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RESEARCH ARTICLE

Errors in fluid therapy in medical wards

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Abstract *Background* Intravenous fluid therapy remains an essential part of patients' care during hospitalization. There are only few studies that focused on fluid therapy in the hospitalized patients, and there is not any consensus statement about fluid therapy in patients who are hospitalized in medical wards. *Objective* The aim of the present study was to assess intravenous fluid therapy status and related errors in the patients during the course of hospitalization in the infectious diseases wards of a referral teaching hospital. *Setting* This study was conducted in the infectious diseases wards of Imam Khomeini Complex Hospital, Tehran, Iran. *Methods* During a retrospective study, data related to intravenous fluid therapy were collected by two clinical pharmacists of infectious diseases from 2008 to 2010. Intravenous fluid therapy information including indication, type, volume and rate of fluid administration was recorded for each patient. An internal protocol for intravenous fluid therapy was designed based on literature review and available recommendations. The data related to patients' fluid therapy were compared with this protocol. The fluid therapy was considered appropriate if it was compatible with the protocol regarding indication of intravenous fluid therapy, type, electrolyte content and rate of fluid administration. Main outcome measure: Any mistake in the selection of fluid type, content, volume and rate of administration was considered as intravenous fluid therapy errors. *Results* Five hundred and ninety-six of medication errors were detected during the study period in the patients. Overall rate of fluid therapy errors was 1.3 numbers per patient during hospitalization. Errors in the rate of fluid administration (29.8%), incorrect fluid volume calculation (26.5%) and incorrect type of fluid selection (24.6%) were the most common types of errors. The patients' male sex, old age, baseline renal diseases, diabetes co-morbidity, and hospitalization due to endocarditis, HIV infection and sepsis are predisposing factors for the occurrence of fluid therapy errors in the patients. *Conclusion* Our result showed that intravenous fluid therapy errors occurred commonly in the hospitalized patients especially in the medical wards. Improvement in knowledge and attention of health-care workers about these errors are essential for preventing of medication errors in aspect of fluid therapy.

Keywords Fluid therapy · Iran · Infectious diseases · Medication errors

Impact of findings on practice:

- Fluid therapy errors are common during patients' hospitalization.
- Errors in the rate of fluid administration, incorrect calculation of required fluid volume and incorrect selection of fluid type are the three most common types of fluid therapy errors in the hospitalized patients.
- Preparing local fluid therapy protocol and establishment of educational programs are recommended for health-care providers.

Introduction

Intravenous (IV) fluid therapy is an essential part of patients' care during hospitalization [1]. Most patients in

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the hospital setting need IV fluid therapy due to different reasons such as altered fluid intake, increased fluid losses or electrolyte imbalance [2].

Assessment of patients' fluid and electrolyte status is usually based on patients' medical history, present illness, vital signs, weight changes, fluid balance chart (input and output), autonomic and hemodynamic responses, skin and mucous membrane properties in physical examination, and serum and urine biochemistry [3]. However, clinical assessment of volume and electrolyte status and their clinical consequences are confounded by some factors such as extremes of age, preexisting diseases, severity of acute illness and variety of general physiological changes [4, 5].

Incorrect selection of IV fluid type, volume, concentration and errors in rate of fluid and electrolyte administration can increase patients' morbidity and mortality [6]. Clinical complications such as pulmonary edema, heart failure or volume depletion were reported following errors in rate of fluid administration [7–9]. Hypotonic fluid therapy can induce iatrogenic hyponatremia in the hospitalized patients [10]. Additionally, fluid therapy–related errors can increase patient- and health-care system costs [10]. There are only few studies that have evaluated appropriateness of fluid therapy in the hospitalized patients, and there is not any consensus statement about fluid therapy in the medical wards.

Aim of the study

The aim of the present study was evaluation of IV fluid therapy status and related errors in hospitalized patients in the infectious diseases wards of a referral teaching hospital, Tehran, Iran.

