

ORIGINAL STUDIES ORIGINALNI NAUČNI RADOVI

THE BURDEN OF FLUID CREEP IN THE EARLY POSTOPERATIVE PERIOD AFTER ELECTIVE SURGERY IN PATIENTS REQUIRING ADMISSION TO THE INTENSIVE CARE UNIT

ZNAČAJ TEČNOSTI KOJE SE KORISTE ZA RASTVARANJE LEKOVA U RANOM POSTOPERATIVNOM PERIODU NAKON ELEKTIVNE HIRURGIJE KOD PACIJENATA KOJI ZAHTEVAJU PRIJEM U JEDINICU INTENZIVNE NEGE

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Abstract

Introduction. Fluid creep refers to intravenous fluids used in every critically ill patient as part of routine care, including fluids administered as vehicles for medication or electrolytes, or small volumes used to keep venous lines open. It represents an additional and often unrecognised source of fluid and electrolyte load. We aimed to quantify and characterise fluid creep in our surgical Intensive Care Unit and determine its contribution to water, sodium, and chloride burden. **Material and Methods.** This prospective observational study was conducted at the University Clinical Center of Vojvodina over 60 days. A total of 53 patients undergoing elective surgery and requiring at least 48 hours of postoperative intensive care were included. Daily fluid creep volume and composition were recorded, and the electrolyte load was calculated using manufacturer-reported sodium and chloride concentrations. **Results.** The only fluid used for fluid creep was 0.9% sodium chloride. Fluid creep accounted for 19% of total daily fluid volume on postoperative day 0 and 24% on postoperative day 1. Its contribution to total sodium and chloride load increased from 17% to 30%. After 48 hours, B-lines on lung ultrasound and peripheral oedema were observed in 51% of patients. **Conclusion.** Fluids used as drug vehicles represent a substantial proportion of total intravenous fluid administration and significantly contribute to sodium and chloride load. Recognition of fluid creep may improve fluid management in postoperative intensive care patients.

Key words: Postoperative period; Intensive Care Units; Infusions; Intravenous; Fluid Therapy; Water-Electrolyte Balance; Sodium Chloride; Drug Carriers; Drug Administration Routes; Pulmonary Edema

Introduction

Postoperative fluid and electrolyte management is a key component of perioperative care. Individual-

Sažetak

Uvod. Tečnosti za rastvaranje lekova predstavljaju intravenske tečnosti koje se rutinski primenjuju kod svih kritično obolelih bolesnika i obuhvataju tečnosti koje se koriste kao rastvarači za lekove i elektrolite, kao i manje zapremine namenjene održavanju prohodnosti venskih linija. Predstavljaju dodatni i često neprepoznat izvor unosa tečnosti i elektrolita. Cilj studije bio je kvantifikovati i kvalifikovati količinu i vrstu prepisanih tečnosti za rastvaranje lekova u našoj hirurškoj jedinici intenzivne nege, kao i odrediti njihov doprinos ukupnom opterećenju vodom, natrijumom i hloridima. **Materijal i metode.** Ova prospektivna opservaciona studija sprovedena je u Univerzitetском kliničkom centru Vojvodine tokom 60 dana. Uključena su 53 bolesnika podvrgnuta elektivnim operacijama što je zahtevalo najmanje 48 sati postoperativnog lečenja u Jedinici intenzivnog lečenja. Dnevni volumen i sastav tečnosti za rastvaranje lekova su beleženi, a unos elektrolita putem ovih tečnosti izračunat je na osnovu koncentracija natrijuma i hlorida koje je naveo proizvođač. **Rezultati.** Jedina intravenska tečnost koja je korišćena u ovu svrhu bio je 0,9% natrijum-hlorid. Tečnosti za rastvaranje lekova činile su 19% ukupnog dnevnog unosa intravenskih tečnosti nultog postoperativnog dana i 24% prvog dana. Njihov udeo u ukupnom unosu natrijuma i hlorida povećao se sa 17% na 30%. Nakon 48 časova, B-linije na ultrazvuku pluća i periferni edemi registrovani su kod 51% bolesnika. **Zaključak.** Tečnosti koje se koriste kao rastvarači za lekove čine značajan deo ukupne intravenske terapije i značajno doprinose unosu natrijuma i hlorida. Prepoznavanje značaja ovih tečnosti može unaprediti njihovu preskripciju kod postoperativnih bolesnika u Jedinici intenzivnog lečenja.

