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Brief Reports

Pilot Study Identifying Predictive Factors of Diuretic Effectiveness in Emergency Department Patients with Fluid Overload

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□ **Abstract—Background: Effective diuretic therapy in emergency department (ED) patients with fluid overload is challenging. Objectives: The objective of this study was to evaluate clinical and laboratory parameters for predicting an adequate response to initial diuretic therapy in ED patients with edema. Methods: In this prospective, observational study, patients presenting to the ED of a tertiary hospital with edema of cardiac or renal cause were included. Intravenous furosemide was administered according to a prespecified protocol and urine output was recorded. Group comparison and univariable logistic regression analyses were performed to explore the predictive impact of various clinical and laboratory factors on diuretic success defined as urine volume ≥ 600 mL in the first 6 h vs. failure (< 600 mL in the first 6 h)—focusing on urinary sodium and conductivity as a simple and inexpensive test. Results: A total of 101 patients were analyzed. The median 6-h urine output was 1100 mL (interquartile range 600, 1700). A higher systolic blood pressure, estimated glomerular filtration rate, urine sodium, and urine electrical conductivity were each associated with achieving at least 600 mL urine output in 6 h. In univariable analysis, a urine sodium threshold of > 72.5 mmol/L and a urine conductivity > 12.0 mS/cm showed a positive predictive value of 93% and 89%, for sufficient diuresis. Conclusions: Urine sodium and urine electrical conductivity were associated with diuretic success in this pilot study. As these parameters can be determined prior to treatment initiation, their value as predictive markers should be evaluated in further studies. © 2025 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)**

□ **Keywords—fluid overload; volume overload; edema; heart failure; diuretic resistance; loop diuretics**

Introduction

Fluid overload is a frequent reason for presentation to the emergency department (ED), with its most common causes being acute decompensated heart failure (ADHF), aggravation of pre-existing chronic kidney disease, acute kidney injury, or a combination of these (1). Emergency physicians frequently refer to guidelines on treatment of ADHF to seek advice about dosage and timing of diuretic treatment for decongestive therapy. A European Society of Cardiology (ESC) ADHF position paper published in 2019, as well as current guidelines, propose administering a loop diuretic intravenously (i.v.) at a dose corresponding to one to two times the daily oral dose prior to admis-

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sion, and to adjust subsequent diuretic doses according to the urine output or natriuresis over the subsequent 6 h. A urine volume of < 600 mL in the first 6 h (100 mL/h) after treatment initiation can be considered as treatment failure (2,3).

In the ED setting, monitoring of urine output over 6 h to adjust diuretic dosing is cumbersome and prone to errors. Moreover, more rapid and effective diuresis has been associated with earlier discharges and shorter hospital stay length (4,5). Hence, identifying patients who are likely to achieve adequate diuresis could reduce the need for close urinary output monitoring and support timely decisions on discharge and disposition.

Against this background, the aim of this pilot study was to identify clinical and laboratory parameters assessed prior to treatment initiation, which could help predict whether patients achieve the minimal goal of a urine volume of 600 mL over 6 h after administration of a standardized loop-diuretic dose.

Methods

Study Design, Setting, and Population

This was a prospective, observational, monocentric cohort study of patients with clinically conceivable volume expansion requiring hospital admission. The study was conducted in the ED of the University Hospital of Cologne, Germany between September 1, 2020 and March 31, 2022 using convenience sampling. Patients were eligible if they were ≥ 18 years old and presented with peripheral or pulmonary edema attributed to a cardiac or renal cause as determined by the treating physician. Exclusion criteria comprised liver cirrhosis as the cause of the edematous state, pressing need for thoracocentesis or paracentesis, need for referral to intensive care, dependence on or employment relationship with the investigating institution, and inability to give informed consent. Patients were screened for eligibility on weekdays (Monday to Friday) between 8 AM and 6 PM by dedicated study personnel (doctoral student, study nurse, physician investigators) present in the ED. As this was an exploratory observational study, no power calculations were performed.

