# Outcomes of Continuous Infusion Versus Intermittent Bolus Injection of Furosemide in Patients with Acute Decompensated Heart Failure (ADHF): A Prospective Observational Comparative Study

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## ABSTRACT

Acute decompensated heart failure is a frequent cause of hospital admission and is commonly managed with intravenous loop diuretics. Furosemide is usually given either as intermittent bolus doses or as a continuous infusion, but the optimal method of administration remains uncertain in routine clinical practice. The study included forty patients (n=40, 20 per group) diagnosed with heart failure, encompassing both heart failure with preserved ejection fraction (HFpEF) and heart failure with reduced ejection fraction (HFrEF). Patients presenting with symptoms like dyspnea or edema were excluded if their systolic blood pressure fell below 90 mm Hg or if their condition was critically ill. A total of 40 patients with acute decompensated heart failure were included in the study, with 20 patients in each treatment group. Baseline clinical and laboratory parameters were comparable between the groups. Urine output during the three-day treatment period was higher in patients treated with continuous furosemide infusion than in those who received bolus doses ($p = 0.037$). Serum creatinine, sodium, and potassium levels showed no significant differences between the two groups. Vital signs remained stable in both treatment arms throughout the study period. Both dosing methods were effective in relieving symptoms of acute decompensated heart failure. Continuous infusion produced greater diuresis, while bolus dosing also remained effective. The choice of treatment should be based on the patient's clinical condition. Further studies with larger samples are required to assess long-term outcomes.

**Keywords:** Furosemide, Continuous infusion, Intermittent bolus, Heart failure, Fluid management

# INTRODUCTION

Acute decompensated heart failure (ADHF) is a rapid aggravation of chronic heart failure, characterized by a sudden worsening of symptoms that requires quick management to avoid serious consequences and death [1, 2]. Common symptoms include shortness of breath, tiredness, edema, and congestion caused by both circulatory insufficiency and fluid overload [3, 4]. ADHF can afflict patients with or without a prior heart failure diagnosis, but it is more common in those with pre-existing cardiovascular or renal problems, such as hypertension (HTN) and diabetes [5, 6]. Heart failure can be split into two types: heart failure with reduced ejection fraction (HFrEF) and heart failure with preserved ejection fraction (HFpEF). In HFrEF, the left ventricle's pumping efficiency is decreased, with an EF of < 40%, resulting in systolic dysfunction [7, 8]. Heart failure with preserved ejection fraction (HFpEF) is characterized by a nearly normal ejection fraction (LVEF ≥ 50%), but critically, it involves increased left ventricular stiffness and elevated filling pressures [9, 10]. Acute decompensated heart failure (ADHF) can arise from either of the main types of heart failure and presents a significant global healthcare challenge. In India alone, it is responsible for an estimated 1.8 million hospital admissions annually [11, 12]. Various factors can trigger ADHF, such as hypertensive emergencies, excessive dietary salt intake, and a lack of adherence to prescribed diuretics or heart failure therapies like beta-blockers and ACE inhibitors [13, 14]. Additionally, impaired kidney function frequently exacerbates fluid retention, a common complication in heart failure patients [15, 16].

A common cause of ADHF is cardiogenic pulmonary edema, where elevated left ventricular pressures lead to fluid accumulation in the alveoli, hindering oxygen exchange and causing breathing difficulties [17]. This condition is further worsened by neurohormonal responses: a reduced cardiac output activates the sympathetic nervous system and the renin-angiotensin-aldosterone system (RAAS), resulting in vasoconstriction, fluid accumulation, and additional strain on the heart [18, 19]. While these mechanisms initially serve as compensatory responses, they tend to exacerbate heart failure symptoms over time [20]. ADHF is a complex clinical syndrome that reflects the heart's inability to adequately meet the body's circulatory demands. Acute episodes are marked by sudden increases in fluid retention, leading to elevated pressures in the lungs and peripheral tissues [21]. Older adults, individuals with co-existing conditions such as diabetes or chronic kidney disease, and patients with a prior history of heart failure are at greater risk for experiencing ADHF episodes [22].