Cljučne reči: postoperativni period; jedinice intenzivne nege; intravenske infuzije; terapija tečnostima; balans vode i elektrolita; natrijum hlorid; nosači lekova; putevi primene leka; plućni edem

ised administration of intravenous fluids is essential to maintain adequate circulating volume and organ perfusion [1].

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Abbreviations

IV fluids	– intravenous fluids
IFA	– International Fluid Academy
NICE	– National Institute for Health and Care Excellence
ERAS	– enhanced recovery after surgery
GIFTASUP	– Guidelines for Intravenous Fluid Therapy in Adult Surgical Patients
ICU	– Intensive Care Unit
SAPS II	– Simplified Acute Physiology Score
CCI	– Charlson Comorbidity Index

Concepts of rational fluid administration and fluid stewardship emphasise appropriate prescription and avoidance of fluid overload [2]. Perioperative and critical care fluid strategies are further guided by international recommendations such as the International Fluid Academy (IFA) consensus [3], as well as structured principles of fluid management including the “four D’s” and phases of fluid therapy [4], and classification into resuscitation, replacement, maintenance, and nutrition fluids [5].

Current perioperative fluid strategies are also defined by established guidelines such as ERAS, NICE, and GIFTASUP, which primarily emphasise resuscitation and maintenance fluids [6–8]. However, these frameworks do not sufficiently address less apparent sources of fluid administration, such as drug diluents and other ancillary fluids.

These additional inputs, collectively referred to as *fluid creep*, are intravenous (IV) fluids not prescribed for resuscitation or maintenance and include fluids used as medication vehicles, for line flushing, and for intravenous catheter maintenance. Although often considered negligible, they may significantly contribute to cumulative fluid and electrolyte load, particularly sodium and chloride, with potential clinical consequences such as fluid overload and tissue oedema [9–11].

Data on the contribution of fluid creep to postoperative electrolyte load in surgical Intensive Care Unit (ICU) patients remain limited. The primary aim of this study was to quantify fluid creep as a proportion of total intravenous fluid administration and to characterise the types of fluids contributing to it. The secondary aim was to assess its contribution to sodium and chloride load as well as its association with clinical signs of fluid overload.

Material and Methods

Study design and population

This prospective observational study was conducted at the University Clinical Center of Vojvodina, ICU, from February to April 2024. A total of 62 adult patients undergoing elective surgical procedures who required immediate postoperative ICU admission were assessed for eligibility. Patients were eligible for

inclusion if they required postoperative ICU stay for at least 48 hours. Nine patients were excluded from the study: two due to the need for renal replacement therapy, one due to death, four due to parenteral nutrition, and two because of an ICU stay shorter than 48 hours. Therefore, 53 patients were included in the final analysis.

The study was approved by the institutional Ethics Committee (No. 00-2012).

Data collection

Patient data were retrieved from medical records and the institutional electronic clinical information system.

Baseline data

Demographic data, surgical type, SAPS II score, and Charlson Comorbidity Index (CCI) were recorded.

Type and amount of intravenous fluids

The type and volume of IV fluids prescribed to each patient were retrieved from medical records. Data were collected on day 0 and postoperative day 1. Day 0 was defined as the day of the patient’s ICU admission (immediately following admission), and postoperative day 1 as the following day. All data were collected according to the research protocol. Each administered fluid was categorised as either a maintenance fluids or a fluid creep. Fluid creep was defined in this study as all non-resuscitation, non-maintenance intravenous fluids administered as drug diluents, carrier solutions, or for line flushing, including fluids co-administered with medications.

Sodium and chloride load calculation

Sodium and chloride loads were calculated by multiplying the administered volume for each IV fluid by the corresponding electrolyte concentrations reported by the manufacturer or previously published data [12].

Assessment of fluid overload

Peripheral oedema was assessed clinically by physical examination and recorded as present or absent. Lung ultrasound (LUS) was performed using a linear probe (6–12 MHz) to assess eight lung zones according to standardised protocols. B-lines were recorded in each zone, and the presence of more than three B-lines per zone was classified as pathological. Examinations were performed 24 hours and 48 hours after ICU admission [13].

Statistical analysis

Statistical analysis was performed using SPSS version 27, STATISTICA version 12, and Microsoft Excel. Descriptive statistics were used to summarise the data.

