European Review for Medical and Pharmacological Sciences 2024; 28: 3796-3804

Improving management of intravenous maintenance fluids in the emergency department of a university hospital

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Abstract. – OBJECTIVE: Intravenous (IV) fluid therapy is a known source of iatrogenic complications. Guideline implementation can be used to educate and guide physicians on adequate fluid management. In the emergency department (ED), a complex and interruption-driven environment, workload is high and active documentation is required to facilitate audits of fluid management quality.

PATIENTS AND METHODS: Fluid management was evaluated in the ED records of adult non-critically ill patients admitted to a tertiary care center before (PRE: 1/12/2016-31/3/2017) and after (POST: 1/12/2018-31/3/2019) implementation of an educational intervention aiming to optimize IV fluid therapy in November 2018. First, the appropriateness of the 24-hour IV maintenance fluid prescription was evaluated, as prescribed by the emergency physician. Second, factors associated with appropriate prescribing were assessed, as well as the quality of fluid management documentation practice. Prescription appropriateness and documentation quality were evaluated retrospectively using a structured audit instrument and additional review by experts.

RESULTS: A total of 237 patients (2.3%) were included in the PRE-intervention group and 253 patients (2.4%) in the POST-intervention group. The expert panel evaluated 214 prescriptions in 82.3% of patients (PRE: 99, POST: 115), and appropriateness increased significantly (19.2% *vs.* 61.2%, *p*=0.002). A higher odds of an appropriate IV maintenance fluid prescription was determined, attributed to the intervention (adjOR=2.580; 95% CI 1.363-4.884) and in patients having a prehospital intervention (adjOR=1.914, 95% CI 1.022-3.586). Appropriateness of fluid management documentation did not significantly improve after the implementation of the intervention (15.6% *vs.* 16.2%, *p*=0.858).

CONCLUSIONS: The IV fluid prescriptions' appropriateness was significantly higher after guideline implementation. However, documentation quality of fluid management was poor in the studied ED records. Active stewardship programs are warranted to further monitor fluid management quality in the ED.

Key Words:
Intravenous infusions, Fluid therapy, Inappropriate prescriptions, Quality management, Internal audit.

Introduction

The emergency department (ED) is a complex environment where the caregivers' workflow is frequently disturbed (5-7 times per hour), and 30% of the caregivers' time is spent on multitasking actions. These pitfalls result in an increased mental workload and a lower quality of care[1,2]. Although fluid therapy is rarely reported as a cause of patient harm, 20% of hospitalized patients receiving intravenous (IV) fluids is at risk for fluid-related complications or morbidity[3]. Emergency physicians should, therefore, prescribe IV fluids cautiously to patients with no or limited oral intake because they are at risk for hypovolemia, electrolyte disturbances, or even fluid overload when given excess IV fluids[4].

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It is known that knowledge of IV fluids is insufficient among healthcare professionals[5,6], and as a result, inappropriate prescribing of IV fluids is common in adult hospitalized patients[6]. All prescribers, including emergency physicians, require education on fluid management to aim for the most optimal fluid prescription, adapted to the individual patient's volume status and electrolyte balance[7]. Additionally, the ED documentation workload has increased significantly in recent years[8] but is essential for patient follow-up and retrospective analysis for quality purposes, for example, to audit fluid management in the ED[9]. Interventions targeting fluid management are necessary to increase awareness and improve the appropriateness of IV fluid prescriptions on an institutional level. The introduction of an IV fluid bundle has already been shown to be effective in a British study, resulting in a 19% increase in compliance[10]. Other studies using similar strategies have described a comparable effect[11,12].

