

Research Article

# Development of an evidence-based checklist to evaluate dehydration in older patients admitted to a Bahamian Hospital

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## Abstract

**Objective:** To develop standards for dehydration management, and to evaluate these in a survey of older patients presenting to Princess Margaret Hospital (PMH) in Nassau, The Bahamas.

**Research design and methods:** We developed a checklist of evidence-based standards for the diagnosis and management of dehydration. We then used these in a review of the medical records of all 240 patients aged 65 years or older who were treated for dehydration in the Emergency Department (ED) of PMH between 1 January and 31 December 2013.

**Results:** The mean patient age was  $77.9 \pm 8.5$  years, and 148 (61.7%) were women. Dehydration was the principal diagnosis in 110 (45.8%) and the secondary diagnosis in 130 (54.2%). Only 31 patients (12.9%) were recorded as having been assessed for weight loss, 3 (1.3%) for orthostatic hypotension, 15 (6.3%) for skin turgor, 118 (49.2%) for tongue and eyelid dryness, and none for axillary moisture. Serum osmolality, sodium, BUN, and creatinine were ordered for 231 patients (97.1%), but urine specific gravity tests for just 111 (46.3%). Fluid resuscitation was performed using normal saline (216 patients), Lactated Ringer's (2 patients), or other fluids (22 patients). The impact of dehydration is clear from our observation that 10 patients (4.2%) died in the ED, 130 (54.2%) needed admission to medical wards, and only 110 (45.8%) were discharged home.

**Conclusions:** Substantial differences in the clinical assessment and management of dehydration were highlighted using this checklist of evidence-based standards. These may reflect a lack of standardization of protocols, and other units might consider adoption of this checklist to guide the diagnosis and treatment of dehydration in older patients.

## Introduction

Dehydration is a common disorder resulting in a considerable number of emergency admissions in Bahamian older patients. Each year, a substantial number of dehydrated older patients are admitted to the emergency room at the Princess Margaret Hospital (PMH), located in Nassau, The Bahamas [1]. Older people frequently present with both chronic and acute and episodic illnesses, which can lead to excessive water loss [2]. Dehydration has been reported as a primary diagnosis and has also occurred secondary to other diagnoses. Arriving at the proper diagnosis is critical as it significantly affects therapeutic management.

In this study, we investigated the diagnostic procedures and therapeutic management of dehydration in older patients admitted to PMH and compared PMH's practices to standard, evidence-based care. A comprehensive literature review was performed and a checklist of best practice has been created using Level I evidence, which offers the highest-quality, unbiased information available, to deliver the optimum standard of care [3]. We then present findings describing why the approaches taken by the evidence-based standards can be used as a practical guide in the management of dehydration in older people.

## Methodology and procedures

### Study design

We performed a retrospective medical record review and collected data regarding the management of dehydrated older patients who presented to the emergency department (ED) of PMH between 1<sup>st</sup> Jan-31<sup>st</sup> Dec 2013. The clinical practices recorded in the records were compared with a checklist containing evidence-based standards of dehydration management.

### Setting

The research was conducted at PMH, a tertiary-care public hospital associated with the University of the West Indies School of Medicine.

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PMH is located in a busy, urban community of New Providence, The Bahamas.

### Research participants

All patients aged 65 years or older who were admitted to the ED of PMH between 1 January and 31 December 2013 with either a principal diagnosis of dehydration or dehydration secondary to an underlying disease were included in the study.

### Data collection

The protocol was approved by the combined Public Hospitals Authority and University of the West Indies Ethics Committee and by PMH hospital administration. The Statistical Department of PMH generated a list of all patients aged 65 years and older admitted to the ED with a diagnosis of dehydration (principal or secondary) during the study period. Diagnoses were coded using the ICD-9 (International Classification of Disease 9<sup>th</sup> revision) system and the following outcomes were collated: (1) discharged from the ED, (2) admitted to a hospital ward, or (3) died prior to discharge. The patient's encounter sheet was reviewed to (1) determine if the evaluator inquired about a history of weight loss, (2) evaluate the physical examinations performed, (3) determine the type of laboratory tests ordered, and (4) investigate the type of fluid used for resuscitation. A principal diagnosis of dehydration was assigned when it was the first diagnosis listed or the only identifiable diagnosis in the assessment section of the patient's encounter sheet; and a secondary diagnosis of dehydration was assigned when it was listed as subsequent to another disorder [4].

