Point-of-care ultrasound (POCUS) in acute hospitalized older patients focused on hydration

Vladimir Hrabovsky[1,2], Martina Skrobankova[1,2], Zdenek Lys[1,2] Adela Vrtkova[3,4], Veronika Spacilova[1,2], Jan Vaclavik[1,2]

Background. Acutely ill older patients frequently suffer not only from their acute disease, but also polymorbidity and frailty. Dehydration is another typical symptom, usually occurring in its both forms: low-intake dehydration and volume depletion. POCUS is goal-directed bedside ultrasound examination and several studies refer to its positive impact on hydration assessment. The aim of our study was to determine whether POCUS might influence (de)hydration diagnostics and/or treatments in older patients with acute illness.
Methods. We randomized 120 acutely ill patients, aged ≥65 years, into POCUS and non-POCUS groups. All participants underwent routine laboratory tests, including haematocrit, serum and urine osmolality, blood urea nitrogen (BUN), creatinine, BUN/creatinine ratio, and C-reactive protein (CRP). POCUS was performed twice during the first two days to determine chest and abdominal status, with inferior vena cava (IVC) measurements. Length of hospital stay (HL) and consumption of infused fluids (CIF) was evaluated too. Data were analysed with exploratory methods and appropriate statistics.
Results. Among all participants, the serum osmolality significantly correlated with age, BUN, creatinine and CIF. HL correlated with CRP and CIF. No significant correlations between IVC and other followed parameters were found. The POCUS group consumed significantly less infused fluids than the non-POCUS group, what could be influenced by POCUS examination of defined body compartments.
Conclusion. Dehydration is a common feature in older individuals and its diagnostics is rather complicated. The role of POCUS in assessing hydration status remains unclear. However, our study showed, that ultrasound assessment provides next important information for comprehensive understanding of clinical status in older patients and can be beneficial for optimizing the treatment strategy, including fluid management decisions.

Key words: point of care ultrasound, geriatrics, dehydration, volume depletion, inferior vena cava

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[1]*Department of Internal Medicine, University Hospital Ostrava, Ostrava, Czech Republic*
[2]*Faculty of Medicine, University of Ostrava, Ostrava, Czech Republic*
[3]*Department of Deputy Director of Science and Research, University Hospital Ostrava, Ostrava, Czech Republic*
[4]*Department of Applied Mathematics, Faculty of Electrical Engineering and Computer Science, VSB – Technical University of Ostrava, Czech Republic*
Corresponding author: Martina Skrobankova, e-mail: martinaskrobankova@email.cz

INTRODUCTION

Point-of-care ultrasound (POCUS) is defined as a goal-directed, bedside ultrasound (US) examination. POCUS is performed by health care providers to answer a specific diagnostic question or to guide the performance of an invasive procedure[1]. US is non-invasive, and with portable US equipment, is possible to perform examinations directly at the patient's bedside.

An older patient is typically defined as an individual aged 65 years or over. However, in the presence of chronic diseases, particularly sarcopenia, older patients are not strictly defined by age. In the context of an acute illness, frailty is associated with an increased risk of complications and poor outcomes[2]. Moreover, during hospitalization, polymorbidity typically requires frequent transports across the hospital for examinations. These frequent disruptions in normal fluid and food intakes and the separation from a customary social environment can have a negative impact on health conditions.

The present study aimed to assess the importance of POCUS in older patients hospitalized with acute conditions. We focused mainly on hydration, because dehydration is a common feature in these patients, and it is closely connected with increased mortality[3]. Subsequent excessive fluid infusion therapy can lead to hypervolemia or heart failure. Therefore, it remains a challenge to find the optimal method for performing diagnostics, monitoring, and safe corrections in patients with dehydration. Moreover, both types of dehydration (low-intake dehydration and volume depletion) have limited possibilities of identification[4].

The purpose of our study was to determine whether POCUS might influence (de)hydration diagnostics and/or treatments in acute ill older patients.