IV fluids are prescribed for multiple reasons: resuscitation, replacement of ongoing losses, or maintenance therapy. Concerning IV maintenance fluids, there is a tendency to prescribe hypotonic fluids to adult patients because isotonic fluids have been associated with lower urine output and hyperchloremia in studies in both healthy volunteers and adult postoperative patients[13,14]. This approach has also been adopted by the British National Institute for Health and Care Excellence (NICE)[4]. In their 2017 update of the guidelines[4], a glucose-rich solution with a 1 mmol/kg sodium, chloride, and potassium content to maintain basal fluid, calorie, and electrolyte needs in IV fluid therapy for hospitalized adults is recommended. However, assessment of the patient's fluid and electrolyte status is crucial over the course of the entire admission. Different treatment aspects, such as dialysis, drugs, and nutrition, may influence these parameters, necessitating cautious monitoring by physicians[15-18]. Furthermore, malnutrition is often underdiagnosed in the ED and may add to the risk of fluid and/or electrolyte disturbances[19]. Comprehensive management of both fluids and nutrition may thus prevent morbidity, mortality, and unnecessary costs[20].

In the present study, compliance with a locally implemented clinical guideline on fluid management in the ED was evaluated in terms of the appropriateness of the IV maintenance fluid prescription and documentation practice.

Patients and Methods

A guideline on fluid management was introduced in a Belgian university hospital in November 2018, based on the NICE clinical guideline 'Intravenous fluid therapy in adults in hospital'[4]. In this retrospective cohort study, electronic records of adult non-critically ill patients admitted to the hospital through the ED were analyzed before and after the implementation of this guideline on fluid management. This report was written following the SQUIRE guidelines[21].

Study Period

A pre-period (PRE) was defined from December 1st, 2016, until March 31st, 2017, prior to any fluid-related interventions. The post-period (POST) was set after the guideline introduction (December 1st, 2018, to March 31st, 2019).

Guideline Implementation Process

The principal aim of the guideline was to enhance physicians' and nurses' knowledge of fluid management and to introduce a practical toolbox for the less experienced prescriber, as awareness of IV fluids appeared insufficient[5]. The NICE guideline was chosen as the most evidence-based document internationally available at that time. It focuses on three indications for IV fluid administration, namely resuscitation, maintenance, and replacement[4]. A multidisciplinary team consisting of an emergency physician, an intensive care physician, a cardiologist-clinical pharmacologist, and a clinical pharmacist critically reviewed the content. After translation to Dutch and minor adaptations (**Supplementary Material 1**), the guideline was presented to all the hospital's heads of the medical and nursing departments of interest in September-October 2018. Revision was provided upon request. An educational program was set up for optimal guideline implementation, supported by 'fluid stewards'. These stewards were both physicians and nurses trained on the fluid policy's content during a plenary session on November 19th, 2018 (one physician and one head nurse per department), and therefore responsible for the dissemination of the guideline on their wards. The final version of the guideline was printed in full-text (**Supplementary Material 2**) and in a flow chart (**Supplementary Material 3**), after approval of the hospital's Pharmacy and Therapeutics Committee. The hard copy of the guideline was distributed to the physicians, and short-version posters were placed in the ward. Fluid bag

stocks were reviewed and adapted by the pharmacy to enhance availability in November 2018. In the final week of November, oral presentations were additionally organized for physicians during their staff meetings. Nurses were invited to come to a walk-in session on November 21st, 2018, to get a 15-minute presentation of the guideline.

Much attention was provided to the emergency physicians and nurses, both juniors and seniors, because the ER's status of an interrupt-driven environment, with high patient turnover, high admission rates (45%), and limited time for adequate documentation. It is, however, crucial and integrated into the hospital's policy that emergency physicians document a fluid plan to encourage and improve monitoring of the patient's fluid balance, electrolyte status, and oral intake during the first days of a patient's admission, especially when patients are not admitted for critical illness.

Patient Inclusion Criteria

Patients 16 years and older admitted through the ED for a minimum stay of 24 hours were eligible for study inclusion as per the NICE guideline inclusion criteria[4]. Patients were selected at random using their admission number, after stratification based on the admitting discipline, either surgery or internal medicine, in a 1:1 manner (**Supplementary Material 4**). Patients transferred from another hospital were excluded, assuming other ED physicians had already assessed their fluid status. Additionally, patients who were directly admitted to a critical care ward (e.g., intensive care, stroke unit, operating room) or the maternity ward were excluded, as well as psychiatric patients and patients in end-of-life settings.