Methods

During a retrospective study, IV fluid therapy data were collected by two clinical pharmacists of infectious diseases from 2008 to 2010 in the infectious diseases wards of Imam Khomeini Hospital Complex, affiliated to Tehran University of Medical Sciences, Tehran, Iran. The Institutional Review Board (IRB) and the Medical Ethics Committee of the hospital approved the study. Demographic, clinical and laboratory information of the patients who received IV fluid therapy during the course of hospitalization was collected from their medical records. The collected data included age, sex, weight, hemodynamic parameters (blood pressure, pulse rate, mean arterial pressure), vital signs, blood sugar, renal function tests (serum creatinine and urea concentrations), serum electrolytes, causes of hospital admission, past medical history, present illnesses and baseline diseases. Also, the patients' IV fluid therapy information including indication, type, volume and rate of fluid administration was evaluated.

The goals of fluid therapy in the infectious diseases wards were categorized as to keep patients' vein open (maintaining an open IV access by continuous infusion of an intravenous fluid(, drug delivery (for dilution and slow IV infusion of a parenteral drug), fluid replacement (compensation of the body fluids that patients have lost) and maintenance therapy (fluid administration to provide the basic patients' physiological needs).

An internal protocol ("Appendix") for intravenous fluid therapy was prepared based on the literature review and available recommendations [11–14] by the clinical pharmacists. This protocol was approved by the local expert panel consisted of one internal medicine physician, three infectious diseases physicians, two clinical pharmacists and two senior nurses. As we have collected the patients' data retrospectively and confidentially from their medical charts, signed informed consents were not taken.

After approval of the protocol, data related to patients' fluid therapy were compared with the protocol. Fluid therapy was considered appropriate if it was compatible with the protocol regarding indication, type, electrolyte content and rate of fluid administration. Any mistake in the selection of fluid's type, content, volume and rate of administration was considered as fluid therapy error. The definitions for each type of errors have been shown in Table 1 [15, 16]. The medication errors' severity was categorized based on the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP), 1998–2001 [17].

The Statistical Package for Social Sciences (SPSS, Chicago, IL, USA) version 16 was used for data analysis. Data were analyzed by basic descriptive tests. The qualitative variables are presented by their frequency of distribution. The quantitative variables are summarized as means with standard deviation. Descriptive statistics (cross-tabs) followed by the selection of chi-square and risk were used for the evaluation of correlations and calculation of odds ratio and confidence interval. P-values less than 0.05 were considered as significant.

Results

Imam Khomeini Hospital Complex is a 1400-bed tertiary referral teaching hospital, the biggest hospital in Iran with 60 beds in infectious diseases wards. During the study period, 830 patients were hospitalized in these wards. From these patients, 450 (54.2%) individuals (248 men and 202 women) received IV fluid therapy during their hospitalization course. The patients' mean age was 45 ± 19.7 (range, 13–87) years. Baseline clinical and laboratory data

Table 1 Definition of fluid therapy errors

Type of error	Definition
Incorrect type of fluid	Type of fluid was wrong, but indication, volume and rate of administration were correct
Incorrect volume	Volume of fluid was wrong, but indication, type and rate of administration were correct
Error in rate of fluid administration	Rate of fluid administration was wrong, but reason, volume and type of selected fluid were correct
Patients' volume status assessment or indication of fluid therapy errors	Fluid therapy in patient without volume status assessment or administration of fluid in patient who did not need IV fluid therapy
Error in patients' electrolyte status evaluation	Error in the evaluation of patient electrolyte status and calculation of patients' electrolytes requirement
Error in electrolyte therapy	Patients' electrolytes status assessment was made correctly, but selection of appropriate fluid based on its electrolyte content was wrong

Table 2 Demographic data of the patients

Parameter	Mean ± SD or median (range)
Age (year)	45 ± 19.7
Weight (kg)	63 ± 15.1
Serum sodium concentration (mEq/L)	137.2 ± 4.8
Serum potassium concentration (mEq/L)	4.27 ± 0.7
Pulse rate (beats/min)	92 (70–440)
Mean arterial pressure (mmHg)	115 (65–220)
Serum creatinine concentration (mg/dL)	1.3 (0.4–12.6)
Serum glucose (mg/dL)	145 (50–497)
Blood urea nitrogen (mg/dL)	18.9 (4–126)