In heart failure with reduced ejection fraction (HFrEF), systolic function declines due to left ventricular impairment (ejection fraction ≤40%). This often stems from underlying causes such as ischemic heart disease, chronic hypertension, or valvular abnormalities [23]. Heart failure with preserved ejection fraction (HFpEF), defined as a left ventricular ejection fraction (LVEF) of 50% or higher, results from diastolic dysfunction—where the heart's ability to relax and fill is impaired, even though contraction remains intact [24]. Factors like myocardial stiffness, obesity, and age-related cardiac changes are known contributors to HFpEF [25]. A range of precipitating factors can increase the risk of acute decompensated heart failure (ADHF), including acute infections, non-adherence to prescribed medications, lifestyle influences, and the use of drugs such as NSAIDs, which can disrupt fluid regulation and kidney function [26]. Additionally, hypertensive emergencies, ischemic events, and arrhythmias can provoke ADHF by elevating cardiac workload or causing ventricular dysfunction [27]. Given the ongoing study regarding the optimal diuretic delivery in ADHF patients, present study aimed to compare the short term clinical outcomes of continuous infusion versus intermittent bolus injection of furosemide.

# MATERIALS AND METHODS

## Study population and recruitment

The study was carried out between January and June of 2023 within the department of General Medicine at CARE Hospital, located in Banjara Hills, Hyderabad, Telangana. A total of 40 individuals were included, aligning perfectly with the predetermined sample size. Every participant who met the specified inclusion criteria and voluntarily gave their informed consent was brought into the study. This research utilized a prospective observational design, meaning data was gathered over a specific period, and the researchers did not directly intervene in how patients were managed. The main goal was to assess and contrast the clinical outcomes between two different treatment approaches—intravenous bolus versus continuous infusion of furosemide—in patients suffering from acute decompensated heart failure.

## Sample size calculation

To determine the necessary number of participants, the following formula was applied: $n = Z^2 \times p\,(1-p) / d^2$. In this equation, 'n' stands for the sample size, 'Z' represents the standard normal variate corresponding to a 95% confidence level (which is 1.96), 'p' denotes the estimated prevalence of ADHF among cardiac patients, and 'd' signifies the acceptable margin of error (set at 13%). Based on this calculation [28], a sample size of roughly 40 individuals was identified as appropriate. Patients were allocated to treatment groups based on the physician discretion, and no randomization was performed.

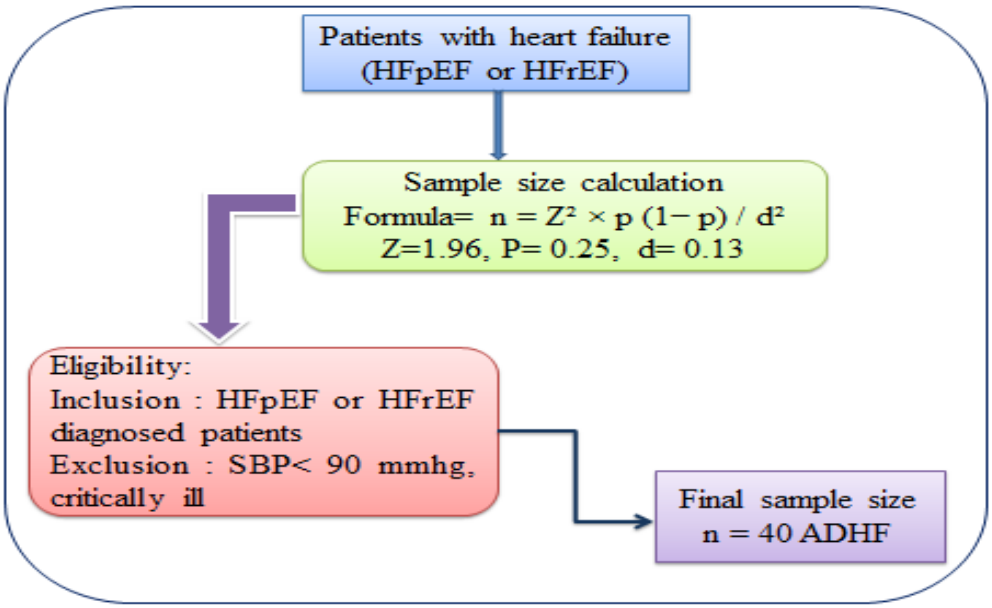



**Figure 1.** Participant flow diagram

## 2.3. Eligibility criteria

Individuals aged 18 years and older who had been diagnosed with acute decompensated heart failure (ADHF), or heart failure with either preserved or reduced ejection fraction, qualified for inclusion if they exhibited at least one symptom (such as dyspnea or orthopnea) and one clinical sign (like rales, peripheral edema, or radiographic evidence of pulmonary congestion). Exclusion criteria included patients with a systolic blood pressure below 90 mm Hg, as well as those in critical condition necessitating immediate life-saving interventions, which would have prevented the collection of baseline measurements.