Evaluation of Guideline Implementation

The primary outcome was the 24-hour IV maintenance fluid prescriptions' appropriateness (documentation of indication, correct composition and prescribed fluid volume/24h).

As secondary outcomes, factors increasing adequate prescribing were determined. The difference in the appropriateness of the emergency physician's fluid management documentation in the ED records after guideline implementation, based on a structured audit instrument evaluating the documentation of (1) volume status assessment and (2) oral intake evaluation.

A priori power analysis was performed using G*Power version 3.1.9.7 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) to determine the sample size needed to assess the IV fluid prescription's appropriateness. The calculation was based on pilot data (n=200), comparing 100 patients in the PRE-period to 100 patients POST-implementation. After exclusion, respectively 35 and 45 patients were prescribed an IV fluid. Prescription appropriateness increased from 17% to 32% (PRE *vs.* POST +15%). In the sample size calculation, a clinically relevant minimum increase of 20% was determined, which was considered acceptable based on the pilot assessment. With a significance level of α=0.05 and 80% power, a minimum sample size of 152 patients was determined to detect a 20% difference.

To evaluate the effectiveness of the fluid guideline's implementation on the patient level, an audit instrument was applied, previously developed and validated for fluid management evaluation in the ED[9]. Four researchers [three emergency physicians (one senior, two juniors) and a clinical pharmacist] individually reviewed the ED patient records. The researchers jointly performed the expert evaluation of the IV fluid prescriptions' appropriateness and discussed until consensus. The overall documentation was only considered adequate if the emergency physician had documented all items of both the 'assessment' and 'oral intake' sections.

Ethical Considerations

This study was approved by the institutional Ethics Committee (B.U.N. 1432020000235) and performed according to the ethical standards of the Helsinki Declaration on Ethical Principles for Medical Research Involving Human Subjects. Informed consent was waived based on the study's retrospective character.

Patient and Public Involvement Statement

There was no active patient involvement in this study.

Statistical Analysis

Descriptive statistics were applied to characterize the cohort, reporting percentages and medians with interquartile ranges (IQR). Proportions were compared using the Chi-square test. Bonferroni correction was applied if required. Risk factors were identified in a multivariable logistic regression analysis using forward stepwise selection. The final model was tested for multicollinearity (Variance Inflation Factor of each variable $\leq$5) and normality of residuals. *p*-values

less than 0.05 were considered statistically significant. All data were analyzed using IBM SPSS Statistics® version 28.0 (IBM Corp., Armonk, NY, USA).

Results

The inclusion process resulted in 2,959 PRE (25.5% surgical patients) and 2,432 POST-admissions (38.4% surgical patients) eligible for inclusion (Figure 1). After stratified random sampling, 296 patients were reviewed in the PRE-group and 304 patients in the POST-group. Application of the inclusion criteria resulted in 237 PRE-patients and 253 POST-patients. Other reasons for exclusion were missing information in the ED record (n=5), death or palliative care on admission (n=3), and admission for kidney transplant directly referred to the operating room after a nephrologist check-up (n=1). Patient characteristics are presented in Table I.

IV Fluid Prescription Appropriateness

A total of 260 patients (53.1%) were prescribed an IV maintenance fluid to be administered during the 24 hours following ED admission. Forty-six prescriptions were excluded based on their indication (e.g., drug administration, following a specific protocol), resulting in inclusion of 214 prescriptions for evaluation by the expert panel (PRE: 99, POST: 115). The IV fluid's indication was properly documented in 117 records (54.7%), with a statistically significant increase in the POST-records (44.4% *vs.* 63.5%, p=0.005). The overall appropriateness, as assessed by the experts, resulted in an absolute increase of 42% (PRE: 19.2%, POST: 61.2%, p=0.002). Appropri-