Table 3 Patients' baseline co-morbidities

Co-morbidity	Frequency (%)
Cardiovascular diseases	112 (24.5)
Metabolic disorders	80 (17.8)
Gastrointestinal diseases	30 (6.6)
Cancer	27 (6)
Neurologic disorders	27 (6)
Respiratory diseases	18 (4)
Hematologic disorders	14 (3.1)
Rheumatological disorders	9 (2)
Tuberculosis	9 (2)
Congenital disorders	5 (1. 1)
Without any co-morbidity	119 (26.4)
Total	450 (100)

of the patients have been summarized in Table 2. Cardiovascular disorders were the most common preexisting co-morbidity in the patients (Table 3). Types of the available fluids in these wards were sodium chloride 0.9% (NS), sodium chloride 0.45% (1/2 NS(, dextrose water 5% (D5W), dextrose 5% plus sodium chloride 0.9% (DS), Ringer's solution (R), Lactated Ringer's solution (LR) and dextrose 3.33% plus sodium chloride 0.33% (1/3,2/3). The

Table 4 Patients' final diagnosis and frequency of the related errors

Diagnosis	Numbers of patients (%)	Numbers of errors (%)	Rate of errors per patient
Skin, connective tissues and bone infections	82 (18.2)	106 (17.7)	1.3
Respiratory tract infection	78 (17.3)	99 (16.7)	1.3
Tuberculosis	64 (14.2)	55 (9.2)	0.9
HIV and related opportunistic infections	64 (14.2)	106 (17.8)	1.7
Sepsis	54 (12)	88 (14.7)	1.6
Urinary tract infections	53 (11.7)	47 (7.9)	0.9
Endocarditis	30 (6.7)	63 (10.6)	2.1
CNS infections	25 (5.7)	32 (5.4)	1.3
Total	450 (100)	596 (100)	1.3 (mean)

patients' final diagnosis and related fluid therapy errors are shown in Table 4. Five hundred and ninety-six IV fluid therapy errors were detected during the study period with an average rate of 1.3 fluid therapy errors per patient. Patients with diagnosis of endocarditis, HIV and its related opportunistic infections, and sepsis experienced more errors than patients with tuberculosis and urinary tract infections (Table 4).

Errors in the rate of fluid administration (29.8%), incorrect calculation of the required volume of fluid (26.5%) and incorrect selection of the fluid type (24.6%) were the most common types of fluid therapy errors, respectively. Based on the NCC, MERP definitions (Table 5), severity of the errors was categorized as D (39.7%), C (36.6%), E (15.8%), F (7.7%) and G (0.2%).

Based on the patients' vital signs, hemodynamic parameters, physical examination and serum biochemical data, appropriate patients' volume status assessment had not been made in 48.7% of the patients.

Table 5 Types and severities of the detected errors

Type of error	Numbers of errors (%)	Errors' severity category [numbers (%)]
Error in electrolyte	25 (4.2)	C[4 (16)], D[8(32)], E[9(36)], F[3(16)], G[1(4)]
Incorrect type of fluid	147 (24.6)	C[40 (27.2)], D[56(38.1)], E[33(22.5)], F[18(12.2)]
Incorrect volume of fluid	158 (26.5)	C[72 (45.6)], D[58(36.7)], E[18(11.4)], F[10(6.3)]
Rate of fluid administration	178 (29.8)	C[80 (44.8)], D[81(45.5)], E[14(7.9)], F[3(1.7)]
Fluid therapy indication	88 (14.7)	C[22 (25)], D[34(38.6)], E[20(22.7)], F[12(13.7)]
Total	596 (100)	C[218(36.6)], D[237(39.7)], E[94(15.8)], F[46(7.7)], G[1(0.2)]

Based on the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) 1998–2001, severity of each error was defined as follows:

C: An error occurred that reached the patient but did not cause patient harm

D: An error occurred that reached the patient and needs monitoring to confirm that it resulted no harm to patient

E: An error occurred that resulted in temporary harm to the patient and required intervention