### Data management

In total, 283 cases were diagnosed with dehydration based on ICD-9 codes. Only 242 (86%) of the charts were retrieved, and the remainder (14%) was classified as missing data. The diagnosis did not match the diagnosis entered on the patient encounter sheet in two cases, and these cases were classified as conflicting data. Missing data and conflicting data were excluded from the study.

### Measurements

We evaluated diagnosis and treatment of dehydration across four domains of clinical practice: history taking, physical examination, laboratory tests, and therapeutic management. A comprehensive literature review was conducted to identify relevant evidence-based standards for each domain. PMH's performance was compared at the domain-level with the selected evidence-based standards. We aimed to identify any differences between PMH's practices and evidence-based standards and reveal the root causes of any variations.

To compare history taking and physical examination performance, we used guidelines defined by Gross et al. [5]. To compare the appropriate use of laboratory tests to diagnose dehydration, we used guidelines set by Faes et al. (serum osmolality, creatinine, and BUN), Oppliger et al. (urine specific gravity >1.030), and Sarhill (sodium levels) [6-8]. To compare the therapeutic management of dehydrated patients, we used Recommendation 1 of the British Consensus Guidelines on Intravenous Fluid Therapy for Adult Surgical Patients [9].

### Data analysis

This study primarily reported data as descriptive statistics. Central tendency measures were used, and data dispersion was presented as ranges and standard deviation for continuous variables (e.g., age). Categorical variables were summarized using frequency tables.

These variables included patient sex, history, physical examination findings, types of laboratory tests ordered, and types of fluids used for resuscitation. Study analyses were performed using IBM SPSS Statistic 20.0.

The primary endpoint of this study was dehydration diagnostic accuracy. A checklist of best practice was used to assess PMH's rate of compliance compared against selected evidence-based standards. Four domains of clinical practice are included in this checklist: namely, history, physical examination, laboratory investigations and therapeutic managements.

## Results

A total of 6,818 adults aged 65 years and older were admitted to the ED of PMH between 1 January and 31 December 2013. In terms of sex, 2,911 were males and 3,907 were females. Of these, 283 (4.2%) patients were treated for dehydration, and 240 cases met the inclusion criteria for the analysis.

### Demographic characteristics and diagnoses

Demographic characteristics of the population along with patients' outcomes are presented in table 2. There were more women 148 (61.7%) than men 92 (38.3%) treated for dehydration and the majority of the patients treated 130 (54.2%) were admitted to PMH's medical wards.

The patients' diagnoses are summarized in tables 3 and 4. Dehydration was the principal diagnosis in 110 cases (45.8%). Table 3 shows the type and severity of dehydration.

Severity based on serum Na conc. in mmol/L: Mild >145 and ≤150, Moderate >150 and ≤155, Severe >155 [10]. Patients with dehydration as the secondary diagnosis are shown in table 4. Several cases had multiple comorbidities contributing to dehydration.

### Evaluation of history taking and physical examination practices

Table 5 summarizes the findings from our evaluation of history taking, physical examination and laboratory tests practices used at PMH based on the evidence-based standards outlined previously.

