International Emergency Nursing 57 (2021) 101010

Contents lists available at ScienceDirect

International Emergency Nursing

journal homepage: www.elsevier.com/locate/aaen

# A cross-sectional survey of knowledge pertaining to IV fluid therapy and hyponatraemia among nurses working at emergency departments in Denmark

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ARTICLE INFO

*Keywords:*
Hyponatraemia
Fluid therapy
Intravenous fluids
Administration practice
Nurse
Knowledge

ABSTRACT

*Introduction:* Inappropriate fluid therapy may induce or worsen existing hyponatraemia with potentially life-threatening consequences. Nurses have an important role in assisting physicians in IV fluid prescribing. However, research is lacking in Denmark about nurses' knowledge pertaining to IV fluid therapy and hyponatraemia.
*Methods:* An explorative cross-sectional survey was performed among Danish emergency department nurses in Spring 2019. Knowledge about IV fluid therapy was assessed for three common clinical scenarios, and multiple-choice questions were used to measure knowledge about hyponatraemia.
*Results:* 112 nurses responded to all scenario questions corresponding to 6.2% (112/1815) of the total population of nurses working at emergency departments in Denmark. In two of the three scenarios, a minority of nurses (8–10%) inappropriately selected hypotonic fluids. Nearly one third (31%) selected a hypotonic fluid for a patient with meningitis, which is against guideline recommendations. The study revealed limited knowledge about severe symptoms of hyponatraemia, patients at high risk, and hyperglycaemia-induced hyponatraemia.
*Conclusion:* In accordance with guideline recommendation, the majority of nurses did not select hypotonic fluids in three clinical scenarios commonly encountered in the emergency department. However, when setting up an educational program, further awareness is needed regarding symptoms of hyponatraemia, high-risk patients, and hyperglycaemia-induced hyponatraemia.

## 1. Introduction

Administering intravenous (IV) fluids containing water, electrolytes, and glucose is one of the most common therapeutic interventions performed in the emergency department (ED) [1]. IV fluids are used to treat frequent conditions such as hypovolaemia, dehydration and electrolyte imbalance, and for maintaining fluid balance [2]. In a growing number of countries, nurses are legally permitted to prescribe selected medications [3,4]. Generally, in Denmark, IV fluids are prescribed by a physician, and only in special cases may the responsibility of initiating specific fluids be delegated to nurses [5]. Although nurses generally are not responsible for determining what IV fluid is appropriate for the patient, they play a vital role in assisting and ensuring appropriate IV fluid therapy. Nurses observe the patient, monitor patient parameters, and administer medicine. They collect and evaluate data obtained from multiple sources throughout the day, and based on these observations, the physician prescribes medication, including IV fluids. Also, nurses may be the first to initiate timely responses if complications occur as they are the first to encounter patients. Therefore, nurses should be aware of indications, contraindications, and adverse drug reactions.

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https://doi.org/10.1016/j.ienj.2021.101010
Received 10 July 2020; Received in revised form 17 March 2021; Accepted 4 April 2021
Available online 14 June 2021

Considering the increasing pressure on the health system due to ageing populations, as well as the general trend of nurses taking up tasks from the medical profession [6,7], the nurses' role in IV fluid therapy is expected to be even more important in the future.

Intravenous fluid therapy is often seen as routine, which prevents health professionals from fully recognising the risks associated with it [8]. Intravenous fluids are medicines, and like any other medicinal product, they can have serious and even fatal consequences if not prescribed and administered correctly. One of the serious adverse effects of IV fluids is hyponatraemia (plasma sodium (P-Na) < 135 mmol/L) caused by inappropriate therapy with hypotonic fluids [9]. Hypotonic fluids are characterised by lower concentration, or tonicity, of electrolytes (mainly sodium) to plasma and, therefore, possess the ability to dilute plasma and lower P-Na [10]. It should be noted that the outer labelling of IV fluids may be misleading because these are not always consistent with how the IV fluid reacts in the body. For instance, 5% Glucose is labelled as 'isotonic' despite becoming physiologically hypotonic once the glucose is metabolised. In healthy individuals, the body maintains P-Na within the normal range (135 to 142 mmol/l) by controlling water intake (thirst/nausea) and excretion (urine output) [11]. However, in the acutely ill patient, water excretion is frequently reduced due to secretion of the antidiuretic hormone (ADH) [10], which in combination with hypotonic IV fluids, leads to an excess of water relative to sodium resulting in hyponatraemia. Most patients with hyponatremia have hypotonicity. Tonicity promotes water movement into or out of a cell by osmosis and makes cells swell or shrink. Hyponatraemia results in increased entry of water into cells causing cerebral symptoms (hyponatraemic encephalopathy) due to brain swelling (oedema) in a non-distensible cranium, which, if not addressed acutely, might evolve to brain damage and death.