### 2.4. Data collection

The investigation's methodological framework commenced with a comprehensive examination of pertinent existing literature. Subsequently, the complete research protocol was submitted to the Institutional Ethics Committee (IEC) at CARE Hospital, undergoing a thorough ethical review process and ultimately receiving approval. Ethical clearance was granted in strict adherence to institutional guidelines, designated by certificate number IEC/CARE/21989/2023/PharmD.

### 2.5. Statistical Analysis

Statistical analysis was performed using SPSS version 22. Categorical variables were summarized as frequencies and percentages. Continuous variables were expressed as mean ± standard deviation (SD) for approximately normally distributed data and as median with interquartile range (IQR) for non-normally distributed data. Between-group comparisons were performed using the independent-samples t-test for normally distributed continuous variables and the Mann–Whitney U test for non-normally distributed continuous variables. The Mann–Whitney U test was used to compare the distributions of continuous variables between the independent bolus and continuous-infusion groups without assuming normality. Categorical variables were compared using the chi-square test, as appropriate. All tests were two-sided, and a p-value <0.05 was considered statistically significant. Effect sizes and 95% confidence intervals were reported where calculable from the available data.

## RESULTS

With study population and baseline characteristics we discovered improved heart rate, electrolyte balance, obesity, creatinine clearance, and blood pressure compared with short-term effects of an IV bolus and an infusion of furosemide over a three day follow up period.

### 3.1. Gender distribution

In a research comparing continuous infusion versus intermittent bolus injections of furosemide in patients with acute decompensated heart failure (ADHF), males were more commonly impacted than females (Figure 2).

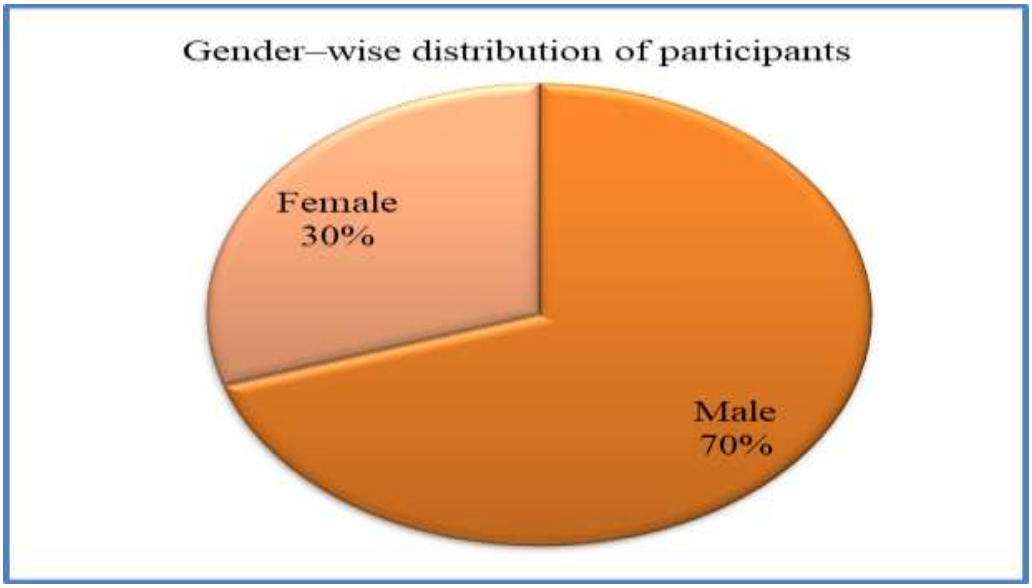



**Figure 2.** Gender–wise distribution of participants

**Illustration:** The figure 2 illustrates the gender distribution among patients enrolled in the study comparing continuous infusion versus intermittent bolus injection of furosemide in acute decompensated heart failure (ADHF). Out of a total of 40 participants, 28 were male and 12 were female. This indicates that males were more frequently affected by ADHF in the study population.

**Distribution of participants based on age**

Dividing patients by age can indeed provide valuable insights into how different age groups are affected by a particular condition or situation. This analytical framework facilitates the development of healthcare strategies tailored to the distinct requirements of each age cohort, which may enhance the effectiveness of both therapeutic interventions and preventive initiatives (Figure 3).