Study Protocol

Decongestive treatment was applied according to a local standard operating procedure (SOP) throughout the study period, which was put in place prior to publication of current ESC ADHF guidelines and position paper statement (2,3). It mandated administration of a bolus of 40 mg furosemide i.v. as a first dose in diuretic-naïve patients and 80 mg for those with diuretic pretreatment. However, treating physicians were allowed to decide against the SOP guidance if deemed necessary.

Measurements

All study-associated information was collected and recorded by dedicated study personnel. Up until 6 h after administration of the diuretic, the study personnel remained by the side of the patient to ensure accurate measurements. After obtaining written consent, vital signs, biometric parameters, and clinical characteristics (such as presence of dyspnea or reason for presentation to the ED) were assessed by study personnel, and spot urine was collected prior to administration of furosemide. Urine volume over the first 6 h after initial diuretic administration, as well as diuretic therapy, was recorded and all data were captured using prespecified report forms. Urine was typically collected using a urinal, as Foley catheters were placed only if deemed medically necessary and not for study purposes. Urine electrical conductivity was assessed at the bedside in the ED as a surrogate of total electrolyte concentration (WTW Multi 3510 IDS, WTW, Weilheim, Germany). Measuring urine conductivity as a point-of-care alternative to determine urine composition has been previously proposed in the literature and was evaluated in this study as alternative point-of-care test for hospitals where urine electrolyte measurements are not readily available (for a short overview on urinary conductivity, see the Appendix, available online) (6,7).

Outcomes

The primary outcome variable was achievement of a sufficient urine volume over 6 h defined as a cumulative urine volume of at least 600 mL (100 mL/h) in accordance with the ESC ADHF guideline (2,3).

Data Analysis

Numerical variables are displayed as medians (interquartile range [IQR]); categorical and dichotomous variables are given as the frequencies and proportion (%), respectively. For comparative analysis, two-sided Mann-Whitney-*U* test was used. Clinical and laboratory features that were analyzed with regard to their capability to predict outcome included age, body surface area (calculated according to Du Bois and Du Bois), furosemide-equivalent dose of prescribed daily diuretic medication (i.e., 40 mg i.v. furosemide was defined as equivalent to 80 mg furosemide per os or 20 mg torasemide per os), i.v. furosemide dose administered in the ED, systolic blood pressure, estimated glomerular filtration rate (eGFR; estimated with Chronic Kidney Disease Epidemiology Col-

laboration equation), spot urine concentrations of sodium, potassium, and urea, as well as urine electrical conductivity (8–10). Univariable logistic regression analysis using promising parameters from group-wise comparison as independent variables, such as urine sodium, was performed to explore their capability as stand-alone tests to predict treatment success based on a single measurement. Receiver operating characteristic curves were plotted, and Youden's J index was used for optimal threshold selection.

Data preparation and processing, as well as all analyses, were performed using R (R Core Team, R version 4.2.0 [2022-04-22]). p-Values < 0.05 were considered significant.

Ethics Approval and Trial Registration

The study protocol was approved by the institutional review board of the University of Cologne (19-1036-NIS). The study was registered on www.clinicaltrials.gov (NCT03967717).

Results

A total of 102 patients were enrolled. For 1 patient, urine output over 6 h was not available, leaving 101 patients for analysis of the primary outcome variable.