Hyponatraemia, the most common electrolyte disorder in hospitalised patients, is frequently hospital-acquired due to a combination of hypotonic IV fluids administration and reduced renal water excretion. Hoorn and colleagues found that 10% of children admitted to ED developed acute hyponatraemia due to hypotonic fluid administration [12], and worldwide, more than 100 cases of death or permanent brain damage have been reported resulting from hospital-acquired hyponatraemia after administration of hypotonic IV fluids. Many of these involved otherwise healthy children and adults [10]. Previous attempts to reduce the risk of hospital-acquired hyponatraemia caused by IV fluids include the European Pharmacovigilance Risk Assessment Committee's warning on hospital-acquired hyponatraemia for hypotonic IV fluids in 2017 [13], and, in 2018, the American Academy of Pediatrics published a guideline on the use of maintenance IV fluid therapy in children after concerns of hospital-acquired hyponatraemia were raised [14].

Despite several attempts to minimise the risk, knowledge is lacking as to whether physicians' inappropriate prescribing practice continues to be a concern, and to which extent nurses are aware of the IV fluid challenges relative to hospital-acquired hyponatraemia to be able to assist physicians in prescribing of IV fluids and prevent the risk. To the best of our knowledge, there is no research on nurses' knowledge of IV fluid therapy in an emergency care setting nor to what extend they receive training and are familiar with clinical guidelines. Hence, we conducted a survey about IV fluid therapy and hyponatraemia among physicians and nurses working at EDs in Denmark. Notably, results from nurses and physicians are published separately because nurses and physicians have different roles in IV therapy, and with this follows different expectations and responsibilities (see Sindahl et al. for results on physicians) [15].

Given the risk of hospital-acquired hyponatraemia due to administration of hypotonic fluids and nurses' pivotal role in ensuring high-quality IV fluid therapy, the primary aim of this study was to explore knowledge about IV fluid therapy and hyponatraemia among nurses working at EDs in Denmark and identify if this was in accordance with the evidence and clinical guidelines.

## 2. Methods

### 2.1. Study setting and design

This study is an explorative study using a non-probability sample design. We conducted a cross-sectional survey among nurses working at EDs throughout Denmark using a self-administered structured questionnaire. We focused on EDs because many IV fluid prescriptions are initiated in the ED, and inappropriate IV fluid therapy is particularly likely in EDs [16]. The recruitment started in March 2019 and ended in May of that year.

### 2.2. Recruitment

We invited all 38 EDs in Denmark, distributed over 21 hospitals, by mail to participate in the survey. In case of no response to the initial invitation, two additional reminder attempts were made. In order to increase the response rate, we offered two options to fill out the questionnaire. In agreement with the head of the ED, the questionnaire was distributed either via an online link by the head of the department or as a paper version distributed in person and completed during the daily meeting.

Participation was anonymous and voluntary, and consent was not needed according to the Danish Data Protection Authority.

### 2.3. Development of the questionnaire

Since there was no pre-existing validated survey questionnaire that addressed the aim of the study, the questionnaire was developed by item generation through a review of the literature and the European Medicines Agency's database of adverse drug reactions (EudraVigilance). To ensure the questions were representative of the concepts they were intended to reflect (hospital-acquired hyponatraemia), it was validated by a team of experts including an intensive care physician with extensive ED experience, pharmacovigilance officers, and researchers in social pharmacy, pharmacoepidemiology, and regulatory science (including a former practising nurse) [17].

The questionnaire was cognitive pretested among four physicians to identify questions that were poorly understood, ambiguous, or produced invalid responses. We used the techniques 'thinking aloud' and 'individual debriefing'. Questions for the 'individual debriefing' were prepared before the interview in order to search for potential problems not covered by the 'thinking aloud technique' [18,19].

The final questionnaire consisted of four parts:

1. Demographic questions,
2. Clinical scenario questions,
3. Knowledge questions,
4. Final questions about the use of aids (e.g., treatment guidelines).

All questions were closed-ended (fixed-alternative) with multiple-response choices, including an option of 'do not know'.

### 2.4. Outcome measures

Three common clinical scenarios (hereafter called scenarios) encountered in EDs were used to measure knowledge about IV fluid therapy [20,21]. Indications for fluid therapy in the scenarios included hypovolaemia and maintenance, which are the most frequent reasons for prescribing IV fluids [1,22]. Also, the three scenarios were based on prevalent real-life cases. In all scenarios, it was noted that the patient was not tolerating any oral intake, and all scenarios selected for this survey represent conditions associated with increased ADH secretion where the risk of developing hyponatraemia is well-documented [10]. The scenarios covered (see Appendix for full details):

1. A high-risk patient (i.e., a patient with potentially increased intracranial pressure) with hypovolaemia (a state of decreased intravascular volume) but without hyponatraemia;
2. A child in need of maintenance IV fluids without hypovolaemia and hyponatraemia;
3. A hypovolaemic and hyponatraemic patient, but without severe symptoms of hyponatraemia.