F: An error occurred that resulted in temporary harm to the patient and required initial or prolonged hospitalization

G: An error occurred that may have resulted or contributed to patients' death

Diabetes mellitus was an underlying disease in 75 out of 450 (16.7%) patients who received fluid therapy during hospitalization course. Sixty-five (86.7%) of these diabetic patients had uncontrolled blood sugar defined as random blood sugar over 180 mg/dL or pre-meal blood sugar over 140 mg/dL [18]. Approximately 6 (9.2%) and 16 (24.6%) out of the patients with uncontrolled blood sugar received DW and DS as fluid therapy, respectively. With respect to physical examination, hemodynamic parameters, urine output and blood urea nitrogen–serum creatinine ratio of more than 20, 85 out of 450 patients (18.8%) who received IV fluid therapy had volume-deficit status at the time of hospital admission. Seven of these hypovolemic patients (8.2%) received ½ NS as IV fluid therapy. One hundred and four (23.1%) of the patients who received fluid therapy had a history of hypertension as baseline disease. From these patients, 15 (14.4%) of them received NS as main fluid therapy during hospitalization.

Due to unavailability of required data, evaluation of patients' electrolyte status was not possible in 222 (49.3%) of the patients. One hundred and forty (31.1%) of patients included in the study had at least one electrolyte disturbance. Hyponatremia, hypernatremia, hypokalemia and hyperkalemia were detected in 44 (31.4%), 6 (4.3%), 11 (7.9%) and 5(3.6%) of the patients, respectively. In 90 (64.3%) of patients with electrolyte disturbance, at least one error occurred in selection of fluid type. Twenty-seven out of 44 patients with hyponatremia (61.4%) and 4 out of 6 patients with hypernatremia (66.7%) received 1/2NS and NS, respectively, as fluid therapy in this study. For seven of 11 patients with hypokalemia (63.6%), sugar-containing solutions (DW or DS) were selected as fluid for replacement or maintenance therapy.

Following the analysis of the data, we found significant correlation between occurrence of fluid therapy errors and male sex [OR = 1.4, 95% CI (1.1–1.8)], patients' age over 50 years [OR = 1.1, 95% CI (1–1.4)], baseline serum creatinine over 1.2 mg/dL [OR = 1.8, 95% CI (1.4–2.6)], diabetes mellitus as co-morbidity [OR = 1.5, 95% CI (1.4–2.4)], and diagnosis of endocarditis [OR = 2.3, 95% CI (2.1–3.9)], HIV [OR = 1.9, 95% CI (1.6–2.8)] and sepsis [OR = 2.1, 95% CI (1.3–2.5)].

Discussion

As we know, this is the first study that has evaluated fluid therapy errors in adult infectious diseases wards in hospital setting. At least one error was detected in different stages of fluid therapy, including fluid's indication, type, content, volume and administration rate. Errors in the rate of fluid administration, incorrect volume calculation and incorrect type of fluid selection were the most common types of errors, respectively. Most of the errors in this study were categorized as errors that reached the patients and need monitoring to prevent patients from diseases.

There are just few studies that have evaluated IV fluid therapy in adult inpatients. These studies reported incorrect fluid infusion rates as the most common error associated with fluid therapy [15, 19, 20]. Frequency of errors in the administration rate of fluids was about 30% in the present study, which is comparable with those of the previous studies [15, 16, 21–23].

Use of devices for controlling fluid administration rate is a practical approach for the prevention of errors in the rate of fluid or drug delivery. These devices have been usually used for acutely or critically ill patients in acute care setting or intensive care units. Unfortunately, infusion rate control devices are not readily available in our wards.

Patients' volume status assessment is one of the challenging areas for the health-care providers in the medical wards. Patients' vital signs, hemodynamic parameters,

serum and urine electrolytes, serum biochemistry, daily intake and output, renal function tests, and physical examination finding are usually used for patients' volume status assessment in the medical wards. Approximately half of patients in the infectious diseases wards had not appropriate volume status assessment. Errors in the fluid therapy's volume were detected in more than 25% of the patients in the present study.