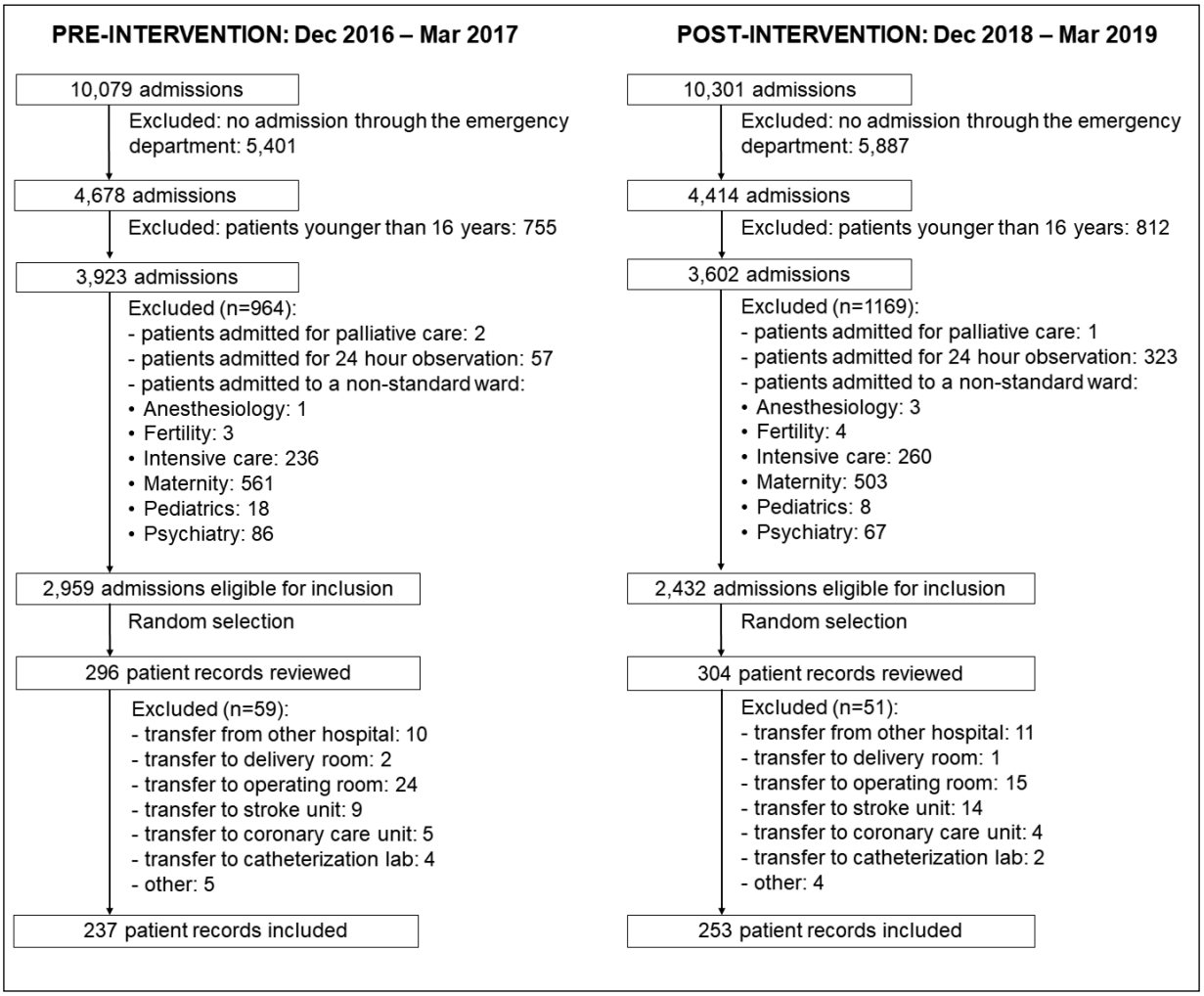

Figure 1. Screening and inclusion process.

Table I. Patients' characteristics.