### Evaluation of therapeutic management practices

We also investigated the types of fluids used to correct dehydration. Only two patients (0.8%) were given LR solution, recommended by the British Consensus Guidelines on Intravenous Fluid Therapy for Adult Surgical Patients. Conversely, 90% of patients were given normal

**Table 1.** Checklist of best practice.

	Parameters to be documented	Normal Values
<b>History</b>	Weight loss of 3% from baseline	
<b>Physical Examination</b>	Orthostatic hypotension	
	Loss of skin turgor	
	Absence of axillary moisture	
	Eyelid dryness	
	Tongue dryness	
<b>Investigations</b>	Urine specific gravity	1.000–1.030
	Serum osmolality	275–295 mosm/kg (mmol/kg)
	Serum creatinine	0.7–1.3 mg/dL (50–110 μmol/L)
	BUN	7–20 mg/dL (2.1–8.0 mmol/L)
	Serum Na	135 - 145 mEq/liter (mmol/L).
<b>Management</b>	Balanced Electrolyte Soln.	

**Table 2.** Demographics characteristics of the population & patient outcomes.

Variable	Total Population (N=240)
Age, (mean $\pm$ SD)	77.9 $\pm$ 8.5
Age, (range)	65–102
Sex, n (%)	
Male	92 (38.3)
Female	148 (61.7)
<b>Summary of Patient Outcomes</b>	
Outcome	Total Population, n (%) (N=240)
Admitted	130 (54.2)
Died	10 (4.2)
Discharged	100 (41.7)

**Table 3.** Summary of cases with dehydration as the principal diagnosis.

Type	Total Population, n (%) (N=110)
Hypernatraemic	8 (7.3)
Hyponatraemic	6 (5.5)
Unspecified	96 (87.3)
<b>Severity</b>	
Mild	7 (6.4)
Moderate	11 (10.0)
Severe	7 (6.4)
Unspecified	85 (77.2)

**Table 4.** Summary of comorbidities in patients with dehydration as a secondary diagnosis.

Comorbidities	Total Population, n (%) (N=130)
Constipation	7 (5.4)
Fever	2 (1.5)
Decubitus ulcers	17 (13.0)
Uncontrolled diabetes	35 (26.9)
Malignancy	29 (22.3)
Pneumonia	51 (39.2)
Gastrointestinal conditions	25 (19.2)
Bowel obstruction	3 (2.3)
Sepsis	47 (36.2)
Dementia/delirium	12 (9.2)
Other	43 (33.1)

**Table 5.** Frequency of adherence to standards for history taking, physical examination and laboratory tests practices.

Standards	Frequency, n (%) (N=240)
<b>History</b>	
Weight loss of 3% baseline	31 (12.9)
<b>Clinical Examination</b>	
Orthostatic BP	3 (1.3)
Skin Turgor	15 (6.3)
Axillary moisture	0 (0.0)
Eyelid dryness	118 (49.2)
Tongue dryness	118 (49.2)
<b>Biochemical Markers</b>	
Urine specific gravity	111 (46.3)
Serum Osmolarity	233 (97.1)
Serum creatinine	233 (97.1)
BUN	233 (97.1)
Serum Na	233 (97.1)

saline, and 9.2% were given other forms of fluid therapy, including 5% dextrose plus 0.45% NS solution and 5% dextrose solution.

## Discussion

This study demonstrates the clinical utility of an evidence-

based checklist for the diagnosis and management of dehydration in older patients. A retrospective review of medical records was performed, comparing the management of dehydration in older subjects by physicians in the emergency department of PMH to that of evidence-based standards. The results demonstrated a substantial difference between clinical practices at PMH and selected evidence-based standards. However, despite these differences, the protocols implemented at PMH are generally in harmony with most evidence-based practices and patient outcomes compare favorably with larger centers [11]. Even though our study was restricted to the older segment of the population, these are important national data owing to the fact that the results of the 2010 Bahamas Census show that Bahamians are living longer compared to previous years [12]. To our knowledge, this is the first and only such study conducted among older dehydrated patients in the Bahamas.

Dehydrated patients generally present with a constellation of symptoms attributable to depletion of both the intracellular and extracellular fluid volumes. Having a focused protocol to guide history, physical examination, laboratory investigations and fluid resuscitation is a useful tool in this regard. To facilitate this, each of the four domains mentioned was assessed by comparing how closely PMH performed based on available evidence. A comprehensive literature review was conducted in order to choose relevant standards by which each domain can be accurately compared.

