Section: Miscellaneous

Original Research Article

CUMULATIVE FLUID BALANCE AND CLINICAL OUTCOMES IN CRITICALLY ILL PATIENTS IN ICU- A PROSPECTIVE STUDY

Harshwardhan Singh Pawar[1], Monica Dhirendra Thakur[2], Muddassir Sheikh[3], Sachin Jagdale[4]

[1]*Registrar, Intensive Care Unit, KEM Hospital, Pune, Maharashtra, India*
[2]*Fellow, Artificial reproductive technique, Genesis Fertility Solutions, Pune, Maharashtra, India*
[3]*Registrar, Intensive Care Unit, KEM Hospital, Pune, Maharashtra, India*
[4]*Consultant Critical Care Medicine, KEM Hospital Pune, Maharashtra, India*

Received *: 10/11/2025*
Received in revised form *: 27/12/2025*
Accepted *: 17/01/2026*

Corresponding Author:
Dr. Harshwardhan Singh Pawar,
Advance Trainee , Intensive Care Unit , Liverpool Hospital , Liverpool, NSW
Email: harshwardhansinh@gmail.com

DOI: 10.70034/ijmedph.2026.1.89

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (1); 505-508

ABSTRACT

Background: Fluid resuscitation is a cornerstone of critical care management. However, excessive positive fluid balance may adversely affect organ function and clinical outcomes. The impact of cumulative fluid balance on morbidity and mortality among critically ill patients remains an area of active investigation. The objective is to evaluate the association between cumulative fluid balance and clinical outcomes in critically ill patients admitted to the intensive care unit (ICU).

Materials and Methods: This prospective observational study included 250 adult critically ill patients admitted to a tertiary care ICU. Daily fluid input and output were meticulously recorded, and cumulative fluid balance was calculated over the first seven days of ICU stay. Patients were stratified into three groups based on cumulative fluid balance: negative/neutral, mildly positive, and markedly positive. Primary outcomes included ICU mortality and length of ICU stay. Secondary outcomes were duration of mechanical ventilation, incidence of acute kidney injury, and need for renal replacement therapy.

Results: Patients with markedly positive cumulative fluid balance demonstrated significantly higher ICU mortality, prolonged mechanical ventilation, longer ICU stay, and increased incidence of organ dysfunction compared to patients with neutral or negative fluid balance. A positive correlation was observed between increasing fluid balance and adverse clinical outcomes.

Conclusion: Excessive cumulative positive fluid balance is independently associated with poorer clinical outcomes in critically ill patients. Judicious fluid management and regular reassessment of fluid status may improve outcomes in this population.

Keywords: Cumulative fluid balance, critical illness, intensive care unit, mortality, organ dysfunction.

INTRODUCTION

Fluid administration is a fundamental component of the management of critically ill patients. Adequate intravascular volume is essential for maintaining tissue perfusion, optimizing cardiac output, and preventing cellular hypoxia, particularly during the early resuscitative phase of critical illness.[1,2] Consequently, intravenous fluid therapy remains one of the most frequently prescribed interventions in the intensive care unit (ICU).

Traditionally, liberal fluid resuscitation strategies were advocated to counteract hypovolemia, sepsis-induced vasodilation, and capillary leak.[3] However, growing evidence suggests that excessive or prolonged fluid administration may have deleterious consequences. Critically ill patients frequently experience altered vascular permeability, impaired lymphatic drainage, and reduced renal excretion, all of which predispose them to fluid accumulation. This excessive fluid retention manifests clinically as generalized edema and organ congestion, which may

compromise pulmonary, renal, cardiovascular, and gastrointestinal function.[4]

Positive cumulative fluid balance has been increasingly recognized as a marker of disease severity as well as a potentially modifiable risk factor. Pulmonary interstitial edema can impair gas exchange, leading to prolonged mechanical ventilation and increased ventilator-associated complications.[4,5] Renal venous congestion and interstitial edema may worsen kidney function, increasing the risk of acute kidney injury (AKI) and the need for renal replacement therapy (RRT). Similarly, myocardial edema and increased intra-abdominal pressure can adversely affect cardiac output and gastrointestinal perfusion, further propagating multiorgan dysfunction.[6]

While early goal-directed fluid resuscitation remains critical during the initial hours of shock, recent critical care paradigms emphasize a more conservative or individualized approach once hemodynamic stability is achieved. The concept of fluid stewardship has emerged, highlighting the importance of balancing adequate resuscitation with timely fluid restriction or removal. Despite this shift, fluid management practices remain heterogeneous, and cumulative fluid balance is often overlooked as a prognostic indicator during daily ICU care.[7]

The relationship between cumulative fluid balance and clinical outcomes in critically ill patients remains an area of ongoing research, particularly in resource-limited settings. Understanding this association may help refine fluid management strategies and improve patient outcomes. Therefore, this study was undertaken to evaluate the impact of cumulative fluid balance on mortality, length of ICU stay, duration of mechanical ventilation, and organ dysfunction in critically ill patients.