	PRE (n=237)	POST (n=253)	Total (n=490)
Male sex (n, %)	124 (52.3)	130 (51.3)	254 (51.8)
Age on admission (median, IQR)	69 (36)	70 (34)	70 (36)
Surgical patients (n, %)	114 (48.1)	146 (57.7)	260 (53.1)
Internal medicine patients (n, %)	123 (51.9)	107 (42.3)	230 (46.9)
Prehospital care (n, %)	74 (31.2)	89 (35.3)	163 (33.3)
Time of admission (n, %)			
- 7 AM-2 PM	95 (40.1)	113 (44.7)	208 (42.4)
- 2 PM-8 PM	90 (38.0)	93 (36.8)	183 (37.3)
- 8 PM-7 AM	52 (21.9)	47 (18.6)	99 (20.2)
Time spent in emergency department (median, IQR)	315 (122)	328 (176)	322 (153)
Triage code			
- Blue (<4 hour)	17 (7.2)	12 (4.7)	29 (5.9)
- Green (<2 hours)	87 (36.7)	104 (41.1)	191 (39.0)
- Yellow (<60 min)	118 (49.8)	122 (48.2)	240 (49.0)
- Orange (<10 min)	14 (5.9)	15 (5.9)	29 (5.9)
- Red (immediate consult)	1 (0.4)	0 (0.0)	1 (0.2)

ateness of the fluid type (i.e., an IV fluid containing glucose, sodium, and potassium) and volume also improved significantly in the records of patients admitted in the POST-period (respectively, PRE: 9.1%, POST: 61.2%, $p<0.001$, and PRE: 18.2%, POST: 29.6%, $p=0.033$).

Risk Factor Analysis of Prescription Appropriateness

The logistic regression model was statistically significant ($\chi^2=17.107$, df=5, n=214, $p=0.004$). The model explained 10.9% (Nagelkerke R^2) of the variance in appropriateness and correctly classified 71.0% of cases. The results of the final model of the multivariable logistic regression analysis are shown in Table II. Guideline implementation significantly increased the odds of a more appropriate IV fluid prescription based on expert evaluation [Adjusted Odds Ratio (AdjOR)=2.580; 95% Confidence Interval (CI) 1.363-4.884]. The patients admitted by ambulance, and thus having a prehospital intervention by ED medical caregivers, were also more likely to have an adequate fluid prescription (AdjOR=1.914, 95% CI 1.022-3.586). The admitting discipline (surgery or internal medicine), time spent in the ED, and adequacy of fluid management documentation did not significantly influence prescription appropriateness.

Fluid Management Documentation

Table III shows the PRE-POST evaluation of the documentation of fluid management in the ED. The overall documentation did not significantly improve after the implementation of the intervention ($p=0.858$), neither for the assessment of volume status ($p=0.556$) nor for the evaluation of oral intake ($p=0.730$). In terms of fluid balance documentation, a significant increase was shown in documentation adequacy (PRE: 44.3%, POST: 58.2%, $p=0.002$). The documentation of clinical observations also significantly increased in the POST records (PRE: 40.1%, POST: 56.1%; $p<0.001$).

Table II. Multivariable logistic regression model for the appropriateness of the 24-hour intravenous maintenance fluid prescription.

Risk factors	Adjusted Odds ratio	95% confidence interval	*p*-value
Guideline implementation (intervention)	2.580	1.363-4.884	0.004*
Admitting discipline	0.862	0.462-1.610	0.642
Admission via ambulance	1.914	1.022-3.586	0.043*
Time spent in the emergency department (minutes)	0.998	0.995-1.001	0.120
Adequate documentation of fluid management	1.761	0.746-4.162	0.197
Constant	0.360		.052

*p-value was considered statistically significant when <0.05.

Table III. Results of fluid management documentation.