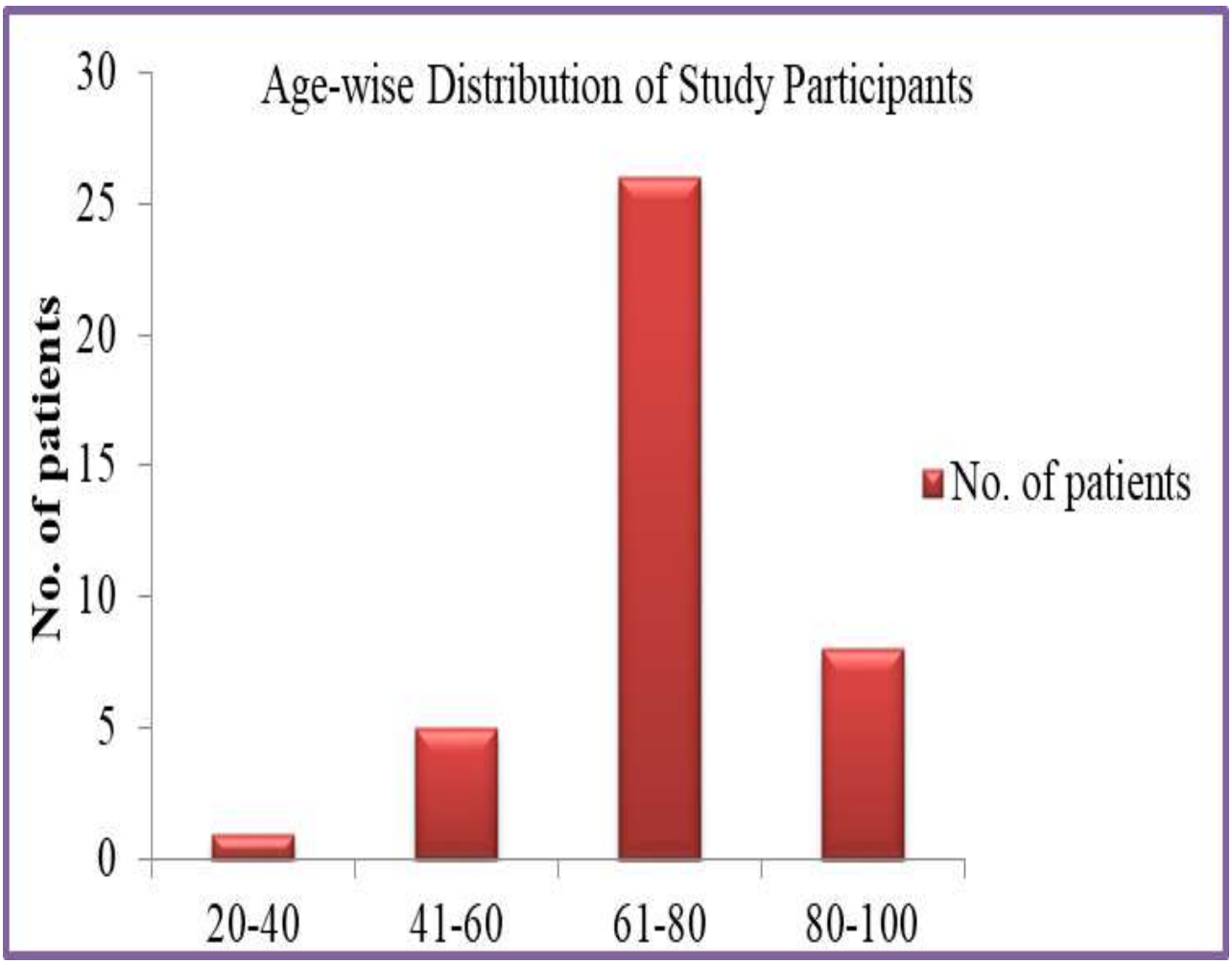



**Figure 3.** Age-wise Distribution of Study Participants

**Illustration:** The data demonstrate a discernible pattern in the age distribution of participants, with a substantial proportion of cases occurring among individuals aged over 60 years. This observation is consistent with established literature, which highlights advanced age as a significant risk factor for acute decompensated heart failure in various clinical settings.

**3.3. Distribution of Comorbidities**

Among the study population, hypertension and type 2 diabetes mellitus emerged as predominant comorbid conditions, with 26 out of 40 participants identified as being at elevated risk due to the presence of these factors (Figure 4).