Baseline Characteristics and Administered Furosemide Dose

The median age was 74.0 years (IQR 65.5, 82.0) and 54 (53.5%) were male. Dyspnea was the reason for presentation to the ED in 61 (60.4%) patients, whereas 71 (70.3%) reported worsening dyspnea and 86 (85.2%) increasing peripheral edema in the last 7 days. Loop diuretics were part of the pre-existing medication in 79 (78.2%) of the patients, thiazides in 15 (14.9%), and potassium-sparing diuretics in 31 (30.7%), but the dose was not changed in 80 (79.2%) of the cases in the last 7 days prior to enrollment. The cause of edema was suspected to be cardiac in 63 (62.4%), renal in 12 (11.9%), and cardiorenal in 24 (23.8%) of the cases. The first diuretic dose in the ED was 40 mg i.v. furosemide in 23 (22.8%) of the patients, 80 mg i.v. furosemide in 72 (71.9%) of the cases, and higher in the remaining cases. This was in accordance with the local SOP in 90 (89.1%) cases, whereas 7 (6.9%) patients received less and 4 (4.0%) more than the recommended dose. The administered dose followed the recommended doses in the ESC guideline in 54 (53.5%) of the cases, with 37 (36.6%) receiving less and 11 (10.9%) more than the recommended dose.

Urine Output

Median urine output over 6 h was 1100 mL (IQR 600, 1700 mL) and the median weight loss was 0.9 kg (IQR 0.5, 1.4 kg). Median urine volume per 40 mg i.v. furosemide was 625 mL (IQR 350, 1075 mL). Treatment failure—defined as 6-h urine volume < 600 mL—was observed in 25.8% (26/101) of patients (median 6-h urine output 400.0 mL, IQR 212.5, 537.5 mL); 13.9% of patients showed a 6-h urine volume between 600 mL and 900 mL (ESC-recommended target corridor) and 60.4% showed a urine volume ≥ 900 mL.

Factors Predicting Treatment Success

Patients with treatment success (i.e., ≥ 600 mL/6-h urine volume) had a significantly higher body surface area, higher initial systolic blood pressure, higher eGFR, and higher initial spot urine sodium concentration, as well as a higher urine conductivity (Table 1). Diuretic premedication and age, as well as several other parameters, did not show any significant influence.

Receiver operating characteristics curves were constructed based on univariable models incorporating the above-mentioned parameters as independent variables and treatment success as the dependent variable (Figure 1). Clinically applicable cut-off levels were derived and their predictive capability was evaluated (Table 2). An initial urine sodium of > 72.5 mmol/L or an initial urine conductivity of > 12.0 mS/cm showed positive predictive values (PPV) of 93% and 89% for treatment success. Notably, 47% and 52% of the patients exceeded these thresholds. In contrast, other factors, such as eGFR, had lower PPVs.

Discussion

For patients presenting to the ED with edema of cardiac or renal etiology, group-wise comparison showed that patients with a urine output of ≥ 600 mL over 6 h after a first dose of i.v. furosemide had a higher body surface area, higher initial systolic blood pressure, and higher eGFR. The negative impact of a reduced eGFR on response to diuretic treatment has been well established, but an eGFR cut-off alone showed an insufficient PPV for treatment success (4,5,11,12).

In addition, our study showed that two easy-to-measure urinary parameters are associated with urine output: a higher sodium concentration as well as a higher conductivity in the initial spot urine sample. Further analyses revealed that a urine sodium concentration of $>$ 72.5 mmol/L or a conductivity of > 12.0 mS/cm in the initial urine sample were the two parameters that

Table 1. Characteristics of Patients Who Failed to Achieve a 6-Hour Urine Volume of At Least 600 mL After Administration of i.v. Furosemide

Predictor	Urine Output < 600 mL n = 26	Urine Output ≥ 600 mL n = 75	*p*-Value
Age, years	71.5 (66.3, 75.0)	76.0 (65.5, 82.5)	0.081
BSA, m^2	1.92 (1.70, 2.01)	2.01 (1.9, 2.16)	0.004**
Diuretic premedication, %	80.0	73.1	0.800
Daily diuretic dose, mg	60 (3, 124)	20 (10, 80)	0.204
i.v. Furosemide, mg	80 (40, 80)	80 (80, 80)	0.731
BP, systolic, mm Hg	121 (109, 140)	142 (126, 166)	< 0.001**
eGFR, mL/min per 1.73m^2	29 (16.5, 52.5)	43 (31, 64)	0.031*
Urine Na^+, mmol/L	48 (37, 66)	84 (50, 105)	0.002**
Urine K^+, mmol/L	36 (24, 54)	34 (22, 48)	0.691
Urine urea, mg/dL	843 (616, 1,283)	813 (582, 1,454)	0.824
Urine conductivity, mS/cm	10.25 (8.28, 12.56)	12.6 (10.14, 15.95)	0.033*
Urine Na^+ * eGFR, mmol/min per 1.73m^2	1.40 (0.55, 2.49)	2.65 (1.54, 5.52)	0.001**
Urine Na^+/plasma creatinine, mmol/mg	2.85 (1.17, 3.83)	4.86 (2.58, 8,82)	0.002**