## History, physical examination and laboratory findings

The demographic data of this study has shown a disproportionate number of admissions of males vs. females presenting with dehydration. The higher number of females observed in this study reflects the status quo of clinic visits and hospital admissions by sex in the Bahamas. That is, females of every age strata in the Bahamas attend physicians much more than their male counterparts. This is similarly reflected in the geriatric population as demonstrated by the collected data.

In terms of +history taking, weight loss was only recorded in 31 (12.9%) of the medical records reviewed (Table 5). Gross et al. showed that a history of 3% weight loss from baseline is a significant indicator of dehydration [5]. The minimal documentation of this critical clinical parameter suggests that a history of weight loss is commonly ignored. It also highlights the importance of documenting pertinent negatives as well as positives when diagnoses are highly dependent upon history. Another area of inadequate documentation was demonstrated in the measurement of orthostatic hypotension which is known to be an important feature of dehydration [5]. This examination was only documented in three patients (Table 5). The lack of documentation could be related to mobility issues in this age group or dehydration-related weakness and lethargy, all of which can hinder assessment of standing and sitting blood pressures.

Laboratory tests were ordered for the majority of the cases reviewed (Table 5). Measuring biochemical parameters, such as serum sodium, osmolality, and urine specific gravity, can aid in dehydration diagnosis [5-8,13,14]. Where laboratory data is missing, diagnosis was made based on clinical observations, such as hypotension, eyelid or tongue dryness, and decreased skin turgor. Additionally, while the evidence-based standards were not documented in all dehydrated patient records, certain terms, such as lethargy, weakness, “ashy” skin, cachexia, muscle wasting, and sunken orbits, appeared frequently. These factors may have precluded the need for biochemical analysis. The least-used laboratory test was urine specific gravity, likely due to decreased urine output in these dehydrated patients [15].

## Decisions regarding therapeutic management

Choosing the best fluid to resuscitate elderly patients can present challenges. While normal saline was the fluid of choice for most physicians at PMH, it has been associated with decreased renal perfusion and hyperchloraemic metabolic acidosis induction [16-20]. As a result, we used Recommendation 1 of the British Consensus Guidelines on Intravenous Fluid Therapy for Adult Surgical Patients for our evidence-based standard. Recommendation 1 states “*Because of the risk of inducing hyperchloraemic acidosis in routine practice, when crystalloid resuscitation or replacement is indicated, balanced salt solutions e.g. Ringer’s lactate/acetate or Hartmann’s solution should replace 0.9% saline*” [9].

While some authors express conflicting views on this issue, there is overwhelming evidence supporting the benefits of LR over normal saline [21,22]. For example, one study evaluating the post-surgical outcome of patients undergoing repair of abdominal aortic aneurysm found that patients receiving copious amount of intra-operative normal saline developed more hyperchloremic acidosis and received larger volumes of transfused platelets compared to patients receiving LR [23]. Furthermore, the use of LR has been shown to reduce the occurrence of systemic inflammatory response syndrome and CRP levels in patients diagnosed with acute pancreatitis [24].

Wilkes *et al.* (2001) further highlighted the benefits of balanced electrolyte solutions. This study observed that infusion of balanced electrolyte solutions, such as Hartmann’s, was associated with a lower incidence of hyperchloraemic metabolic acidosis, and these solutions were able to maintain adequate mucosal perfusion more efficiently than normal saline [20]. Addition of a weak organic acid, such as lactate, to normal saline creates a “balanced” crystalloid solution that theoretically minimizes the risk of developing acidosis [25].

Finally, Williams *et al.* compared the effects of intravenous LR with a 0.9% sodium chloride solution on 18 healthy volunteers aged 20-48 years [26]. Subjects infused with normal saline had significantly increased serum osmolality, decreased blood pH, abdominal discomfort, and increased time to first urination. How these data relate to older, predominantly black Bahamians warrants further investigation, as NS has been used successfully at PMH as the first line therapy for managing dehydration with little to no recorded adverse events in this population.