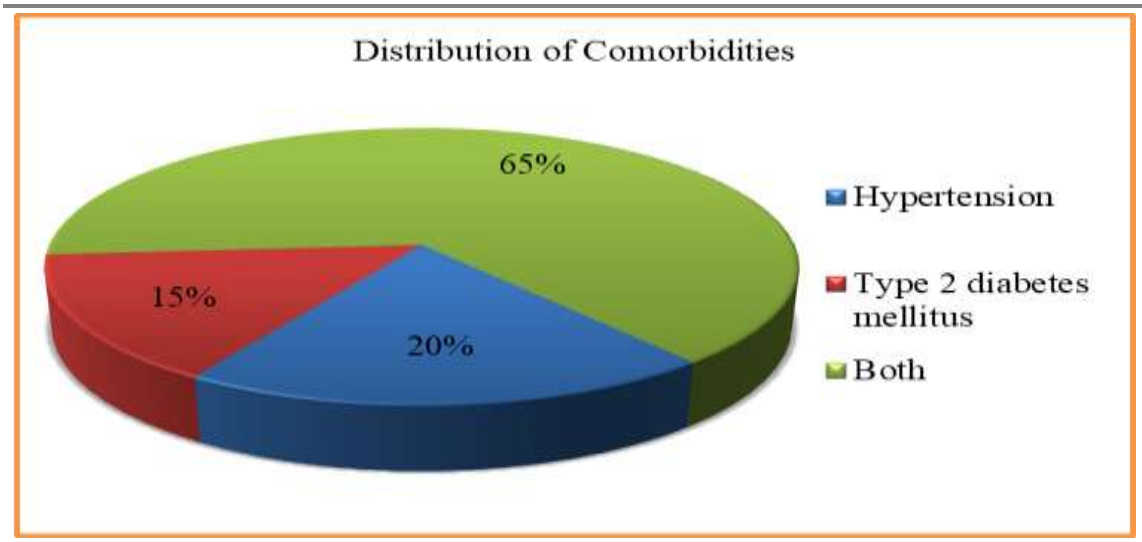



**Figure 4:** Distribution of Comorbidities

**Illustration:** The figure 4 depicts the hypertension and type 2 diabetes mellitus were the predominant comorbid conditions, affecting 26 patients (65%) in the study cohort.

**Comparison of Gender with Study group**

The gender distribution among patients in both treatment groups. In Group 1 (n = 20), 15 participants (75%) were male and 5 (25%) were female. In Group 2 (n = 20), 13 participants (65%) were male and 7 (35%) were female. Although males predominated in both groups, the proportion of female participants was slightly higher in Group 2 (Table 2).

**Table 2.** Comparison of Gender with Study group

| | Study groups | |
|---|---|---|
| | Group1 (n=20) | Group2 (n=20) |
| Male | 15 (75%) | 13 (65%) |
| Female | 5(25%) | 7 (35%) |

**Distribution of chief complaints**

The figure 5 depicts the distribution of primary presenting symptoms among patients admitted with acute decompensated heart failure (ADHF) (Figure 5).




**Figure 5:** Distribution of chief complaints

**Illustration:** Cough was the most frequently reported complaint, observed in 16 patients (40%). Orthopnea was reported in 6 patients (15%), edema in 5 patients (12.5%), while palpitations and chest pain were each noted in 3 patients (7.5%). These findings highlight cough and orthopnea as the predominant symptoms in the study population.

**Comparison of vital signs in study group**

Median changes in systolic blood pressure from Day 1 to Day 3 didn't differ significantly between bolus and continuous Infusion groups (median 0.5 vs -1.5 mmHg, p= 0.859). Similarly no significant differences were observed in diastolic blood pressure, heart rate and pulse rate (Table 3).

**Comparison of electrolytes in study groups**

In this investigation comparing continuous infusion and intermittent bolus injection of furosemide in individuals with acute decompensated heart failure, a total of 40 cases were analyzed. Patients were monitored over a three-day period, with urine output on Day 1 evaluated in relation to that measured on Day 3 (Table 4).

**Comparison of urine output in study group**

Comparisons of Continuous Infusion vs intermittent bolus injection of furosemide in acute decompensated heart failure patients, 40 cases were recorded. Three days of follow up is done Day 1 Urine Output are compared with Day 3 (Table 5).