Continuous variables were expressed as mean $\pm$ standard deviation or median (interquartile range), depending on data distribution, while categorical variables were presented as frequencies and percentages. The primary outcome was the proportion of fluid creep in the total fluid intake. Secondary outcomes included sodium and chloride load, as well as clinical signs of fluid overload. Results were presented in tables and figures. A p-value < 0.05 was considered statistically significant.

Results

A total of 53 patients were included. Patient characteristics are presented in **Table 1**.

Most patients were male (66%), whereas females accounted for 34% (n = 18). Most patients (70%) were older than 65 years, with a mean age of 67.2 years (range, 44–77). The mean body mass index (BMI) was 25.63 kg/m².

Vascular surgery was performed in 68% of patients, while 32% underwent abdominal surgery. The mean SAPS II score was 30, and the median Charlson Comorbidity Index was 4.

Total daily fluid intake was 3971 $\pm$ 857 mL on day 0 and 3890 $\pm$ 731 mL on postoperative day 1 (p > 0.05) (**Table 2**).

The proportion of fluid creep was 19% on day 0 and 24% on postoperative day 1 (p > 0.05) (**Figure 1A**).

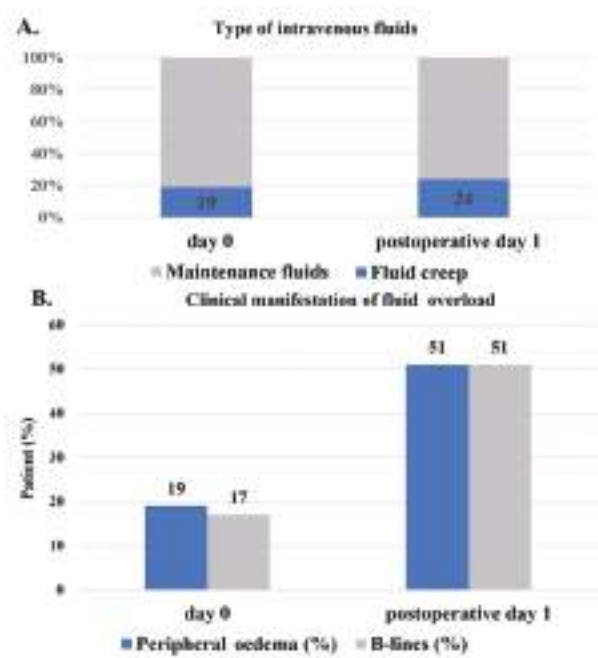


Figure 1. (A) Relative contribution of maintenance fluids and fluid creep on day 0 and postoperative day 1. (B) Changes in clinical parameters, including peripheral oedema and B-lines on lung ultrasound. Increased fluid creep was associated with worsening clinical findings.

Over the first 48 hours, fluid creep accounted for 21.6% of cumulative intravenous fluid intake.

Intravenous fluids administered as vehicles for medications accounted for the majority of fluid creep

Table 1. Demographic and clinical characteristics of patients

Demographic and clinical data (n=53)	
Male (n)	35 (66%)
Age (years)	Mean 67.2 (range 44-77)
BMI (kg/m ²)	25.63
Age > 65 years (n, %)	37 (70%)
Type of surgery (n,%)	Abdominal 17 (32%) Vascular 36 (68%)
SAPS II (points)	30
CCI (points)	5

Data are presented as mean values, numbers or percentages. body mass index; Simplified Acute Physiology Score; Charlson Comorbidity Index.

Table 2. Detailed fluid composition with fluid creep separately analysed as a distinct component of total intravenous fluid administration

Fluid composition	DAY 0 (mL, %)	POD 1 (mL, %)
Maintenance fluids IV	3216 (81%)	2956 (76%)
Fluid creep (total) IV	755 (19%)	934 (24%)
1. vehicles for IV medications	551 (73%)	645 (69%)
2. IV fluids co-administered with analgesics	204 (27%)	289 (31%)
Total IV fluids	3971 $\pm$ 857	3890 $\pm$ 731

Data are presented as mean values in millilitres and percentages. Total values are expressed as mean $\pm$ standard deviation in millilitres; DAY 0 – day of admission to the Intensive Care Unit, postoperative day 1.