## Patient outcomes

More than half of the patients were admitted to a hospital ward for further management, and several died in the ED (Table 2). Thirty-seven of the admitted patients and half of the patients who died had one or more prior visits to the ED for dehydration. It is unclear whether the dehydration severity was the primary contributing factor in hospital admission or death, because severity was largely unspecified (Table 3). However, it is clear that more people were diagnosed with dehydration secondary to another condition than those who were diagnosed with dehydration as the primary condition (Table 3,4).

Similar findings were made by Warren *et al.* who showed that 6.7% of hospital admissions of elderly patients in the United States included a diagnosis of dehydration, but only 1.4% listed dehydration as the primary diagnosis while dehydration was secondary to some other cause [11]. Pneumonia, sepsis, diabetes, and malignancies were among the comorbidities, and 17.4% of all patients with dehydration diagnoses died within 30 days of diagnosis.

## Recommendations

This study examines the feasibility of using a checklist containing evidence-based standards for the management of dehydration in older patients. It compares dehydration management of older patients in the ED of PMH with these standards, determines the clinical applications of these standards, and based on the foregoing, the authors have provided specific management recommendations. All of the selected standards contain Level I evidence [3].

The following are the key recommendations of this study. For history and physical examination, we recommend the guidelines set by Gross *et al.* [5]. Specifically, they show that a weight loss of about 3%, orthostatic blood pressure readings, skin turgor, axillary moisture and eyelid and tongue should be examined in all suspected patients. We recommend the use of the guidelines set by several authors who have proven that biochemical markers are important factors in the diagnosis of dehydration. In particular, serum osmolality as well as the BUN and creatinine gives an indication of the tonicity, whilst serum sodium is paramount in describing the type of dehydration (e.g. hypo- or hypernatremic). Additionally, a urine specific gravity of greater than 1.030 is a sensitive indicator dehydration [6-8,13,14].

Finally, in regards to therapeutic management of dehydrated patients, the authors agree with Recommendation 1 of the British Consensus Guidelines on Intravenous Therapy for Adult Surgical patients, which recommends the use of balanced electrolyte solutions for fluid therapy [9]. In direct contrast, we suggest against the use of normal saline as substantial evidence has shown the development of hyperchloremic metabolic acidosis when normal saline solution is used to resuscitate dehydrated patients [17,18,19].

One pertinent question that has arisen from this review is: would the admission and mortality rates have been lower if every case had been assessed entirely using the selected evidence-based standards indexed in the checklist? While further studies with more focused documentation of the severity of dehydration might answer these questions, it is clear that consistent utilization of all four domains is essential for the proper management of dehydration and improved patient outcome.

## Conclusions

To our knowledge, this study is the first to describe dehydration management in older patients seeking treatment at the ED of PMH. In order to evaluate and analyze the collected data, we developed a checklist in which actual clinical practice could be compared with selected evidence-based standards. PMH did not entirely perform all of the elements included on the checklist. However, the significance of this difference is difficult to interpret, because the sample size was relatively small, and the administrative guidelines and protocols currently used at PMH are different from those outlined by the selected standards. With the exception of axillary moisture, all of the evidence-based standard parameters were performed at PMH. It is imperative that physicians managing dehydrated older patients apply evidence-based practices in their diagnoses and treatments in order to achieve the best possible clinical outcomes.

Managing dehydration in older patients requires knowledge of both the physiology and the fluid and electrolyte requirements of these individuals. Once recognized, a methodical system using evidence-based standards should be employed to guide management. A well-researched algorithm supported by strong clinical evidence can be a helpful tool in centers such as PMH. A checklist indexing the



requirements for proper diagnosis and therapeutic intervention can be modified to meet the needs of individual institutions. Itemizing each element of the four domains may improve diagnostic accuracy as well as provide a means that minimizes the potential of overlooking pertinent findings. Since the checklist used in this study has currently not been implemented at PMH, its usefulness in diagnosing and treating dehydration in older patients, has not yet been established. A prospective trial investigating its benefits may yield more valuable information.