**Table 1.** Baseline Characteristics of Patients in the Intermittent Bolus and Continuous Infusion

| Baseline characteristic | Bolus group (n=20) | Continuous infusion group (n=20) | Total | P value |
|---|---|---|---|---|
| Age, years | 64.2 ± 10.8 | 63.5 ± 11.2 | 63.9 ± 10.9 | 0.842 |
| Male sex, n (%) | 15 (75.0) | 13 (65.0) | 28 (70.0) | 0.490 |
| HFrEF, n (%) | 11 (55.0) | 10 (50.0) | 21 (52.5) | 0.752 |
| HFpEF, n (%) | 9 (45.0) | 10 (50.0) | 19 (47.5) | |
| LVEF, n (%) | 43.6 ± 11.5 | 44.8 ± 12.1 | 44.2 ± 11.7 | 0.751 |
| Hypertension, n (%) | 14 (70.0) | 12 (60.0) | 26 (65.0) | 0.507 |
| Type 2 diabetes mellitus, n (%) | 13 (65.0) | 11 (55.0) | 24 (60.0) | 0.519 |
| Chronic kidney disease, n (%) | 7 (35.0) | 6 (30.0) | 13 (32.5) | 0.736 |
| Coronary artery disease, n (%) | 8 (40.0) | 7 (35.0) | 15 (37.5) | 0.744 |
| Other Comorbidities | 4 (20.0) | 5 (25.0) | 9 (22.5) | 0.705 |
| Serum creatinine, mg/dL | 1.78 ± 0.72 | 1.74 ± 0.68 | 1.76 ± 0.70 | 0.858 |
| Blood urea, mg/dL | 62.4 ± 22.1 | 60.8 ± 20.6 | 61.6 ± 21.3 | 0.812 |

| | | | | |
|---|---|---|---|---|
| Urine output, mL/24 h | 1,420 ± 385 | 1,445 ± 402 | 1,433 ± 391 | 0.842 |
| Urine output, mL/72 h | 4,260 ± 1,155 | 4,335 ± 1,206 | 4,298± 1,178 | 0.842 |

**Table 3.** Comparison of median change in vital parameters (Day1 to Day 3)

| Variable | Statistics | Bolus | Infusion | P value |
|---|---|---|---|---|
| Systolic Blood Pressure | Median | 0.50 | -1.50 | 0.859 |
| | Inter quartile rage | (0.00,20.00) | (-8.75,20.00) | |
| Diastolic Blood Pressure | Median | 5.00 | -1.50 | 0.326 |
| | Inter quartile range | (0.00,10.00) | (-10.00,10.00) | |
| Heart Rate | Median | -3.00 | 1.50 | 0.330 |
| | Inter quartile range | (-18.5,3075) | (-12.50,13.00) | |
| Pulse Rate | Median | 0.00 | -1.50 | 0.508 |
| | Inter quartile range | (-5.00,15.00) | (-9.00,6.00) | |

There was no statistically significant changes were observed in systolic and diastolic blood pressure, pulse rate, or heart rate ($p > 0.05$ for all) between the bolus and infusion groups.

**Table 4.** Comparison of electrolytes in study groups

| Variable | Statistics | Bolus | Infusion | P value |
|---|---|---|---|---|
| Difference in Sodium | Median | -2.50 | -1.50 | 0.472 |
| | Inter quartile range | (-7.5,1.00) | (-3.75,1.00) | |
| Difference in Potassium | Median | 0.100000 | -0.75000 | 0.684 |
| | Inter quartile range | (-0.250000, 0.575000) | (-0.075000, 0.375000) | |
| Difference in serum creatinine | Median | -0.60000 | -0.185000 | 0.914 |
| | Inter quartile range | (-1.370000, 0.147500) | (-0.217500, 0.027500) | |

No statistically significant difference with respect to serum sodium ($p = 0.472$), potassium ($p = 0.684$) or creatinine levels ( $p = 0.914$) between the two groups and no clinically meaningful differences were observed in electrolyte parameters or renal function between continuous infusion and bolus dosing of furosemide in acute decompensated heart failure.

**Table 5.** Comparison of urine output in study group

| Variable | Statistics | Bolus | Infusion | P value |
|---|---|---|---|---|
| Urine Output | Median | -1112.500 | -628.850 | 0.037* |
| | Inter quartile range | (-1766.250, - 291.250) | (-1062.500,650.00) | |

Urine-output change was calculated as Day 3 urine output minus Day 1 urine output. Negative values indicate a reduction in urine output from Day 1 to Day 3; values closer to zero indicate a smaller reduction. $P < 0.05$ was considered statistically significant.