After each scenario, participants were asked to select the first-line treatment of choice between eight commonly used IV fluids with different tonicity and electrolytes and/or carbohydrates content.

After the three scenarios, participants were asked to answer three questions about hyponatraemia because monitoring and early recognition of severe symptoms and high-risk patients may prevent or minimise severe consequences of hyponatraemia. Topics for these questions included:

- Hyperglycaemia and P-Na,
- Severe symptoms of hyponatraemia,
- Patients at high risk of severe symptoms of hyponatraemia.

LimeSurvey version 2.67.2 was used for the electronic version of the questionnaire.

### 2.5. Data analysis

The survey was developed in the context of a larger study, including physicians [15]. Nurses and physicians received the same questionnaire, but post hoc, only questions considered relevant for nurses working in the ED were selected for analysis in this study. This selection was based on discussion with a team of experts, including among others a critical care nurse with research experience in IV fluid therapy. While the quality of care is to be gained by collaborative practice between physicians and nurses, they have different roles in IV therapy. Hence, we opted to evaluate their performances based on different sets of questions from the questionnaire (see questions used for the analysis of nurses in Appendix).

All questions were summarised using descriptive statistics (counts and percentages) of correct responses. For the scenarios, selection of hypotonic fluids was also summarised (counts and percentages). Fischer's exact test was used to explore whether position and years of practice were associated with the administration of hypotonic fluids. P values $< 0.05$ were considered to be significant.

All data handling and analysis were performed using SPSS version 25.

## 3. Results

### 3.1. Characteristics of respondents

Twelve (57%) out of 21 hospitals, and 15 (39%) out of the 38 invited EDs participated in this study. 112 nurses completed the questionnaire giving a response rate of 6.2% (112/1815) based on the estimated number of the total population of nurses working at EDs in Denmark in 2014 (see Fig. 1) [23].

Overall, respondents were experienced: 87.6% treated more than five patients a week with IV fluids, and 62.1% had more than five years of practice. 38.5% of nurses were specialised in emergency nursing; that is, after becoming a registered nurse, they received training in emergency nursing. Only three nurses participated from paediatric EDs, and none participated from EDs of low complexity. Full details of the participating nurses' demographics and professional details are presented in Table 1 below.

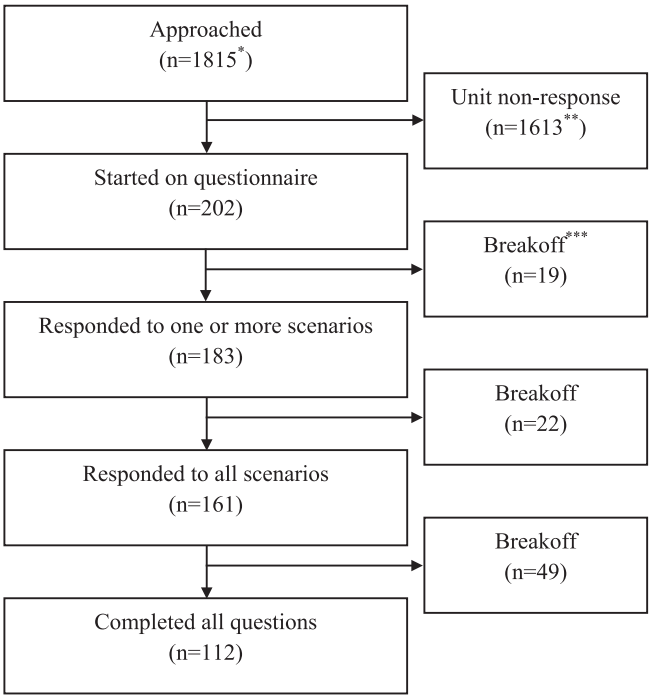


**Fig. 1.** Flow diagram of included nurses. *Estimated source population (i.e., nurses working at EDs in Denmark) from 2014. **This number includes nurses at EDs that refused, nurses at EDs that did not respond to the invitation, and nurses at participating EDs who choose not to participate. ***Respondents started on the questionnaire but failed to complete it, resulting in breakoff.

### 3.2. Response to scenarios and knowledge questions

Of the 161 participants who responded to all scenarios, 0.6% (1/161) answered all three questions correctly, 54.7% (88/161) answered two correctly, 32.3% (52/161) answered one correctly, and 12.4% (20/161) answered none correctly. The fluids selected for each scenario are presented in Fig. 2.

In the first scenario, describing a normonatraemic and hypovolaemic woman with meningitis and thus potentially having increased intracranial pressure, 64.0% (103/161) choose the correct intravenous fluid (isotonic saline solution) to restore normal hydration status. Hypotonic solutions, including the moderate hypotonic electrolytes solution, Ringer's acetate, were incorrectly selected by 31.1% (50/161).