PATIENTS AND METHODS

This prospective randomised clinical trial was approved by the Ethics Committee of the University Hospital Ostrava. All participants provided informed consent. We included 120 adult patients, aged ≥65 years, that were hospitalized with an acute illness in the Internal Department of the University Hospital Ostrava. We enrolled all patients admitted during the year 2020, except specific periods in the spring and autumn, due to COVID-19 pandemic restrictions. Patients were ineligible, when they were admitted to the intensive care unit, had planned examinations, or required palliative care.

Routine laboratory tests were carried out for all patients immediately on admission, and tests were repeated as needed. During hospitalization, the patients underwent all required examinations, and they were treated in accordance with their initial and subsequent diagnoses. For each patient, we recorded: haematocrit, serum and urine osmolality, serum levels of blood urea nitrogen (BUN), creatinine, the BUN/creatinine ratio, C-reactive protein (CRP), the length of hospital stay (HL) and consumption of infused fluids (CIF). The CIF was evaluated during the first 48 h (CIF48) and during the entire hospitalization period (CIFtotal). We also calculated the CIF per day of hospitalization (CIF/day).

Patients were initially randomized to two groups: the POCUS group and the non-POCUS group. CONSORT flow diagram is presented in the figure (Fig. 1). The POCUS was performed on the first and second days after admission (LOGIQ V2 US, GE Healthcare) in supine position. Lung examination included images from three points per hemithorax: anterior upper and lower points and PLAPS (posterior lateral alveolar pleural space) point. The findings were divided into three (A, B, C) profiles. A-profile was defined by A-lines, lung sliding and curtain sign at the lung bases, B-profile by three or more hyperechoic B-lines, also called lung comets, in a single rib interspace and C-profile by irregular pleural line with hypoechoic subpleural focal images, generated by lung condensation. Subsequently presence of pericardial, pleural or peritoneal fluid and basic liver, biliary and kid-