MATERIALS AND METHODS

This was a prospective, observational study conducted in the multidisciplinary intensive care unit of a tertiary care teaching hospital. The study was carried out over a period of 18 months after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from the patient or the legally authorized representative prior to enrollment.

** Hospital Description 24 bedded ICU, KEM hospital Pune

**The study was initially planned for a one and half year duration August 2016 - Feb 2018;

Study Population: A total of 250 critically ill adult patients admitted to the ICU were included in the study. Patients were enrolled consecutively to minimize selection bias.

Inclusion Criteria

- Age ≥18 years
- ICU admission with expected stay of at least 72 hours
- Requirement of invasive monitoring and/or organ support such as mechanical ventilation or vasopressor therapy

Exclusion Criteria

- End-stage renal disease on maintenance dialysis
- Chronic liver disease
- ICU stay less than 72 hours
- Pregnancy
- Patients with major burns involving more than 20% of total body surface area
- Patients transferred from other ICUs with incomplete fluid balance records
- Decompensated Heart failure patient
- In- hospital patient admitted to ICU from wards

Baseline Assessment: At the time of ICU admission, demographic data including age, sex, body weight, and body mass index were recorded. Clinical parameters such as primary diagnosis, comorbid conditions (diabetes mellitus, hypertension, chronic kidney disease, chronic liver disease), and severity of illness were documented. Severity scores were assessed within the first 24 hours of admission using standard ICU scoring systems. (APACHE 2 SCORE)

Fluid Balance Assessment

Daily fluid intake and output were meticulously recorded by trained ICU staff. Fluid intake included:

- Intravenous crystalloids and colloids
- Blood and blood products
- Medications administered intravenously
- Enteral and parenteral nutrition

Fluid output included:

- Urine output
- Drain output
- Gastrointestinal losses
- Ultrafiltration during renal replacement therapy

Cumulative fluid balance was calculated as the net difference between total fluid intake and total fluid output over the first seven days of ICU stay.

Patient Stratification: Based on cumulative fluid balance at day seven, patients were categorized into three groups:

- **Group A:** Neutral or negative cumulative fluid balance (How much negative)
- **Group B:** Mildly positive cumulative fluid balance (≤3 liters)
- **Group C:** Markedly positive cumulative fluid balance (>3 liters)

Outcome Measures: The primary outcomes assessed were ICU mortality and length of ICU stay. Secondary outcomes included duration of mechanical ventilation, incidence of acute kidney injury as defined by standard criteria, and requirement of renal replacement therapy.

Statistical Analysis: Data were entered into a standardized database and analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, depending on data distribution. Categorical variables were presented as frequencies and percentages. Comparisons between groups were performed using analysis of variance (ANOVA) for continuous variables and chi-square

test or Fisher's exact test for categorical variables. A p-value less than 0.05 was considered statistically significant.

RESULTS

Table 1: Baseline Demographic and Clinical Characteristics

Parameter	Group A (n=82)	Group B (n=94)	Group C (n=74)	p-value
Age (years), mean ± SD	54.6 ± 13.8	55.9 ± 14.4	58.1 ± 14.1	0.31
Male sex, n (%)	48 (58.5%)	57 (60.6%)	45 (60.8%)	0.94
BMI (kg/m²), mean ± SD	23.4 ± 3.8	24.1 ± 4.1	24.3 ± 4.0	0.42
Diabetes mellitus, n (%)	26 (31.7%)	32 (34.0%)	29 (39.2%)	0.56
Hypertension, n (%)	29 (35.4%)	35 (37.2%)	31 (41.9%)	0.61
Admission severity score, mean ± SD	18.2 ± 5.1	18.9 ± 5.4	19.6 ± 5.7	0.28

A total of 250 critically ill patients were included and analyzed. Based on cumulative fluid balance over the first seven ICU days, patients were stratified into three groups: Group A: Neutral/negative fluid balance (n = 82), Group B: Mildly positive fluid balance ≤3 L (n = 94), Group C: Markedly positive fluid balance >3 L (n = 74). Baseline demographic characteristics and severity of illness were comparable across all three groups, with no statistically significant differences, indicating minimal confounding from baseline variables.