The second scenario presented a 5-year-old boy in need of maintenance IV fluid. The appropriate option (isotonic saline solution with 5% glucose) was selected by 0.6% (1/161). The most commonly selected fluid (71 out of 161, corresponding to 44.1%), was the isotonic saline solution, which is not an optimal choice as the child also needs carbohydrates. Hypotonic intravenous fluids were incorrectly selected by 8.1% (13/161).

The third scenario was a 75-year-old hypovolaemic and hyponatraemic (P-Na = 110 mmol/L) woman in treatment with thiazide diuretics without severe symptoms of hyponatraemia. 75.8% (122/161) selected the appropriate fluid (either Ringer's acetate or isotonic saline solution), while 9.9% (16/161) incorrectly selected hypotonic intravenous fluids.

Percentage of correct responses to the three knowledge questions are listed in Table 2 below. Correct answers are marked in bold.

### 3.3. Analyses of associations between position/years of practice and selection of hypotonic fluids

Table 3 presents the test of the association between position/years of practice and the selection of hypotonic fluids. The analysis showed that,

**Table 1**
Characteristics and distribution of respondents indicating gender, age, number of weekly treated patients, years of practice, and position, and characteristics of hospitals/emergency departments (EDs) indicating location (region), size, complexity, and patient type served.

| | | Responded to one or more scenarios | | Responded to all scenarios | | Completed all questions | |
|---|---|---|---|---|---|---|---|
| | | n | (%) | n | (%) | n | (%) |
| All | | 183 | (100.0) | 161 | (88.0) | 112 | (61.2) |
| **Characteristics of respondents** | | | | | | | |
| Gender | | | | | | | |
| | Female | 165 | (90.2) | 145 | (90.1) | 103 | (92.0) |
| | Male | 16 | (8.7) | 15 | (9.3) | 8 | (7.1) |
| | Other | 2 | (1.1) | 1 | (0.6) | 1 | (0.9) |
| Age | | | | | | | |
| | 18–34 years | 72 | (39.3) | 66 | (41.0) | 43 | (38.4) |
| | 35–44 years | 51 | (27.9) | 46 | (28.6) | 34 | (30.4) |
| | $\geq$ 45 | 60 | (32.8) | 49 | (30.4) | 35 | (31.2) |
| Number of weekly treated patients with IV fluids | | | | | | | |
| | 0 patients | 6 | (3.3) | 4 | (2.5) | 3 | (2.7) |
| | 1–5 patients | 19 | (10.4) | 16 | (9.9) | 13 | (11.6) |
| | >5 patients | 158 | (86.3) | 141 | (87.6) | 96 | (85.7) |
| Years of practice | | | | | | | |
| | $\leq$ 5 years | 67 | (36.6) | 61 | (37.9) | 40 | (35.7) |
| | More than 5 years | 116 | (63.4) | 100 | (62.1) | 72 | (64.3) |
| Position | | | | | | | |
| | Registered nurse | 108 | (59.0) | 95 | (59.0) | 66 | (58.9) |
| | Emergency nurse | 70 | (38.3) | 62 | (38.5) | 42 | (37.5) |
| | Head nurse | 5 | (2.7) | 4 | (2.5) | 4 | (3.6) |
| **Characteristics of EDs*** | | | | | | | |
| Region | | | | | | | |
| | Northern Denmark | 46 | (25.1) | 41 | (25.5) | 22 | (19.6) |
| | Zealand | 16 | (8.7) | 14 | (8.7) | 10 | (8.9) |
| | Southern Denmark | 25 | (13.7) | 20 | (12.4) | 16 | (14.3) |
| | Mid-Jutland | 79 | (43.2) | 70 | (43.5) | 50 | (44.6) |
| | Capital | 17 | (9.3) | 16 | (9.9) | 14 | (12.5) |
| Size | | | | | | | |
| | Large | 64 | (35.0) | 59 | (36.6) | 33 | (29.5) |
| | Medium | 74 | (40.4) | 65 | (40.4) | 50 | (44.6) |
| | Small | 45 | (24.6) | 37 | (23.0) | 29 | (25.9) |
| Complexity | | | | | | | |
| | High | 64 | (35.0) | 59 | (36.6) | 33 | (29.5) |
| | Medium | 119 | (65.0) | 102 | 63.4) | 79 | (70.5) |
| | Low | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) |
| Type | | | | | | | |
| | Combined general population ED** | 50 | (27.3) | 41 | (25.5) | 32 | (28.6) |
| | Adult ED | 106 | (57.9) | 97 | (60.2) | 65 | (58.0) |
| | Paediatric ED | 4 | (2.2) | 3 | (1.9) | 2 | (1.8) |
| | Trauma centre | 23 | (12.6) | 20 | (12.4) | 13 | (11.6) |

*Characteristics of the emergency departments was based on a report of emergency departments by the Danish Ministry of Health.
**Combined general population EDs provide care for all patients in one area, while separate general population EDs provide care to children and adults in separate locations within a facility.

in our sample, only one test was significant. In scenario three, nurses who had 5 or fewer years of practice were 2.7 times more likely to administer hypotonic fluids compared to nurses with more than 5 years of practice. However, due to the small sample size, the confidence intervals are wide and exclude firm conclusions.