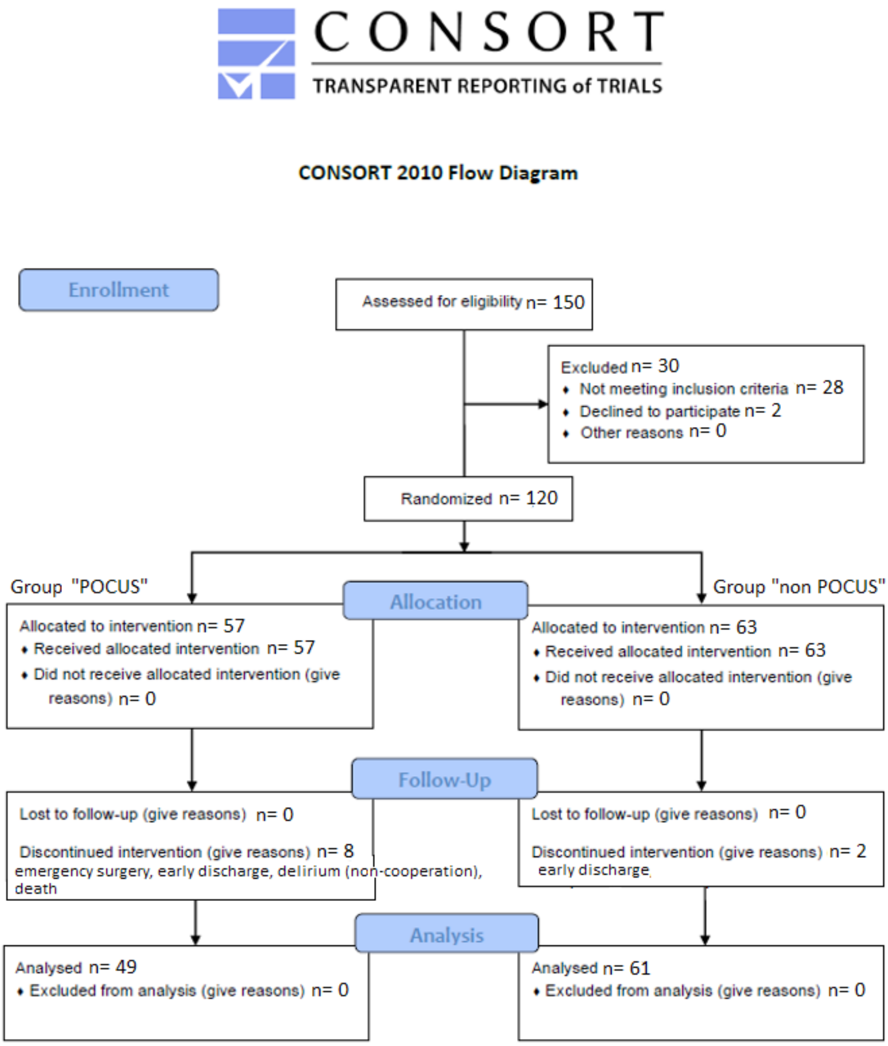

Fig. 1. Consort flow diagram, 2010. Available online from: https://www.evscienceconsultant.com/blog/flowchart-of-your-study, 29th May 2023.

ney abnormalities were assessed. Inferior vena cava (IVC) inspiratory and expiratory diameters with collapsibility index (IVC-CI = [expiratory diameter – inspiratory diameter]/expiratory diameter) were measured in subxiphoid long axis position during quiet respiratory cycle, 2 cm from the junction of IVC and right atrium (M-mode). Measurement was repeated twice and average was used. US-examiners were specialists with licence and not attending physicians. They were blinded to the laboratory results and carried out only examination with conclusion and recommendation, according to the US finding. US images except IVC diameters were not statistically assessed.

Simple randomization was performed with computer generated sequence of random assignments of patients to two defined groups. A third independent person, who does not work at the given workplace had the materials for randomization. Categorical variables are presented as the absolute and relative frequencies (%). Numerical variables are expressed as the median and interquartile range (IQR). We compared groups with an appropriate statistical test – the Mann-Whitney test or the Chi-square test for independence. The relationship between two numerical variables was evaluated with Spearman's rank correlation coefficient and its test of significance. The significance of the change in selected parameters over time was tested with the paired Wilcoxon test. The significance level was set to 0.05. All statistical analyses were performed with R software (version 4.0.3, www.r-project.org).

RESULTS

This study included 120 patients: 46 males (38.3%) and 74 females (61.7%), with a median age of 78 years. The POCUS group included 57 patients, and the non-POCUS group included 63 patients. The CIF48 was significantly lower in the POCUS group than in the non-POCUS (*P*=0.036). No other significant differences were found between groups (Table 1).

Among all patients, we found significant, positive correlations between age, serum osmolality, BUN, and the BUN/creatinine ratio (Fig. 2). In addition, the CIF48 and CIF/day were significantly positively correlated with the haematocrit and CRP, and negatively correlated with serum osmolality. The CRP was positively correlated with the HL and the parameters for the consumption of infused fluids.

In the POCUS group (n=57) free fluid was detected in the pleural, pericardial or abdominal cavity twice, once and three times, respectively. Lung imaging results were classified as physiologic in 44 patients, B-profile in 12 patients, and consolidation in 1 patient. The median time

Table 1. Summary characteristics of older participants evaluated with or without POCUS.