As median (interquartile range) unless stated otherwise.
BSA = body surface area; i.v. = intravenous; BP = blood pressure; eGFR = estimated glomerular filtration rate.
* $p \leq 0.05$
** $p \leq 0.01$.

showed the highest PPVs of 93% and 89% for a target urine volume of at least 600 mL in 6 h in this pilot study.

A spot urine sodium concentration of 50–70 mmol/L 2 h after diuretic administration has been shown to predict urine output and even probability for ED presentation in the next 30 days (13–15). Spot urine sodium 2 h after diuretic administration is recommended by the ESC and American experts as an alternative to urine volume measurement to adapt diuretic dosing, and has been used successfully to guide diuretic therapy in recent trials (2,3,16–18). Still, this does not inform on ad hoc decongestive treatment. Instead, our data suggest that a spot urine measurement of sodium *prior to* commencement of treatment can also be a valuable tool for identifying patients likely to respond to diuretic therapy. Implementing spot urine sodium in the diagnostic algorithm early after admission might facilitate treatment decision and reduce the need for timed follow-up assessments, which can be challenging to perform in crowded ED settings. In contrast, for patients that do not reach the thresholds determined by our pilot study, continuous urinary output monitoring and early reassessment is warranted to guide potentially necessary therapeutic escalation, such as intensifying diuretic regimens, applying sequential nephron blockade, or consulting cardiology or nephrology specialists.

In EDs, where urine sodium measurements are not readily available, assessing spot urine conductivity at the bedside may offer a novel, rapid, and easily applicable alternative. Urine conductivity has previously been used as a surrogate marker for urine electrolytes and, in our study, proved to be both simple and quick to measure at the bedside (6,7). Therefore, it may serve as a valuable and cost-effective alternative in EDs lacking immediate access to laboratory-based urine electrolyte analysis. Further prospective studies should therefore be conducted to evaluate its clinical utility.

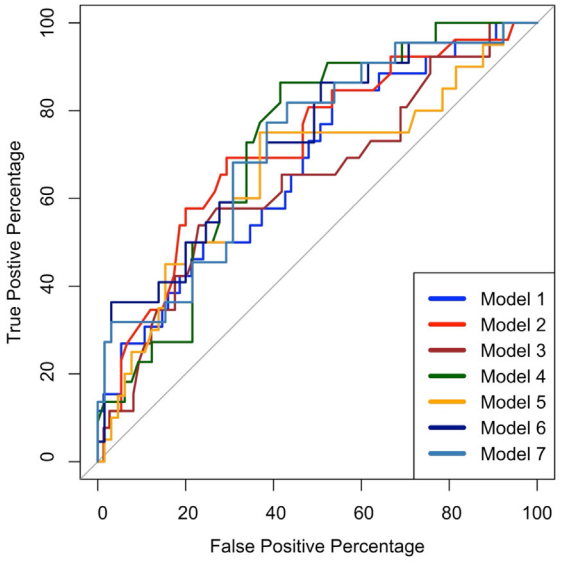
Limitations

This observational study can only be used for hypothesis generation, as it has several limitations. First, it was a single center pilot study with small sample size and was carried out during routine care by convenience sampling, which may have biased our results. Although multivariable logistic regression models were explored during the analysis phase, they did not yield substantial gains in predictive power. Given the study's pilot nature, limited sample size, and the risk of overfitting, we did not include these results to preserve parsimony and maintain clinical applicability for ED workflows. Additionally, a local SOP guiding diuretic dosing was in place, which limits external validity. Dosing recommendations in our