## 4. Discussion

This study was an explorative study of knowledge about IV fluid therapy and hyponatraemia among nurses working at EDs in Denmark. In two of the three clinical scenarios commonly encountered in the ED, the majority of respondents were compliant with current evidence and clinical guidelines. One result stands out; nearly one-third selected a hypotonic fluid for a patient at high risk of severe symptoms of hyponatraemia due to potentially increased intracranial pressure, which is against guideline recommendations.

### *4.1. Fluid management in patients with potentially increased intracranial pressure*

In 2017/2018, the European product information of physiologically hypotonic IV fluids (including Ringer's lactate/acetate) was updated to include, among others, a warning of hospital-acquired hyponatraemia in patients with potentially increased intracranial pressure [13]. Also, according to the Danish Endocrine Society, treatment with Ringer's lactate/acetate should be avoided in patients with potentially increased intracranial pressure, and UpToDate, a commonly used clinical resource, recommends only to employ isotonic fluids in patients with increased intracranial pressure [24,25]. An explanation of the large number of nurses (31.1%) selecting a hypotonic fluid (including Ringer's acetate) for a patient with meningitis may be that these guidelines are not directed to nurses or included in teaching material. It is worth noting, though, that more than half of these nurses selected the moderately hypotonic fluid, Ringer's acetate. Rational pharmacotherapy is defined as the right medicine to the right patient at the right time and with the right dosage. In this case, concerning a patient with potentially increased intracranial pressure where a small decrease in P-Na may be critical, even the moderately hypotonic fluid, Ringer's acetate should be avoided. With a slightly lower sodium concentration than the physiologic range in plasma (130 mmol/l versus 135 to 142 mmol/l in plasma), Ringer's acetate is hypotonic, and larger amounts can drive sodium levels to hyponatraemic ranges, leading to cerebral damage. Moreover,