Hyponatremia in the hospitalized patients is usually iatrogenic and occurs following the administration of hypotonic fluids. Hypotonic fluids have been reported as the most commonly used IV fluids in both pediatric and adult hospitalized patients [24]. Half saline was the most common type of administered fluid in the infectious diseases wards in present study. Hyponatremia is the most common consequence of hypotonic fluids administration in the patients with normal or near-normal serum sodium concentrations [12, 24, 25]. In these patients, administration of NS did not result in either hypernatremia or fluid overload. Therefore, administration of NS is recommended for the prevention of hyponatremia in medical patients with normal or near-normal serum sodium concentrations [24, 26, 27].

Administration of sugar-containing fluids in patients with uncontrolled blood sugar was another physicians' error in fluid therapy encountered in this study. Although sugar-containing fluids such as DW and DS can be used in diabetic patients with controlled blood sugar, these solutions are not recommended for hospitalized patients with acute infections and uncontrolled blood sugar. In diabetic patients with normal blood pressure, NS can be a suitable alternative [23].

Incorrect fluid therapy indications were detected in about 15% of the patients in this study. Patients who are able to take fluids and food orally are not justified candidates to receive IV fluid therapy support. Some of the patients with eating and drinking ability, without any volume and electrolyte problems, received IV fluid therapy.

An additional example of fluid therapy error in this category was administration of another intravenous solution for patients' drug delivery in parallel with maintenance fluid therapy while their drugs were compatible with the maintenance IV fluids.

Errors in patients' electrolyte replacement therapy were minimal (4.2%) in this study. Hospitalized patients in the infectious diseases wards usually are not acutely ill and in toxic conditions; therefore, close monitoring of serum electrolytes is not usually done as in patients with unstable conditions or critically ill status.

Most errors in this field occurred in the detection of patients' electrolyte disturbances, calculation of amount or volume of required electrolyte, selection of appropriate fluid with respect to characteristic of the available products, and rate of patients' electrolyte disturbance correction.

The patient' male sex, old age, baseline renal diseases, diabetes co-morbidity, and hospitalization due to endocarditis, HIV infection and sepsis are predisposing factors for the occurrence of fluid therapy errors in our patients. The infectious diseases wards of our hospital are referral for HIV/AIDS care. Most HIV-positive patients entered in this study were injection-drug-user men. These patients were hospitalized due to endocarditis and HIV-related opportunistic infections. Co-morbidities such as hypertension, diabetes and renal diseases are more prevalent in the old-age patients. As mentioned in the Results section, most errors in the area of fluid's type occurred in the diabetic and hypertensive patients. Patients with baseline renal failure are more vulnerable to fluid and electrolyte disturbances as kidney is the cornerstone organ for the body fluid and electrolyte balance. In the selection of appropriate fluid, attention to patients' baseline diseases such as diabetes, hypertension and renal diseases is critical. Sepsis is an unstable and critical medical condition, and due to wide range of patients' body physiological responses especially in the early phase of this phenomenon, these patients need close monitoring of hemodynamic parameters and fluid therapy must be individualized based on minute patients' conditions.

Findings of this study showed high rate of IV fluid therapy errors in the infectious diseases wards. In the teaching hospitals such as ours, medical interns and residents are partly responsible for patients' care. Infectious diseases management in patients is the main service in infectious diseases wards that can cause lack of awareness of health-care providers about other aspects of patients' problems including fluid therapy.

The main limitation of the study is that the patients' fluid therapy information was collected from their medical charts. Our findings need to be confirmed in a prospective controlled study. Also, we did not follow the patients for consequences of fluid therapy errors.

Conclusion

The result showed that fluid therapy errors occurred commonly in the hospitalized patients in medical wards. Improvement in knowledge and attention of health-care workers about importance of initial patients' volume status assessment, indication for fluid therapy interventions, criteria for selection of appropriate type of fluid, characteristics of available fluids and electrolytes formulary in the wards and hospital and close monitoring of patients' hemodynamic and laboratory parameters are essential for the prevention of medication errors in the area of patients'

fluid therapy. It also must be kept in mind that administration of any intravenous fluid should be considered an invasive procedure that required patients' close monitoring. Preparing local fluid therapy protocol and establishment of educational programs are recommended for the teaching hospitals.