Urine output was assessed during the three-day observation period, and the change between Day 1 and Day 3 was compared between the intermittent-bolus and continuous-infusion groups. The median change in urine

output was −1112.500 mL in the bolus group and −628.850 mL in the continuous-infusion group. The difference between the groups was statistically significant (Mann–Whitney U = 123.000, $p$ = 0.037). The continuous-infusion group demonstrated a smaller reduction in urine output from Day 1 to Day 3 compared with the bolus group.

## DISCUSSION

This investigation set out to compare how effective continuous infusion was against intermittent bolus administration of furosemide in patients experiencing acute decompensated heart failure (ADHF). Both treatment methods led to notable improvements across hemodynamic stability, kidney function, and how symptoms were managed. However, the only statistically significant difference observed was in urine output, suggesting that these two regimens had a distinct impact on diuresis.

Specifically, patients receiving the continuous infusion produced significantly more urine compared to those in the bolus group (p = 0.037), implying that a continuous drip might provide a more sustained diuretic effect and better fluid removal. This finding echoes earlier work by researchers such as Mullens ets al. [22] and Felker et al. [23], who highlighted the benefits of continuous furosemide infusion in maintaining stable plasma concentrations, thereby promoting ongoing diuresis and minimizing sharp fluctuations in renal perfusion. Similarly, Testani et al. [13] demonstrated that continuous infusion could effectively reduce volume while also tempering neurohormonal activation, optimizing fluid management for the ADHF population.

The optimal mode of intravenous furosemide administration in acute decompensated heart failure (ADHF) remains an area of clinical investigation. The landmark Diuretic Optimization Strategies Evaluation (DOSE) trial was a prospective, double-blind, randomized trial involving 308 patients with ADHF. Patients were randomized to intravenous furosemide administered either as a bolus every 12 hours or as a continuous infusion and to either a low-dose or high-dose strategy. Over the 72-hour treatment period, there was no significant difference between bolus and continuous infusion in patients' global assessment of symptoms or change in serum creatinine [23]. Thus, the DOSE trial did not demonstrate a significant advantage of continuous infusion over intermittent bolus administration for its primary efficacy or renal safety outcomes.

Subsequent systematic reviews and meta-analyses have reported heterogeneous findings. An updated meta-analysis of randomized trials involving patients with ADHF reported greater diuresis and reduction in body weight with continuous infusion compared with intermittent bolus administration, although differences in urinary sodium excretion and hospital stay were not significant [29].

A systematic review and meta-analysis of eight randomized controlled trials involving 669 patients found that continuous infusion was associated with greater 24-hour urine output and weight reduction, whereas mortality, duration of hospitalization, raised serum creatinine, and hypokalemia did not differ significantly between treatment strategies [30].

Similarly, a systematic review and meta-analysis of 12 parallel-group randomized controlled trials involving 923 patients found greater body-weight reduction with continuous infusion but no significant differences in mortality, length of hospital stay, or 24-hour urine output. No significant differences were observed in hypokalemia, hyponatremia, increased serum creatinine, or hypotension [31].

More recent evidence has further expanded this literature. A 2026 updated systematic review and meta-analysis of 22 randomized controlled trials involving 2,633 participants reported that continuous infusion was associated with improvements in several decongestion-related outcomes, including freedom from congestion, weight loss, 24-hour urine volume, and some clinical parameters. However, the authors did not demonstrate a significant

long-term survival advantage, and the certainty of evidence varied across outcomes [32]. A separate recent meta-analysis focusing specifically on renal outcomes found no statistically significant difference in worsening renal function between continuous infusion and intermittent bolus administration, supporting the absence of a clear renal safety advantage for either strategy [33].

The present study provides complementary prospective observational evidence from a tertiary-care hospital in India. Unlike the DOSE trial, which used randomized treatment allocation and included 308 patients, our study compared continuous infusion and intermittent bolus furosemide in 40 patients with ADHF under routine clinical conditions over a three-day observation period. Baseline demographic and clinical characteristics of the two treatment groups are presented in Table 1. The present study evaluated short-term changes in hemodynamic parameters, renal function, electrolytes, and urine output. A statistically significant difference was observed in the assessed change in urine output, whereas no significant between-group differences were observed in serum creatinine, sodium, potassium, blood pressure, or heart rate. These findings provide additional real-world observational data regarding short-term physiological responses to the two administration strategies. However, because of the observational design, small sample size, non-random treatment allocation, and short follow-up, the present findings should be interpreted as complementary to the randomized evidence from the DOSE trial rather than as evidence of superiority of continuous infusion.