Characteristic	Total (n=120)	POCUS (n=57)	Non-POCUS (n=63)	*P*[b]
Demographics				
Sex				
Male	46 (38.3)	23 (40.4)	23 (36.5)	0.807
Female	74 (61.7)	34 (59.6)	40 (63.5)	
Age, y				
Total	78 (71; 82)	78 (72; 83)	77 (71; 82)	0.844
Male	78 (72; 81)	78 (73; 82)	76 (72; 81)	0.441
Female	78 (71; 84)	77 (71; 85)	78 (71; 83)	0.724
Laboratory data				
HT	0.37 (0.32; 0.40)	0.37 (0.32; 0.40)	0.37 (0.33; 0.40)	0.494
S-osmol (mmol/kg)	287.0 (277.0; 295.0)	288.0 (283.0; 298.0)	285.0 (273.0; 293.0)	0.101
U-osmol (mmol/kg)	413.0 (337.5; 561.5)	423.0 (335.0; 568.0)	401.0 (342.2; 560.0)	0.704
BUN (mmol/L)	7.1 (5.1; 11.1)	7.0 (4.9; 12.8)	7.7 (5.3; 10.8)	0.975
Creatinine (μmol/L)	94.0 (73.0; 143.8)	94.0 (73.0; 165.0)	94.0 (73.0; 136.5)	0.775
BUN/creatinine ratio	73.2 (60.2; 89.7)	75.3 (60.3; 91.0)	73.0 (60.1; 88.2)	0.789
CRP (mg/L)	20.1 (4.5; 103.4)	26.7 (3.9; 107.0)	17.8 (5.4; 93.8)	0.838
HL (days)	5.0 (4.0; 8.0)	5.0 (4.0; 8.0)	5.0 (4.0; 8.0)	0.935
CIF48 (mL)	2500 (1500; 3700)	2000 (900; 3500)	2800 (1875; 3975)	0.036
CIFtotal (mL)	3700 (2000; 6212)	3000 (1200; 5300)	4500 (2300; 6450)	0.051
CIF/day (mL)	665 (394; 1021)	571 (250; 790)	720 (472; 1100)	0.053

[a]Values are the median and interquartile range or the number (%)

[b] *P*-values were based on the Mann-Whitney test or the Chi-square test of independence.

POCUS, point-of-care ultrasound; HT, haematocrit, S-osmol, serum osmolality, U-osmol, urine osmolality, BUN, blood urea nitrogen, CRP, C-reactive protein, HL, length of hospital stay, CIF48, consumption of infused fluids during the first 48 h, CIFtotal, CIF during entire hospital stay, CIF/day, CIF per day of hospitalization.

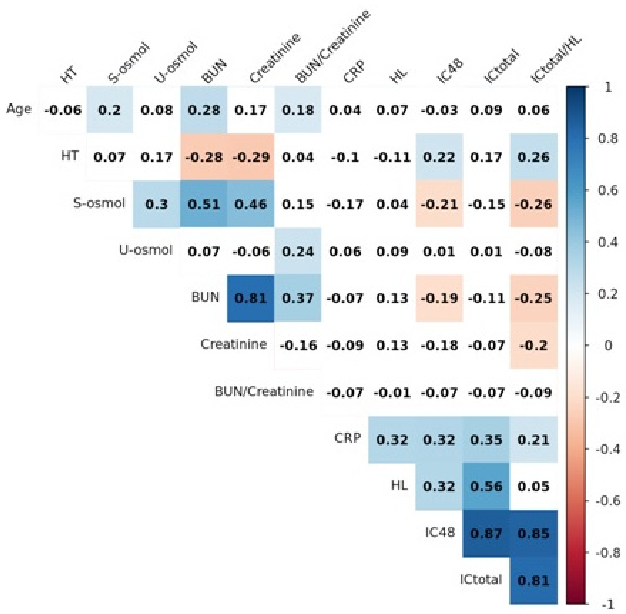

Fig. 2. Correlation matrix shows Spearman's rank correlation coefficients for selected parameters in all patients. Coloured cells indicate a significant correlation ($P<0.05$).