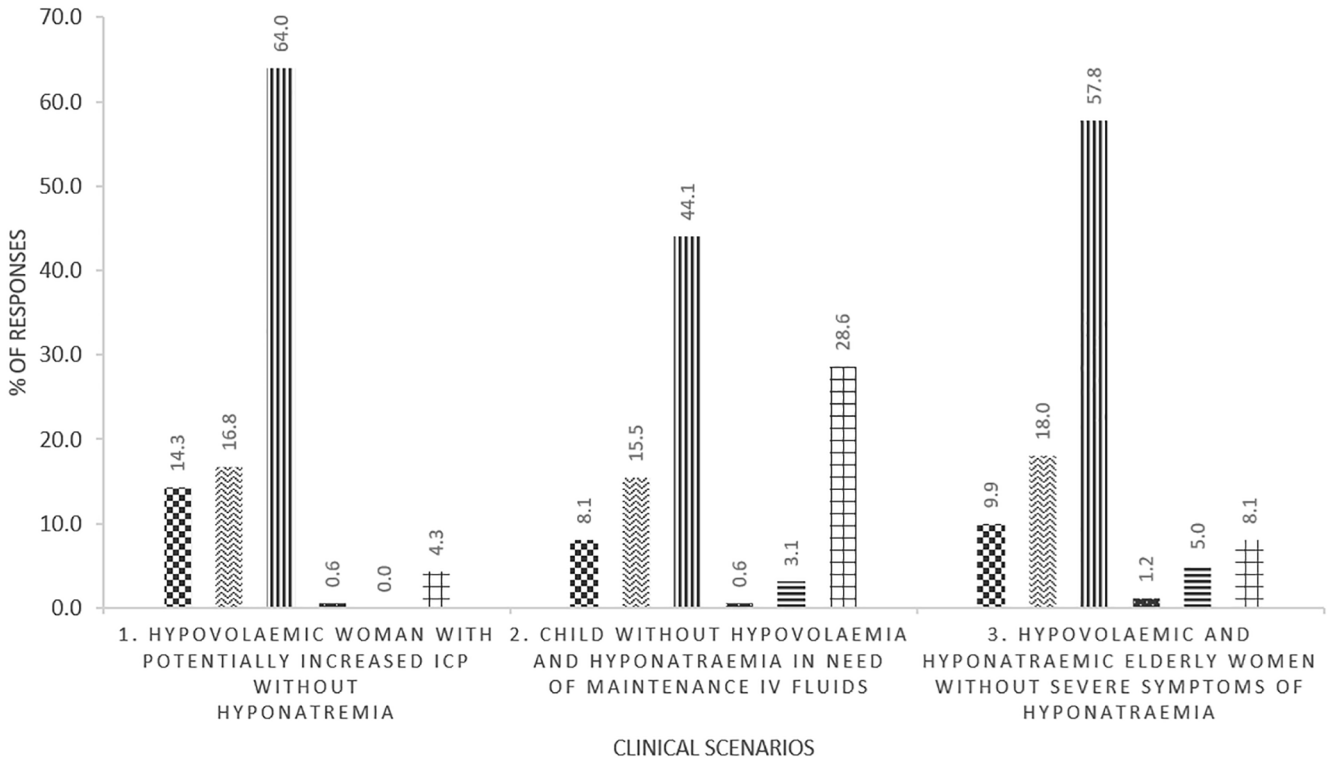


**Fig. 2.** Percentage of responses showing prescribing practice in three common clinical scenarios encountered in the ED. Strong hypotonic fluids included 5% Glucose, Potassium-Sodium-Glucose, Sodium-Chloride-Glucose, and Darrow-glucose.

it is crucial to be able to identify patients at high risk of severe consequences upon inappropriate IV fluid treatment. In our study, most nurses (69.6%) were able to identify meningitis as a disease indicative of potentially increased intracranial pressure. However, this result should be interpreted with caution, as very few nurses (6.1%) were able to identify all the presented symptoms/diseases correctly.

### 4.2. *Routine maintenance fluids in children*

Treatment with hypotonic fluids in children for routine maintenance requirements is against guideline recommendation [14,24,26]. Numerous studies of maintenance IV fluids in children have shown that isotonic fluids are effective in preventing hospital-acquired hyponatraemia [27–29]. Furthermore, there is no evidence of increased adverse effects such as hypernatraemia, hyperchloraemic metabolic acidosis, and fluid overload with isotonic maintenance fluids [14]. However, it remains uncertain how many patients would need to be treated with isotonic fluids to prevent a rare but potentially devastating event like hyponatraemic encephalopathy [30]. Few nurses (8.1%) selected a hypotonic fluid for a child in need of maintenance fluid. This is remarkable in light of recent studies conducted in physicians revealing a much higher use of hypotonic maintenance fluids in children [31,32]. Although isotonic maintenance fluids reduce the risk of hospital-acquired hyponatraemia, it will not eliminate the problem as hospital-acquired hyponatraemia is common in children receiving isotonic fluids as well [33]. Hence, hyponatraemia should always be considered a cause of neurological symptoms in hospitalised patients regardless of the IV treatment. Since the occurrence of severe symptoms of hyponatraemia is a medical emergency requiring immediate treatment to prevent neurological sequelae and death, nurses must recognise severe symptoms of hyponatraemia. When participants were asked to mark severe symptoms of hyponatraemia requiring acute treatment from a list of six options, including three distractors, fewer than a third of the respondents answered all six correctly. Consistent with a study conducted in the UK and The Netherlands, our results suggest that severe symptoms may not be recognised and, therefore, not treated properly [34,35].

### 4.3. *The elderly patient and hyponatraemia*

The third scenario describes a 75-year-old woman with hyponatraemia (P-Na = 110 mmol/L) and symptoms of hypovolaemia (cold and pale skin, heart rate at 100 bpm, and a slightly increased respiratory rate) in treatment with thiazide diuretics, but importantly, without severe symptoms of hyponatraemia (e.g., seizure and decreased consciousness). Hyponatraemia is a frequent electrolyte disorder in the elderly population. It is often multifactorial and mainly caused by increased ADH, frequent prescription of drugs associated with hyponatraemia (e.g., thiazides and antidepressants), or endocrinopathies such as adrenal insufficiency [36]. The numerous causes of increased ADH place virtually all acutely ill hospitalised patients at risk of the development of hyponatraemia [10]. In the present scenario, increased ADH may be caused by hypovolaemia and the pain, stress, and inflammation after the fall. Treatment of hyponatraemia is guided by the symptomatology of the patient. Irrespective of the cause, hyponatraemia with severe symptoms should be treated immediately with 3% hypertonic saline to rapidly increase P-Na until the symptoms subside. In the absence of severe symptoms, there is no immediate need for correction of P-Na. In the current scenario, the use of isotonic saline solution or Ringer's acetate/lactate seems a logical choice since it raises the P-Na and restores the plasma volume. Water goes where sodium goes, and as isotonic saline solution and Ringer's acetate/lactate have a high content of sodium (130–154 mmol/L), it will remain and increase the plasma volume thereby decreasing the stimulus for ADH secretion [13,37]. A decrease of ADH is likely to cause a prompt water diuresis leading to a sudden increase of P-Na. It should be noted that rapid and excessive correction of P-Na can lead to brain injury due to osmotic demyelination syndrome (ODS) [38]. Thus, regular monitoring of P-Na, blood glucose, and clinical response is needed so that responses to IV fluid treatment can be evaluated and altered or stopped as appropriate [16]. When monitoring and diagnosing hyponatraemia, it is important to be aware