		PRE (n=237)	POST (n=253)	*p*-value
Fluid status assessment				
Fluid balance (n, %)	Documented	138 (58.2)	112 (44.3)	0.002*
	Not documented	99 (41.8)	141 (55.7)	
Parameters (n, %)	Documented	192 (81.0)	211 (83.4)	0.490
	Not documented	45 (19.0)	42 (16.6)	
Observations (n, %)	Documented	95 (40.1)	142 (56.1)	<0.001*
	Not documented	142 (59.9)	111 (43.9)	
Laboratory values (n, %)	Documented	206 (86.9)	224 (88.5)	0.585
	Not documented	31 (13.1)	29 (11.5)	
Total records (n, %)	Adequate	60 (25.3)	70 (27.7)	0.556
	Not adequate	177 (74.7)	183 (72.3)	
Evaluation of oral intake				
Intake (n, %)	Documented	164 (69.2)	182 (71.9)	0.506
	- (Ab)normal	104 (43.9)	90 (35.6)	
	- Nil-by-mouth	60 (25.3)	92 (36.4)	
	Not documented	73 (30.8)	71 (28.1)	
Nausea or vomiting (n, %)	Documented	125 (52.7)	126 (49.8)	0.515
	- Present	51 (21.5)	51 (20.2)	
	- Not present	74 (31.2)	75 (29.6)	
	Not documented	112 (47.3)	127 (50.2)	
Total records (n, %)	Appropriate	91 (38.4)	101 (39.9)	0.730
	Not appropriate	146 (61.6)	152 (60.1)	
Overall documentation (n, %)	Appropriate	37 (15.6)	41 (16.2)	0.858
	Not appropriate	200 (84.4)	212 (83.8)	

*p-value was considered statistically significant when <0.0056.

Discussion

In this single-center retrospective study, the impact of an educational intervention focusing on fluid management in non-critically ill adult patients was evaluated on IV fluid prescription appropriateness and documentation practice in the ED. The appropriateness of IV maintenance fluids prescribed by emergency physicians improved significantly after the guideline was implemented. Unfortunately, the documentation of fluid management did not improve after the guideline was implemented.

The Institute of Health Improvement recommends the implementation of care bundles to reduce care variations and increase patient safety[22]. Nevertheless, the level of evidence of the effect on clinical outcomes following care bundle implementation is still low because few randomized controlled trials have been performed in this domain[23]. Concerning fluid management, McDougall et al[24] did not find an effect on iatrogenic electrolyte disturbances or acute kidney failure occurrence. When chosen incorrectly, IV fluids can cause fluid overload and influence disease severity, requiring a thorough volume status assessment[25,26]. Every patient should be evaluated individually by the clinician, taking into account risk factors linked to a decompensated fluid status, electrolyte imbalances, and other complications associated with hospitalization. An important aspect is the nutritional intake evaluation, that starts in the ED[19]. If patients can feed themselves enterally, IV catheters can be avoided. These catheters inserted at the ED have a high likelihood of becoming idle after 24 hours (OR 2.4; 95% CI 1.7-3.3)[27], which increases the risk for healthcare-related complications[28]. A second

important aspect regards other drugs given to the patient. Fluid overload can arise when drugs are administered intravenously and diluted in an infusion bag, resulting in additional sources of fluids and electrolytes, the so-called fluid creep[29]. Pharmacodynamic effects of administered medication to the patient can also affect fluid and electrolyte status[17]. Overall, numerous factors have to be considered to establish causality between inappropriate IV fluid prescribing and certain adverse drug events, rendering this kind of real-world studies very challenging.

It is essential to know when to prescribe an IV fluid, how much, and for how long, depending on the patient's characteristics. In contrast to similar studies reporting on fluid management improvement projects[11,30,31], the presented audit results show a significant increase of 42% in prescription appropriateness. This result shows that interventions, such as the one described in this study, provide an opportunity to close the existing knowledge gap on IV fluid therapy.