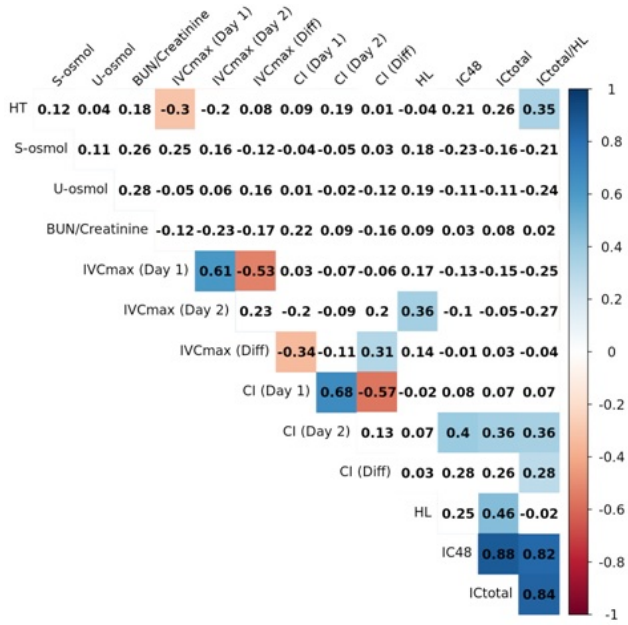

Fig. 3. Correlation matrix with Spearman's rank correlation coefficients for selected parameters for 49 patients in the POCUS group with known data for both examinations.

HT, haematocrit; S-osmol, serum osmolality; U-osmol, urine osmolality; BUN, blood urea nitrogen; CRP, C-reactive protein; HL, length of hospital stay; CIF48, consumption of infused fluids during the first 48 h; CIFtotal, consumption of infused fluids during the entire hospital stay; CIF/day, consumption of infused fluids per day of hospitalization.

to the first US examination was 22 h (IQR: 17–24 h). In this group, we found no correlations between the IVC expiratory diameters or the IVC-CI and the other parameters followed. However, we only acquired complete data in both examinations for 49 patients (Table 2). In this subgroup (n=49), significant correlation only between the IVCmax (day 1) and haematocrit was found (Fig. 3). An increase in the IVCmax diameter correlated with the CIF.

Coloured cells indicate a significant correlation ($P<0.05$). Diff: difference between Day 2 and Day 1; IVCmax, maximum inferior vena cava expiratory diameter; IVC-CI, inferior vena cava collapsibility index; HL, length of hospital stay; CIF48, consumption of infused fluids during the first 48 h; CIFtotal, consumption of infused fluidsduring the entire hospital stay; CIF/day, consumption of infused fluids per day of hospitalization; HT, haematocrit; S-osmol, serum osmolality; U-osmol, urine osmolality.

DISCUSSION

POCUS is defined as a goal-directed, bedside ultrasound examination performed by a health care provider to answer a specific diagnostic question or to guide the performance of an invasive procedure[1]. Ultrasound (US) is non-invasive method, which was dynamically improved during the second half of the 20th century. With a portable ultrasound device, exams can be performed directly at the patient's bedside. POCUS has become an inseparable part of comprehensive examinations for a wide range of patients, including older adults.

An older patient is typically defined as a person aged 65 years and over. However, in the presence of chronic diseases, particularly sarcopenia, older patients are not strictly defined by age. Their examinations are often complicated, uncomfortable, and financially expensive[5].

In the present study, we performed POCUS in 57 patients remained in bed without the need for transfer or repositioning. Examinations included all the parameters commonly examined with X-rays (i.e., pleural fluid, lung consolidation) or with the standard US, in cardiac (pericardial fluid) and abdominal (ascites, organ damage) cavities. In patient with ascites, we also performed POCUS for US guidance, which was previously shown to reduce the risk of complications in paracentesis[6].

Table 2. Inferior vena cava diameters and changes over time for 49 patients in the POCUS group.

Parameter	Day 1	Day 2	Difference (Day 2 – Day 1)	P^a
IVCmax (cm)	1.50 (1.12; 1.89)	1.62 (1.40; 1.83)	0.06 (−0.09; 0.30)	0.079
IVC-CI	0.29 (0.18; 0.54)	0.34 (0.26; 0.51)	0.04 (−0.07; 0.10)	0.227

Values are the median and interquartile range.
IVCmax, maximum inferior vena cava expiratory diameter; IVC-CI, inferior vena cava collapsibility index; [a]*P*-values are based on the paired Wilcoxon test.

Dehydration can be classified into two different types: low-intake dehydration, which is caused by insufficient drinking; and volume depletion, which is due to excess loss of fluid and salts (e.g., due to diarrhoea or vomiting). A third type, usually occurred in geriatrics, could be a combination of these two types[7,8].