Table 2. Statistical Metrics Provided by Univariable Models with Different Parameters Available Prior to Diuretic Treatment to Predict Treatment Success

Predictor	Cut-Off	Proportion of Patients	PPV (95% CI)	NPV (95% CI)	LR+ (95% CI)	LR− (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)
BSA [m^2]	2.025	41%	0.86 (0.71–0.95)	0.34 (0.22–0.47)	2.08 (0.99–4.36)	0.68 (0.50–0.91)	0.48 (0.36–0.60)	0.77 (0.56–0.91)
BP, systolic [mmHg]	131	60%	0.87 (0.76–0.94)	0.45 (0.29–0.62)	2.30 (1.27–4.16)	0.42 (0.27–0.65)	0.71 (0.59–0.81)	0.69 (0.48–0.86)
eGFR [mL/min per 1.73m^2]	29.5	67%	0.83 (0.72–0.91)	0.45 (0.27–0.64)	1.67 (1.08–2.57)	0.43 (0.25–0.73)	0.77 (0.66–0.86)	0.54 (0.33–0.73)
Urine Na^+ [mmol/L]	72.5	47%	0.93 (0.80–0.98)	0.41 (0.27–0.57)	4.29 (1.47– 12.52)	0.48 (0.34–0.67)	0.58 (0.46–0.71)	0.86 (0.64–0.97)
Urine conductivity [mS/cm]	12.0	52%	0.89 (0.76–0.96)	0.38 (0.23–0.55)	2.52 (1.15–5.51)	0.49 (0.33–0.74)	0.63 (0.50–0.75)	0.75 (0.51–0.91)
Urine Na^+* eGFR [mmol/min per 1.73 m^2]	2.08	52%	0.87 (0.74–0.94)	0.43 (0.26–0.61)	2.18 (1.16–4.10)	0.45 (0.28–0.72)	0.69 (0.57–0.80)	0.68 (0.45–0.86)
Urine Na^+/plasma creatinine [mmol/mg]	3.8	25%	0.89 (0.76–0.96)	0.40 (0.26–0.57)	2.71 (1.22–5.99)	0.50 (0.34–0.72)	0.62 (0.49–0.73)	0.77 (0.55–0.92)

Optimal cut-off values were identified using Youden's J index.
PPV = positive predictive value; CI = confidence interval; NPV = negative predictive value; LR+ = positive likelihood ratio; LR− = negative likelihood ratio; BSA = body surface area; BP = blood pressure; eGFR = estimated glomerular filtration rate.



Model 1: BSA [m^2]; AUC: 67.5%

Model 2: BP, systolic [mmHg]; AUC: 71.8%

Model 3: eGFR [mL/min per 1.73m^2]; AUC: 64.3%

Model 4: Urine Na^+ [mmol/L]; AUC: 72.4%

Model 5: Urine conductivity [mS/cm]; AUC: 65.8%

Model 6: Urine Na^+ x eGFR [mmol/min per 1.73m^2]; AUC: 73.0%

Model 7: Urine Na^+ / plasma creatinine [mmol/mg]; AUC: 72.2%

BSA, body surface area; BP, blood pressure; eGFR, estimated glomerular filtration rate; AUC, area under the curve

Figure 1. Receiver operating characteristics (ROC) curve analysis of univariable models to predict treatment success (i.e., 6-h urine volume of ≥ 600 mL after administration of i.v. furosemide).
BSA = body surface area; BP = blood pressure; eGFR = estimated glomerular filtration rate; AUC = area under the curve.