Despite the efforts for guideline implementation, the documentation of fluid management in the ED patient record did not improve. However, there was a significant increase in the documentation of fluid balance and clinical observations, as well as the IV fluid's indication in the reviewed patient files. Similar quality improvement initiatives have shown outcomes consistent with our results after hospital-wide implementation of a fluid guideline[11,12,30,31]. As documentation appears challenging, a redesign of the electronic dossier charts into a 'fluid plan' can be considered to optimize documentation practice further[31]. Since patients only spend a short time in the ED, a well-documented fluid plan can enhance physicians' and nurses' time efficiency in terms of patient assessment and monitoring (e.g., blood sample analyses and body weight measurements) by providing a standardized workflow. There are currently no indications in the literature that such a plan is associated with better patient outcomes. Nonetheless, the impact of additional documentation on the physician and nurse workload should be carefully evaluated.

Improving fluid management in the ED, and by extension the hospital, is a multidisciplinary matter. Besides physicians and nurses, the integration of a clinical pharmacist in wards, such as the ED, can be of value to further improve IV fluid use. Pharmacist interventions have the potential to be cost-effective as well[32]. A quality program that critically evaluates the use of these fluids can help to identify and understand real-world issues in clinical practice and to acquire knowledge on their application in specific high-risk patients. Fluid stewardship programs are thus a valuable addition to the hospital to ensure patient safety concerning IV fluids, and to guide physicians with practical and evidence-based guidelines[33].

Limitations

This study was performed in the ED of a university hospital. This may limit the generalizability of the results to other settings because there is a high turnover of physicians in training and, consequently, high educational needs. This requires frequent training on the fluid guideline's content. Data collection was performed by manual retrospective chart review, which may result in missing data and, therefore, affect the expert panel's assessment of prescription appropriateness. To address this concern, the experts reached a consensus after reviewing the electronic patient file through a comprehensive discussion. However, the review was not performed blinded to the intervention, increasing the risk of observer bias. A third limitation was identified in the screening period. A post-period of four months after guideline implementation was set to evaluate the direct impact of the guideline on daily practice due to feasibility reasons. Ideally, educational efforts should be repeated in a timely manner, as well as guideline dissemination, to ensure full dissemination to the emergency physicians' daily practice. Due to the COVID outbreak in 2020, causing a temporary reorganization of the ED workflow, the long-term effect of guideline content on prescription appropriateness in the ED could not be determined, and it was not possible to repeat any educational initiatives.

Conclusions

Implementation and evaluation of care bundles come with several challenges. As a consequence of fluid guideline implementation, a significant increase in IV fluid prescription appropriateness was identified, which may potentially decrease the patient's susceptibility to adverse events. However, the documentation quality of fluid management was poor in the studied ED records, and a fluid plan in the electronic patient file can be required to allow adequate and standardized follow-up by physicians and nurses. Subsequently, active fluid stewardship programs are warranted

to further monitor fluid management and identify areas of concern in the ED, but also in other departments, by performing audits in a timely manner. In addition, these multidisciplinary teams can educate physicians on the importance of volume status assessment, oral intake evaluation, and fluid prescription for all admitted patients to avoid fluid-related harm.

Conflict of Interest
SW was given a congress fee by Fresenius Kabi NV in 2022. The other authors declare that they possess no relevant competing interests.

Ethics Approval
The Committee of Medical Ethics of the Universitair Ziekenhuis Brussel, Belgium, obtained ethical approval for this study (approval number: B.U.N. 1432020000235).

Informed Consent
Informed consent was waived due to the retrospective nature of the study.

Acknowledgments
The authors would like to thank the hospital's Pharmacy and Therapeutics Committee for the critical review of the fluid guideline and follow-up of the implementation. The authors would also like to thank Door Lauwaert for his semi-automated data collection support during the project.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' Contributions
SW, SS, IH and PC were involved in the conceptualization of this study. SW, SS, MV and SV collected the data. SW prepared the manuscript, supervised by AD and PC. All authors approved the final manuscript.

Data Availability
The datasets generated during and/or analyzed during the current study are not publicly available due to sensitivity reasons but are available from the corresponding author upon reasonable request.

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