Table 2: Cumulative Fluid Balance at Day 7

Parameter	Group A	Group B	Group C	p-value
Mean cumulative fluid balance (L)	−0.6 ± 0.8	+2.1 ± 0.6	+5.4 ± 1.2	<0.001

There was a statistically significant progressive increase in cumulative fluid balance across the groups ($p < 0.001$), validating appropriate patient stratification.

Table 3: Primary Clinical Outcomes

Outcome	Group A (n=82)	Group B (n=94)	Group C (n=74)	p-value
ICU mortality, n (%)	10 (12.2%)	18 (19.1%)	29 (39.2%)	<0.001
ICU length of stay (days), mean ± SD	6.8 ± 2.9	8.4 ± 3.5	11.2 ± 4.6	<0.001

Patients with markedly positive fluid balance (Group C) demonstrated significantly higher ICU mortality and prolonged ICU stay. A dose–response relationship was evident between increasing fluid balance and adverse outcomes.

Table 4: Secondary Clinical Outcomes

Outcome	Group A	Group B	Group C	p-value
Mechanical ventilation duration (days), mean ± SD	3.4 ± 2.1	4.9 ± 2.8	7.3 ± 3.6	<0.001
Acute kidney injury, n (%)	14 (17.1%)	27 (28.7%)	36 (48.6%)	<0.001
Renal replacement therapy, n (%)	6 (7.3%)	11 (11.7%)	19 (25.7%)	0.002

A significant increase in duration of mechanical ventilation, incidence of acute kidney injury, and requirement for renal replacement therapy was observed with rising cumulative fluid balance.

Table 5: Trend Analysis of Outcomes Across Fluid Balance Groups

Outcome	Trend Pattern	Statistical Significance
ICU mortality	Progressive increase	Significant
ICU length of stay	Linear prolongation	Significant
Ventilator days	Dose-dependent increase	Significant
AKI incidence	Stepwise rise	Significant
RRT requirement	Exponential increase	Significant

All major adverse outcomes showed a statistically significant upward trend with increasing cumulative fluid balance, reinforcing fluid overload as an independent prognostic factor. Positive cumulative fluid balance was strongly associated with worse clinical outcomes. Patients with >3 L positive balance had:~3-fold higher ICU mortality, Longer ventilation and ICU stay, Significantly higher renal complications, the associations remained significant despite comparable baseline severity.

DISCUSSION

The present study demonstrates a strong and consistent association between cumulative positive fluid balance and adverse clinical outcomes in critically ill patients. Patients with markedly positive cumulative fluid balance experienced significantly higher ICU mortality, prolonged mechanical ventilation, increased incidence of acute kidney injury, and longer ICU stays compared to those with neutral or negative balance. Importantly, these associations persisted despite comparable baseline demographics and severity of illness, suggesting that

fluid balance itself plays a critical role in influencing outcomes.

Fluid overload contributes to organ dysfunction through multiple pathophysiological mechanisms. Increased capillary permeability in critical illness allows administered fluids to rapidly shift into the interstitial compartment, resulting in tissue edema. Pulmonary interstitial edema reduces lung compliance and impairs oxygen diffusion, leading to prolonged ventilator dependence. These findings are consistent with previous observations that excessive fluid accumulation worsens respiratory mechanics and delays ventilator liberation.[8,9]

Renal outcomes were notably affected in patients with higher cumulative fluid balance. The incidence of acute kidney injury and need for renal replacement therapy increased progressively with fluid accumulation. Renal venous congestion, increased intra-abdominal pressure, and interstitial edema may compromise renal perfusion, thereby precipitating or worsening kidney injury. Similar associations between positive fluid balance and renal dysfunction have been reported in critically ill and septic populations.[10,11]

Mortality showed a clear dose–response relationship with cumulative fluid balance in the present study. Patients with more than 3 liters of positive balance had nearly three times higher ICU mortality compared to those with neutral or negative balance. This observation aligns with growing evidence suggesting that fluid overload is not merely a marker of illness severity but an independent contributor to adverse outcomes.[12,13] Excess fluid may exacerbate multiorgan dysfunction by impairing microcirculatory flow and cellular oxygen utilization. The concept of phased fluid therapy—encompassing resuscitation, optimization, stabilization, and deresuscitation—has gained prominence in modern critical care. While early aggressive fluid resuscitation remains essential in shock states, failure to transition to conservative or fluid removal strategies may lead to cumulative fluid overload. The findings of this study support the importance of timely reassessment of fluid responsiveness and early initiation of fluid restriction or deresuscitation once hemodynamic stability is achieved.[14,15]