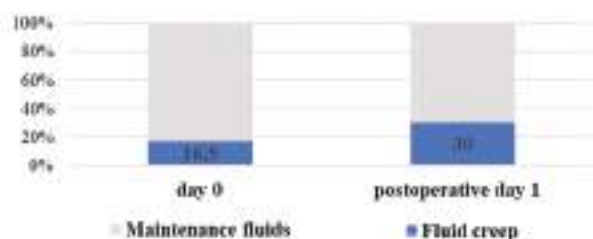


Figure 2. Relative contribution of fluid creep to total sodium and chloride load on day 0 and postoperative day 1

(73% and 69%, respectively), with 0.9% NaCl as the predominant diluent. The remaining proportion consisted of fluids co-administered with analgesics, including those that did not require dilution (**Table 2**).

On day 0, maintenance fluids were the primary source of sodium and chloride (83.1%), whereas fluid creep accounted for 16.9%. On postoperative day 1, the contribution of maintenance fluids decreased to 70%, while that of fluid creep increased to 30% of total electrolyte intake ($p < 0.05$) (**Figure 2**).

Peripheral oedema was present in 19% of patients on postoperative day 0 and in 51% on postoperative day 1 ($p < 0.05$). B-lines on lung ultrasound were observed in 17% of patients on postoperative day 0 and in 51% on postoperative day 1 ($p < 0.05$) (**Figure 1B**).

Discussion

This study suggests that fluid creep may represent a relevant and increasing component of postoperative fluid and electrolyte administration. Although total daily fluid intake did not change significantly between day 0 and postoperative day 1, the composition of administered fluids shifted, indicating that sources of fluid and electrolyte intake may be more important than total volume alone. Similar observations have been reported in other studies, where fluid creep has been shown to contribute significantly to overall intravenous fluid intake, highlighting its often under-recognised role in fluid management [14,15].

The observed increase in the contribution of fluid creep to electrolyte intake in our cohort (from 16.9% to 30%) further supports the concept that fluid creep is a dynamic and progressively important determinant of postoperative electrolyte load. These findings are in line with previous reports indicating that both maintenance fluids and fluid creep contribute substantially to sodium and chloride burden in hospitalised and critically ill patients [14–16].

The predominant use of 0.9% sodium chloride as a drug diluent likely contributed to the increased exposure to sodium and chloride observed in our patients. In our cohort, the majority of fluid creep originated from drug vehicle administration using

saline-based solutions. Although only a limited number of medications require saline dilution, its widespread use appears to be driven more by routine clinical practice than by strict necessity [17–19]. A practical approach to reducing unintended fluid and electrolyte loading from fluid creep involves more thoughtful selection and use of drug diluents. Instead of routinely used 0.9% sodium chloride, compatible alternatives such as 5% dextrose can be used to excess chloride and sodium intake significantly [20,21].

Additionally, the use of more concentrated drug preparations, when clinically appropriate, may reduce the volume of diluents required. Minimising the volumes used for drug infusions and catheter flushing, together with regular review of maintenance fluid prescriptions, may further help limit unnecessary fluid administration. Considering all sources of intravenous fluids in routine clinical practice could reduce fluid and electrolyte burden [15,16].

Importantly, the increase in fluid and electrolyte burden was accompanied by clinical signs of fluid accumulation. Excessive administration of sodium- and chloride-rich fluids may contribute to positive fluid balance, tissue oedema, pulmonary congestion, impaired organ function, and delayed recovery [10,11]. Raising awareness of hidden fluid sources and refining intravenous medication administration could be straightforward, cost-effective ways to manage fluids better and potentially improve patient outcomes. In our patients, peripheral oedema increased from 19% to 51% over 48 hours, while the prevalence of pathological B-lines on lung ultrasound increased from 17% to 51%.

B-lines on lung ultrasound are a sensitive marker of increased extravascular lung water. They may suggest pulmonary congestion in the appropriate clinical context, although they are not specific for fluid overload [21–23].

However, owing to the observational design of the study, causality between fluid creep and the observed clinical findings cannot be established, and the results should be interpreted as an association.

This study has several limitations, including a relatively small sample size and its observational design, which preclude establishing causal relationships between fluid creep and clinical outcomes at the individual patient level.

Conclusion

In this study, intravenous fluids used for drug dilution accounted for nearly one quarter of total intravenous fluid administration, representing a substantial and often under-recognised source of fluid and electrolyte load.

Fluid creep was identified as a clinically relevant and potentially modifiable contributor to perioperative fluid burden. Rational selection of diluent fluids may reduce sodium and chloride exposure and help

mitigate fluid-related complications in postoperative patients, and should be considered in perioperative fluid management protocols.

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