**Table 2**
Percentage of correct responses to knowledge questions*

| | n | (%) |
|---|---|---|
| **Q4: Hyperglycaemia and plasma sodium (n = 118)** | **8** | **(6.8)** |
| In the case of increased blood sugar (above 12 mmol/L), the measured plasma sodium (P-Na) must be corrected because the measured P-Na is: | | |
| - **"falsely low"**; | | |
| - "falsely high"; | | |
| - there is no need for correction; | | |
| - do not know. | | |
| **Q5: Patients at high risk of severe symptoms of hyponatraemia (n = 115)** | | |
| Which of these diseases/symptoms may be indicative of potentially increased intracranial pressure and, therefore, require special attention in relation to fluid treatment since even minor changes in plasma sodium may be critical? | | |
| - **Meningitis (correct)** | 80 | (69.6) |
| - Shortness of breath | 73 | (63.5) |
| - **Concussion (correct)** | 84 | (73.0) |
| - Chest pain | 87 | (75.7) |
| - **Seizure (correct)** | 87 | (75.7) |
| - **Acute liver failure (correct)** | 35 | (30.4) |
| - Acute abdomen | 85 | (73.9) |
| - Hip fracture | 89 | (77.4) |
| **All symptoms/diseases correct** | **7** | **(6.1)** |
| **Q6: Severe symptoms of hyponatraemia (n = 112)** | | |
| Which of the following symptoms are indicative of severe symptoms of hyponatraemia and require acute treatment of hyponatraemia? | | |
| - **Decreased consciousness (correct)** | 107 | (95.5) |
| - **Seizure (correct)** | 100 | (89.3) |
| - Infection | 73 | (65.2) |
| - Chest pain | 70 | (62.5) |
| - **Muscle rigidity (correct)** | 80 | (71.4) |
| - Anaemia | 70 | (62.5) |
| **All symptoms correct** | **33** | **(29,5)** |

*Percentages of correct responses for knowledge questions are based on those who answered the specific question. The total number of respondents is indicated for each question in brackets. Correct responses are in bold.*

of hyperglycaemia-induced hyponatraemia, especially in the elderly where the prevalence of diabetes mellitus is high [36]. In the case of marked hyperglycaemia (above 12 mmol/L), the measured P-Na should be corrected because glucose is an osmotic active substance, leading to the movement of water out of cells, resulting in a reduction of P-Na by dilution. Hence, P-Na will increase again when the plasma glucose is normalised [9]. In our study, few nurses (6.8%) were familiar with the relationship between hyperglycaemia and P-Na, indicating a need for more knowledge. However, overall, the results of scenario three indicate a high degree of compliance as more than three quarters selected the correct fluid, isotonic saline solution or Ringer's acetate, and only 10% selected a hypotonic fluid for this scenario, which is inappropriate because it will worsen the patient's hyponatraemia.

## 5. Strengths and limitations

These findings need to be considered within the context of the strengths and limitations of the study methods. We used a structured approach in developing the survey where a team with different areas of expertise took part in the development of the questionnaire, that was subsequently pretested to establish face validity. In addition, the questionnaire was validated in terms of content validity through a review of experts, including an intensive care physician with extensive experience from the ED and a critical care nurse with research experience in IV fluid therapy. Also, the scenarios were based on prevalent real-life cases.

Our study has several limitations. First, this was an explorative study using a non-probability survey design which limits the generalisability of our results. Hence the findings are preliminary and need to be confirmed by larger studies using a random sample design. However, we suppose that the direction of bias is towards a more positive result since the Hawthorne effect—a tendency to perform better when observed—seems inevitable, and there might have been a selection bias towards those for whom the questions were manageable.

Second, we cannot conclude whether lack of knowledge pertaining to IV fluid therapy and hyponatraemia contributed to adverse patient outcomes. Nevertheless, in light of the general lack of IV fluid administration recording and underreporting of complications to IV fluid

**Table 3**
Association between position/years of practice and selection of hypotonic fluids, and selection of hypotonic fluids.