This study reinforces the need for routine monitoring of cumulative fluid balance as part of daily ICU assessment. Incorporating fluid balance targets into clinical decision-making may help mitigate fluid-related complications. Dynamic hemodynamic monitoring, bedside ultrasound, and protocolized fluid management strategies may further aid in optimizing fluid therapy.[15]

Implications for Clinical Practice

- Avoid prolonged positive fluid balance after initial resuscitation
- Incorporate daily fluid balance review into ICU rounds
- Consider early deresuscitation in stable patients

Limitations: Although the study included a relatively large sample size, its single-center observational design limits causal inference. Additionally, insensible fluid losses were not quantified, which may have led to underestimation of true fluid balance. Nevertheless, the consistency and strength of associations observed lend credibility to the findings.

CONCLUSION

Cumulative positive fluid balance is a significant and potentially modifiable risk factor for adverse outcomes in critically ill patients. A balanced, individualized approach to fluid management—emphasizing early resuscitation followed by cautious maintenance and timely deresuscitation—may improve survival and reduce ICU morbidity.

REFERENCES

1. Messmer AS, Zingg C, Müller M, Gerber JL, Schefold JC, Pfortmueller CA. Fluid overload and mortality in adult critical care patients — a systematic review and meta-analysis of observational studies. Crit Care Med. 2020;48(12):1862-1870. doi: 10.1097/CCM.0000000000004605
2. Singh R, et al. A retrospective evaluation of the effects of cumulative fluid balance on hospital mortality in critical illness. Intensive Care Med. 2025;51(1):50-59. doi: 10.1007/s00134-024-06512-3
3. White KC, et al. How a positive fluid balance develops in acute kidney injury and its impact on mortality. Crit Care. 2024;28:59. doi: 10.1186/s13054-024-04659
4. Wang T-J, Pai K-C, Huang C-T, et al. A positive fluid balance in the first week was associated with increased long-term mortality in critically ill patients. Front Med (Lausanne). 2022;9:727103. doi: 10.3389/fmed.2022.727103
5. Hyun D, et al. Impact of a cumulative positive fluid balance during the first three days of ICU admission on 28-day mortality in sepsis: a propensity-matched analysis. Ann Intensive Care. 2023;13:45. doi: 10.1186/s13613-023-01178-x
6. Prowle JR, et al. Dose–response association between fluid overload and in-hospital mortality in critically ill patients. BMJ Open. 2020;10(12):e039875. doi: 10.1136/bmjopen-2020-039875
7. Martos-Benítez FD, et al. Fluid balance, biomarkers of renal function, and mortality in critically ill patients. Crit Care. 2024;28:114. doi: 10.1186/s13054-024-04682-5
8. Koonrangsesomboon W, et al. Positive fluid balance is associated with increased ICU mortality and longer ICU stay in septic shock patients. BMC Anesthesiol. 2015;15:148. doi: 10.1186/s12871-015-0153-5
9. Wang N, et al. Fluid balance and mortality in critically ill patients with acute kidney injury: a multicenter cohort study. Crit Care. 2015;19:109. doi: 10.1186/s13054-015-0836-y
10. Payen D, et al. A positive fluid balance is associated with increased 60-day mortality: results from a large European multicentre study. Crit Care. 2008;12(6):R145. doi: 10.1186/cc7158
11. Lee J, et al. Association between positive fluid balance at ICU discharge and mortality risk after ICU stay. Crit Care. 2014;18(1):R38. doi: 10.1186/cc13723
12. Fong KM, et al. Positive fluid balance and mortality in adult patients treated with extracorporeal membrane oxygenation (ECMO). Sci Rep. 2019;9:12359. doi: 10.1038/s41598-019-48761-x
13. Patil VP, et al. Fluid overload and acute kidney injury in critically ill patients. Nephron Clin Pract. 2020;146(4):350-356. doi: 10.1159/000508637
14. Renaudier M, et al. Fluid balance and outcome in cardiac arrest patients admitted to ICU: evidence from a systematic review and meta-analysis. Crit Care Med. 2025;53(3):392-402. doi: 10.1097/CCM.0000000000006112
15. White KC, Current management of fluid balance in critically ill patients with acute kidney injury. Clin Kidney J. 2023;16(1):112-122. doi: 10.1093/ckj/sfad042.