SOP were lower than the ones published by the ESC, and recent studies have shown improved diuretic effectiveness if therapy was guided with protocols based on ESC ADHF guidelines (17,18). Finally, the examined population in this trial comprised patients with fluid overload of cardiac, renal, or cardiorenal causes. Although the patients were deliberately selected this way to resemble the situation encountered in the ED, where determining the exact etiology of fluid overload is often not feasible early on, this might limit the comparability with other more defined study populations.

Conclusions

This pilot study demonstrated that prediction of adequate response to the initial diuretic dose in the ED may be feasible prior to treatment initiation and without close monitoring of urine output. Especially, initial urine sodium and urine conductivity showed promising results as easily

accessible parameters and should be evaluated in further clinical studies.

Declaration of competing interest

SMM received travel costs from Bayer Vital AG, received research grants from Elisabeth & Rudolf Hirsch foundation; all other authors have no conflict of interest to declare.

Appendix. Technical Background and Interpretation of Urine Electrical Conductivity

What Is Urine Conductivity?

Urine conductivity is a physical parameter that reflects the total concentration of electrolytes in a urine sample. It is measured in millisiemens per centimeter (mS/cm) and represents the fluid's ability to conduct electrical current—primarily influenced by the presence of sodium, potassium, chloride, and other charged solutes.

How Is it Measured?

Urine conductivity can be measured using a handheld or benchtop conductivity meter with a reusable probe. The probe is immersed in a small volume of fresh urine, and results are displayed immediately. No reagents or disposables are required, making it cost-effective and rapid. After measurement, the probe is rinsed and disinfected.

Why Is this Relevant in Clinical Practice?

Although not routinely used in emergency medicine, urine conductivity has been studied as a surrogate marker for urine osmolality and electrolyte concentration in nephrology, sports medicine, and hydration assessment contexts. In our study, we evaluated its utility as a point-of-care tool for predicting diuretic response in emergency department patients with volume overload—especially in settings where urine sodium measurements are unavailable or delayed.

Clinical Implications and Limitations

Urine conductivity offers a noninvasive, fast, and inexpensive method to estimate diuretic responsiveness. However, it is influenced by multiple solutes and lacks the specificity of direct sodium measurement. Further validation in larger cohorts and diverse clinical settings is warranted prior to broad implementation.

CRediT authorship contribution statement

Christoph Hüser: Project administration, Writing – review & editing, Formal analysis, Investigation, Writing – original draft, Conceptualization. **Lena Hartnack:** Investigation, Data curation, Writing – original draft. **Matthias Johannes Hackl:** Writing – review & editing, Investigation, Resources. **Sadrija Cukoski:** Resources, Writing – review & editing, Investigation. **Sascha Macherey-Meyer:** Investigation, Writing – review & editing. **Christoph Adler:** Investigation, Writing – review & editing. **Kathrin Möllenhoff:** Formal analysis, Resources, Writing – review & editing, Methodology. **Victor Suárez:** Conceptualization, Writing – review & editing, Investigation. **Volker Burst:** Resources, Formal analysis, Writing – original draft, Methodology, Writing – review & editing, Project administration, Conceptualization, Supervision, Investigation.

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Article Summary

1. Why is this topic important?

Fluid overload is a common reason for presentation to an emergency department. Early identification of patients likely to respond to diuretics can streamline effective and resource-conscious care.

2. What does this study attempt to show?

This study evaluates whether baseline clinical or laboratory parameters can predict a sufficient diuretic response before treatment initiation.

3. What are the key findings?

- ☐ A spot urine sodium >72.5 mmol/L or urine conductivity >12.0 mS/cm predicted adequate 6-hour urine output with high positive predictive value in this pilot study.
- ☐ Both outperformed traditional markers such as eGFR and can be assessed prior to treatment.

4. How is patient care impacted?

- ☐ Early, point-of-care urine testing may help emergency physicians identify patients likely to respond to loop diuretics.
- ☐ This could reduce the need for prolonged urine monitoring or posttreatment sodium checks.
- ☐ Incorporating such tools may expedite clinical decision-making and support safe early discharge in selected patients.