| | Hypotonic fluid selection (%) | | Relative Risk | | 95% CI | P* | Hypotonic fluid selection (%) |
|---|---|---|---|---|---|---|---|
| Variable | | | | | | | |
| | Yes | | No | | | | |
| **SCENARIO 1** | 23 | | (38%) | | | | |
| **Years of practice** | 23 | | (38%) | | | | |
| ≤ 5 years | 23 | | (38%) | | 38 | | |
| More than 5 years (ref.**) | 27 | | (27%) | | 73 | | |
| | | | 1.4 | | 0.9–2.2 | 0.16 | 1.4 |
| **Position** | | | 1.4 | | | | |
| Registered nurse | 28 | (30%) | 66 | (70%) | 1.0 | 0.6–1.6 | 1.00 |
| Emergency nurse (ref.) | 18 | (30%) | 42 | (70%) | | | |
| **SCENARIO 2** | | | | | | | |
| **Years of practice** | | | | | | | |
| ≤ 5 years | 6 | (10%) | 55 | (90%) | 1.0 | 0.1–7.1 | 1.00 |
| More than 5 years (ref.) | 7 | (7%) | 93 | (93%) | | | |
| **Position** | | | | | | | |
| Registered nurse | 5 | (5%) | 89 | (95%) | 0.5 | 0.2–1.8 | 0.34 |
| Emergency nurse (ref.) | 6 | (10%) | 54 | (90%) | | | |
| **SCENARIO 3** | | | | | | | |
| **Years of practice** | | | | | | | |
| ≤ 5 years | 10 | (16%) | 51 | (84%) | 2.7 | 1.1–7.1 | 0.05 |
| More than 5 years (ref.) | 6 | (6%) | 94 | (94%) | | | |
| **Position** | | | | | | | |
| Registered nurse | 8 | (9%) | 86 | (91%) | 1.0 | 0.6–1.6 | 1.00 |
| Emergency nurse (ref.) | 7 | (12%) | 53 | (88%) | | | |

* P = Fischer's exact test.
**Ref = reference.
***Combined general population EDs provide care for all patients in one area, while separate general population EDs provide care to children and adults in separate locations within a facility.

therapy, a scenario-based survey was considered a valid measure of IV fluid therapy [20,21].

Third, that the questionnaire was developed in the context of a larger study including physicians is a limitation of the study. A selection of questions were analysed for the aim of this study. If all questions had been included, the overall result of nurses' knowledge would have likely been less than in the current study. The omitted questions, however, were based on agreement between experts providing knowledge to which questions would be most relevant for nurses when assisting and ensuring appropriate IV fluid therapy.

## 6. Implications for emergency nurses

In addition to the current study in nurses, our research team also conducted the survey in physicians [15]. The study in physicians showed that a large proportion of physicians would use hypotonic fluids in patients with potentially increased intracranial pressure and in children in need of maintenance fluids, both of which are against guideline recommendations [13,25,31,32]. The findings in physicians support the recommendations by the National Institute for Health and Care Excellence (NICE) and several other studies regarding the need for guidance on intravenous fluid therapy [16,39,40]. The quality of care depends on collaboration between physicians and nurses. Based on nurses' observations, physicians prescribe IV fluids. Therefore, nurses are an important and needed resource for ensuring appropriate IV fluid therapy and part of the solution of minimising the risk of hospital-acquired hyponatraemia. They are the first to encounter patients and may be the first to detect serious symptoms for which an immediate response is crucial. It is, therefore, of great importance to recognise severe symptoms of hyponatraemia and be able to identify patients at high risk of inappropriate hypotonic fluid administration. For nurses to assist and ensure appropriate IV fluid prescribing, they should receive education in IV fluid treatment, and instructions should be in place. However, research from the UK indicates that formal training in IV fluid therapy is often lacking [8]. Our findings would seem to suggest that the following areas may require additional attention when setting up an educational program for nurses:

- Severe symptoms of hyponatraemia such as decreased consciousness and seizures because it is a medical emergency requiring immediate treatment;
- High-risk patients, that is, diseases/symptoms that may be indicative of potentially increased intracranial pressure and, therefore, require special attention in relation to fluid treatment since even minor changes in plasma sodium may be critical;
- Hyperglycaemia's impact on P-Na and how measured P-Na should be corrected in the setting of marked hyperglycaemia.

## 7. Conclusion

This study is the first of its kind exploring knowledge pertaining to IV fluid therapy and hyponatraemia among nurses in Denmark in order to identify whether this was in accordance with the evidence and clinical guidelines. Although the current study is explorative and the results must be interpreted with caution, it indicates that the majority of nurses are compliant with clinical guidelines regarding the use of hypotonic fluids, which are associated with hospital-acquired hyponatraemia. However, the study revealed limited knowledge and room for improvement about severe symptoms of hyponatraemia, high-risk patients, and hyperglycaemia-induced hyponatraemia. Therefore, we recommend giving these areas additional attention when setting up educational programs for nurses (including basic training) before administering and monitoring IV fluids.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

We would like to thank our colleagues at the Danish Medicines Agency for pre-testing and reviewing the questionnaire. We are indebted to all nurses from throughout Denmark who dedicated their time to answer our questionnaire.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ienj.2021.101010.

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