In contrast, the DOSE trial, conducted by Felker et al. [34], reported no significant differences in overall symptom relief or kidney function between the bolus and infusion strategies. Consistent with those findings, the current study also found no statistically significant differences between the groups regarding systolic blood pressure, diastolic blood pressure, heart rate, or serum creatinine levels ($p > 0.05$). These outcomes suggest that both furosemide administration strategies are effective for stabilizing hemodynamics, with continuous infusion perhaps offering a slight edge in urine output without increasing the risk of kidney dysfunction.

Both dosing approaches successfully maintained stable kidney function, evidenced by the lack of significant changes in serum creatinine and electrolyte concentrations. These results align with observations from Joseph et al. [35] and Kumar et al. [20], who emphasized the critical role of carefully adjusting loop diuretic doses to achieve effective decongestion without compromising electrolyte balance or renal function. The preservation of kidney function noted in this study indicates that, with vigilant monitoring, either regimen can be safely employed in ADHF management.

Out of the 40 patients participating in the study, 28 (70%) were male, and the majority were over 60 years old. This demographic pattern aligns with established epidemiological trends, as ADHF is more frequently seen in older male populations. Comparable demographic characteristics were reported by Adams et al. [36] and Patel et al. [37], who identified advanced age and male gender as significant risk factors for ADHF-related hospitalizations. Hypertension and type 2 diabetes mellitus were the most common co-existing conditions, affecting 65% of participants, consistent with findings from Levy et al. [9] and Van Deursen et al. [38], who recognized these conditions as major contributors to the development and progression of heart failure.

Cough (40%), orthopnea (15%), and pedal edema (12.5%) were the most frequently reported clinical signs. These findings are characteristic of typical fluid overload in ADHF and are consistent with earlier reports by Gheorghiade and Pang [3] and Shams [39], who noted dyspnea, orthopnea, and peripheral edema as hallmark symptoms of acute decompensation. The observed reduction in these symptoms during diuretic therapy suggests that both bolus and infusion regimens were effective in relieving congestion and improving patient comfort. These findings suggest that continuous infusion of furosemide may be preferred in patients requiring continuous diuresis, while bolus dosing remains of furosemide appropriate for rapid symptomatic relief.

### Limitations

This study has several limitations. The prospective observational design and non-random allocation of treatment based on physician discretion may have introduced selection bias and confounding by indication, as clinical factors influencing treatment selection may also have influenced the observed outcomes. The relatively small sample size of 40 patients limits the statistical power and precision of the estimates. Furthermore, the single-center setting may limit the generalizability of the findings to other healthcare settings and patient populations. The three-day follow-up period allowed assessment of short-term outcomes but did not permit evaluation of longer-term outcomes such as rehospitalization, mortality, sustained renal function, persistent electrolyte abnormalities, or other clinical outcomes. Therefore, the findings should be interpreted as short-term comparative observations, and larger multicenter studies with randomized treatment allocation and longer follow-up are warranted.

## CONCLUSION

The present study provides preliminary comparative observations regarding continuous infusion and intermittent bolus administration of furosemide in patients with acute decompensated heart failure. Although a statistically significant difference was observed in the assessed change in urine output, no significant differences were observed in several other evaluated hemodynamic, renal, and electrolyte parameters. Given the small sample size, single-center setting, and non-randomized observational design, these findings should be interpreted cautiously and should not be considered sufficient to guide clinical practice. Larger multicenter randomized controlled trials with adequate statistical power and longer follow-up are warranted to determine the comparative effectiveness and safety of these administration strategies.

### Future Directions

Future studies should employ larger sample sizes and multicenter randomized controlled designs to minimize selection bias and confounding and to improve the generalizability and statistical power of the findings. Longer follow-up should also be incorporated to evaluate clinically relevant outcomes such as sustained renal function, electrolyte disturbances, rehospitalization, and mortality. Such evidence would be necessary before making definitive recommendations regarding the preferred mode of intravenous furosemide administration in acute decompensated heart failure.

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### Conflict of Interest Statement

The authors state that the publication of this paper has no conflict of interest.

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