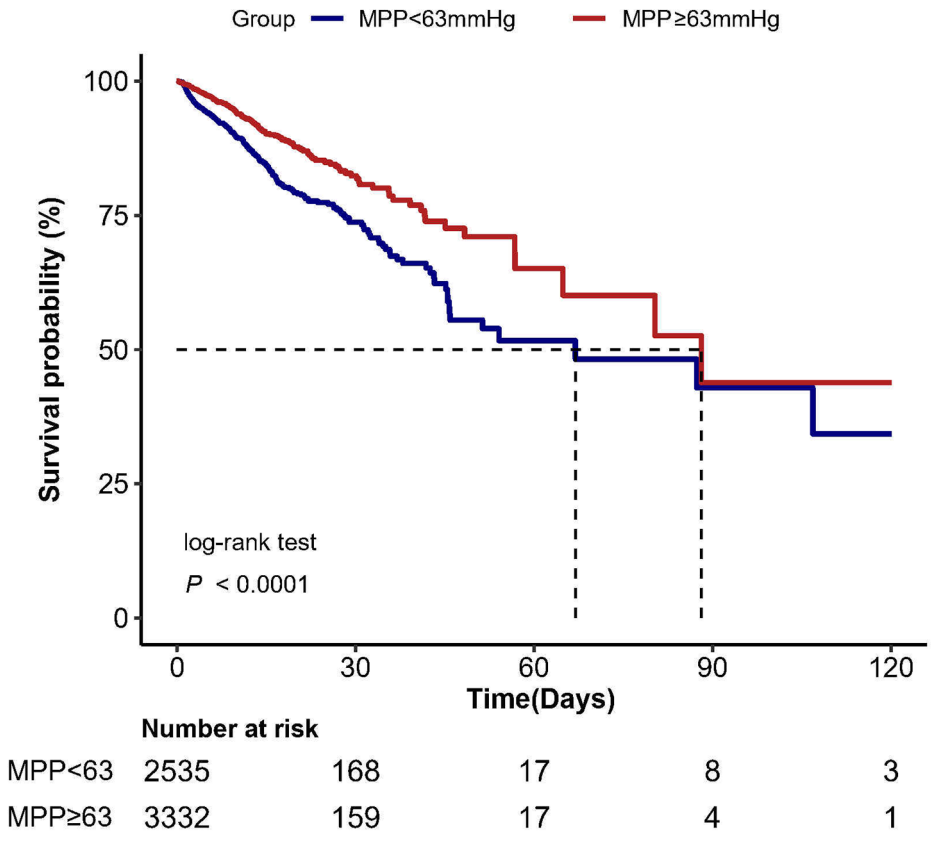

Fig. 3 Kaplan-Meier survival curve of cumulative survival rate during hospitalization

illnesses and pre-existing conditions. This approach is crucial to maintain adequate renal perfusion pressure and prevent the occurrence of AKI. In this study, we found that higher levels of MPP (≥63mmHg) were associated with a lower incidence of AKI, further supporting the potential utility of MPP as a target variable for hemodynamic management in this critically ill septic patient population. Our research findings validate these previous study results in the large-scale MIMIC-IV database. We strengthened the reliability of our research findings by performing multivariable logistic regression analysis, which showed consistent results in subgroup analyses. This emphasizes the importance of utilizing MPP as a valuable indicator for blood pressure restoration and tissue perfusion in critically ill septic patients. Furthermore, we also observed a correlation between higher MPP levels and lower in-hospital mortality rates. In conclusion, these findings support the association between MPP and the risk of AKI in critically ill patients with sepsis.

Clinical implications

MPP is an indicator of the stable perfusion pressure maintained by blood in the arterial system [32]. Targeting high MPP levels in the early stages of patients with sepsis may have potential benefits in preventing renal injury. Previous studies have illustrated that lower levels of MPP may result in inadequate blood supply to the kidneys [33]. Hypotension resulting from factors such as fluid loss and systemic inflammatory response can compromise kidney perfusion, leading to impaired renal function in septic patients [12, 14]. In addition, inflammation can infiltrate and damage inflammatory cells in renal tissues, thereby impairing glomerular filtration function. This impairment can contribute to the development of glomerulonephritis and AKI [4, 5]. Previous animal studies have adequately demonstrated that renal ischemia leads to long-term loss of renal autoregulation [34]. Therefore, for septic patients, maintaining an appropriate level of MPP is crucial to ensure adequate blood flow perfusion to the kidneys. The current study's findings underline the need for closer monitoring of renal perfusion and more active care in critically ill patients, particularly those with sepsis. They support the potential for interventions based on MPP to improve the prognosis of septic patients at risk of AKI. Clinicians can integrate MPP assessment into clinical practice to improve risk stratification, personalize patient care, identify high-risk individuals for AKI, and develop corresponding management strategies. However, the current literature on target MPP levels remains scarce, highlighting the need for additional research and

prospective studies to validate these findings and establish standardized protocols for MPP monitoring and management.

Strengths and limitations

This study evaluated the relationship between early-recorded MPP and early-onset AKI in a large cohort of septic patients using the extensive MIMIC-IV database. The inclusion of a high number of cases aimed to capture real-world scenarios as much as possible. However, the study still has the following limitations. First, this study was a retrospective observational design and, therefore could not determine a causal association between MPP and the occurrence of AKI. Second, the data were gathered from the MIMIC IV database, and despite the inclusion of multivariate adjustments and subgroup analyses, the results were influenced by residual bias and unmeasured potential confounders. Third, in the extracted data, some of the relevant indexes with more missing data failed to be included in the study, and we did not take into account advanced hemodynamic data like the renal resistance index or peripheral vascular resistance. Lastly, to validate our findings, future research should incorporate stronger evidence, such as prospective cohort studies.

Conclusions

In summary, lower levels of MPP are associated with an increased incidence of AKI at 7 days in critically ill patients with sepsis. This study highlights the importance of MPP as a potential predictive factor for the occurrence of AKI in severe septic patients.

Abbreviations

MPP	Mean perfusion pressure
MAP	Mean arterial pressure
CVP	Central venous pressure
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
SAPS II	Simplified acute physiology score II
SOFA	Sequential organ failure assessment
WBC	White blood cell
RBC	Red blood cell
BUN	Blood urea nitrogen
AKI	Acute kidney injury
LOS	Length of stay
CHF	Congestive heart failure
CPD	Chronic pulmonary disease

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12879-024-09706-1.

Supplementary Material 1: Table S1 Percentage of missing data of each variable.

Supplementary Material 2: Figure S1 ROC curve to determine the optimal cut-off point for MPP.

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Author contributions

L.L. and D.B.H. designed the study and drafted the manuscript. X.H.L. and L.L. extracted the data from the MIMIC-IV database. L.L. analyzed and interpreted the data. S.W.Q., M.J.X., and L.Y.H. guided the literature review. L.L., D.B.H., X.H.L., S.W.Q., M.J.X., and L.Y.H. revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Data availability

Data is provided within the manuscript or supplementary information files.The datasets are available in the physionet (https://physionet.org/content/ mimic iv/2.2/).

Declarations

Ethics approval and consent to participate

Not applicable (The data for this study came from the MIMIC public database).

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Intensive Care Unit, The First Affiliated Hospital of Guangxi Medical University, NO 6 Shuang Yong Road, Nanning, Guangxi, China

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