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Conflicts of interest There is no conflict of interest to declare.

Appendix: Infectious diseases Ward's fluid therapy protocol

See Tables 6 and 7.

Table 6 Patients' volume status assessment and recommended approach

Hypovolemia[a]	Hypervolemia[a]	Euvolemia[a] (including NPO patient)	Patient who are eating/ drinking normally
Signs and symptoms	*Sign and symptoms* Ascites, pulmonary edema, CHF	*Fluid therapy recommendation*	No need for fluids if they are taking PO without problems
Hypotension, tachycardia, BUN/Cr > 20, Urine Na < 20 mEq/L, FENa < 1%, Urine osmolality > 450 mOsm/kgH_2O, oliguria (UO < 3 mL/kg over 6 h or less than 400 mL/24 h), skin turgor, dry mucosal membranes	*Fluid therapy recommendation*	For 6–12 h, consider 1/3 Saline-2/3 dextrose at 75–100 mL/h	Avoid intravenous fluids
Fluid therapy recommendation	Avoid additional intravenous fluid	For longer time, normal Saline	
Normonatremic and mildly hyponatremic patients	Maintain IV access with heparin lock		
Always use normal saline			
Severe hyponatremia (Na < 110)			
Hypertonic Saline (3 & 5%)			
Hypernatremic patient[b]			
Half saline or Dextrose 5%			
Significant hemorrhage, anemia or intravascular volume depletion			
Blood transfusions or colloids (albumin/dextran)			
Rate of fluid administration			
100–200 mL bolus to reestablish intravascular volume then			
75–100 mL/h			

Patients' volume status assessment based on patients' VS, hemodynamic parameters, intake and output, serum and urine electrolyte and biochemistry, and renal function tests

VS vital sign, *BUN* blood urea nitrogen, *Cr* creatinine, *FENa* fraction excretion of sodium, *UO* urine output, *CHF* congestive heart failure, *NPO* nil by mouth, *PO* per-oral

[a] Based on volume status assessment, patient will be categorized as hypovolemic, hypervolemic or normovolemic, and following approaches for fluid therapy indication, type and rate of administration are recommended

[b] Rate of sodium correction in hypernatremic patients: For asymptomatic patients, the rate of correction probably should not exceed changes of 0.5 mEq/L/h in plasma sodium. A rule of thumb is to replace half the calculated deficit with hypotonic solutions over 12–24 h. The remaining deficit can then be replaced over the ensuing 24–48 h

Table 7 Estimation of patients' water and sodium deficit

Na deficit: Total body water × (desired serum Na–actual serum Na)

Recommended rate of patient serum sodium correction: 1/3 was calculated deficit over 0.5 meq/l/h and remainder over 8–12 h

Free water deficit = Total body water × [(current serum Na/desired serum Na) − 1]

Total water deficit = Total body water × [1-(140/actual serum sodium)]

Recommended rate of water deficit correction: Administer deficit over 48–72 h (approximately 50–250 mL/h)

Insensible losses: Approximately 10 mL/kg per day: less if ventilated, more if febrile.

Estimation of the total body water (%) with respect to sex and age group

Age	Male	Female
Child	0.6	0.6
Adult	0.6	0.5
Elderly	0.5	0.45

Examples

Calculation of Na deficit for an adult male patient (70 kg) with serum sodium concentration of 126 meq/L

Na deficit: Total body water × (desired serum Na–actual serum Na) = 0.6 × 70 × (135–126) = 378 meq/L

Calculated free and total water deficit for an adult male patient (70 kg) with serum sodium concentration of 156 meq/L

Free water deficit = total body water × [(current serum Na/desired serum Na) − 1] = 0.6 × 70 × [(156–145) − 1] = 420 mL

Total water deficit = total body water × [1-(140/actual serum sodium)] = 0.6 × 70 × [1-(140/156)] = 4,200 mL (4.2 L)

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