Low-intake dehydration (also called intracellular dehydration) is characterized by an elevation in osmolality, in both the intracellular and extracellular compartments. This type of dehydration can be identified by testing the serum or plasma osmolality, and it is defined as >300 mOsm/kg (ref.[4]). We found osmolality levels above this limit in only 21 participants (17%); albeit, during admission, more than half of all participants showed clinical signs of dehydration (e.g., skin turgor, dry mouth, urine colour). On the other hand, it should be emphasized that these clinical signs are not presently recommended for diagnostics[4]. Therefore, we must conclude that few of our patients could be classified as dehydrated due to low intake. Serum osmolality was positively correlated with patient age, creatinine levels and, not surprisingly, urine osmolality.

Volume depletion (also called extracellular dehydration) is characterized by low levels of extracellular fluid, but typically, normal or low serum osmolality levels. Volume depletion can be indicated by an increase in the pulse rate (≥30 beats per minute), when changing position from lying to standing, with or without severe postural dizziness[9]. However, this test has some limitations in older individuals, because it can be affected by physical ability and the use of beta-blockers. Moderate to severe volume depletion is likely in patients with at least four of the following seven signs: confusion, non-fluent speech, extremity weakness, dry mucous membranes, dry tongue, furrowed tongue, or sunken eyes. On the other hand, this diagnostic procedure has not been definitively established[9]. Thus, blood pressure, venous filling, or a US assessment of the IVC may also be useful[10]. The US examination of IVC is performed worldwide for determinations of hypovolemia and fluid intake responsiveness in emergency conditions. We also tried to find some relationships between the IVC parameters and dehydration markers, but results showed only a few significant correlations (Fig. 3). IVC diameters and their increase during the first two days after admission (Table 2) were also insignificant. Interpretation of these findings is rather complicated, because the diameter is influenced by many factors related to the chest and abdomen. In addition, the maximum size of the IVC decreases and the IVC-CI increases with patient age[11]. Orso et al. studied 270 patients with acute illnesses to verify the correlations between the IVC-CI and the expiratory IVC diameter and the blood urea nitrogen (BUN)/creatinine ratio. In their opinion, US was useful for diagnosing dehydration in older individuals[12]. On the other hand, Kaydu et al. studied 35 older adults with hip fractures, and did not find any relationship between bedside US measurements of IVC parameters and the BUN/creatinine ratio. Moreover, the BUN/creatinine ratio was found to be a poor indicator of severe dehydration[13]. Although, in our department, the BUN/creatinine ratio is not used in routine clinical practice, we assessed its importance in the present study. We found that the BUN/creatinine ratio did not correlate with serum osmolality, but correlated with urine osmolality and patient age.

In our opinion one interesting finding was that the POCUS group displayed a significantly lower CIF48 compared to the non-POCUS group (P=0.036; Table 1). We assume that an initial and repeated US examination may have had positive influence on further treatment. US-examiners were not attending physicians and they did not know the laboratory results. It is possible that clinical and laboratory parameters with repeated POCUS findings (IVC measurement, lung images, effusions), as well as their correct interpretation may be beneficial not only for fluid management decisions, but also patient outcomes. However, the length of hospital stay did not differ between the groups in our study.

In summary, POCUS appears to be a highly effective method in many areas of medicine, despite the dubious conclusions of a meta-analysis published recently[14].

The main limitation of this study was the small overall cohort, partly due to the COVID19 pandemic.

CONCLUSION

POCUS is a comfortable method in the complex examination of older patients. Diagnostics of dehydration in elderly is complicated and the role of ultrasound in this process is still unclear. The results of our study corresponded to these known facts. However, significantly lower infusions in patients who underwent the POCUS procedure suggests, that ultrasound can provide important information for optimizing fluid infusions. Repeated examination, especially changes of lung images, effusions and also IVC diameters, which are often controversial, may be useful for further treatment of acute ill older individuals with a potentially positive economic impact.

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Author contributions: VH: study concept and design, manuscript writing; MS: data collection, study design, manuscript writing; ZL: study design, data collection; AV: data analysis, statistical analysis and interpretation; VS: literature search, data collection, manuscript writing; JV: study coordination and design.

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