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## References

1. Statistical Department. Princess Margaret Hospital, Emergency Department, Casualty Records: 2010 - 2013. Nassau: Princess Margaret Hospital; 2014.
2. Schols JM, De Groot CP, van der Cammen TJ, Olde Rikkert MG (2009) Preventing and Treating Dehydration in the Elderly during Periods of Illness and Warm Weather. *J Nutr Health Aging* 13: 150-157. [[Crossref](#)]
3. Sackett DL, Rosenberg WM, Gray JA, Haynes RB, Richardson WS (1996) Evidence based medicine: what it is and what it isn't. *BMJ* 312: 71-72. [[Crossref](#)]
4. Xiao H, Barber J, Campbell E (2004) Economic burden of dehydration among hospitalized elderly patients. *Am J Health Syst Pharm* 61: 2534-2540. [[Crossref](#)]
5. Gross CR, Lindquist RD, Woolley AC, Granieri R, Allard K, et al. (1992) Clinical indicators of dehydration severity in elderly patients. *J Emerg Med* 10: 267-274. [[Crossref](#)]
6. Faes MC, Spigt MG, Olde Rikkert MG (2007) Dehydration in geriatrics. *Geriatrics and Aging* 10: 590-596.
7. Oppliger RA, Magnes SA, Popowski LA, Gisolfi CV (2005) Accuracy of urine specific gravity and osmolality as indicators of hydration status. *Int J Sport Nutr Exerc Metab* 15: 236-251. [[Crossref](#)]
8. Sarhill N, Walsh D, Nelson K, Davis M (2001) Evaluation and treatment of cancer-related fluid deficits: volume depletion & dehydration. *Supportive Care Cancer* 9: 408-419. [[Crossref](#)]
9. Powell-Tuck J, Gosling P, Lobo D, Allison S, Carlson G, et al. (2009) British consensus guidelines on intravenous fluid therapy for adult surgical patients (GIFTASUP). London: NHS National Library of Health.
10. Darmon M, Timsit J, Fancais A, Nguile-Makao M, Adrie C, et al. (2010) Association between hypernatraemia acquired in the ICU and mortality: a cohort study. *Nephrol Dial Transplant* 25: 2510-2515.
11. Warren JL, Bacon WE, Harris T, McBean AM, Foley DJ, et al. (1994) The burden and outcomes associated with dehydration among US elderly, 1991. *Am J Public Health* 84: 1265-1269. [[Crossref](#)]
12. Department of Statistics. Census of Population and Housing 2010, the Commonwealth of the Bahamas. Nassau: Bahamas Government Printing Dept; 2012.
13. Berk L, Rana S (2006) Hypovolemia and dehydration in the oncology patient. *J Support Oncol* 4: 447-454. [[Crossref](#)]
14. Thomas DR, Cote TR, Lawhorne L, Levenson SA, Rubenstein LZ, et al. (2008) Understanding clinical dehydration and its treatment. *J Am Med Dir Assoc* 9: 292-301. [[Crossref](#)]
15. El-Sharkawy AM, Sahota O, Maughan RJ, Lobo DN (2014) The pathophysiology of fluid and electrolyte balance in the older adult surgical patient. *Clin Nutr* 33: 6-13. [[Crossref](#)]
16. Chowdhury A, Cox E, Francis S, Lobo D (2012) A randomized, controlled, double-blind crossover study on the effects of 2-L infusions of 0.9% saline and plasma-lyte® 148 on renal blood flow velocity and renal cortical tissue perfusion in healthy volunteers. *Ann Surg* 256: 18-24. [[Crossref](#)]
17. Mahler S, Conrad S, Wang H, Arnold T (2011) Resuscitation with balanced electrolyte solution prevents hyperchloremic metabolic acidosis in patients with diabetic ketoacidosis. *Am J Emerg Med* 29: 670-674. [[Crossref](#)]
18. Kellum JA (2002) Saline-induced hyperchloremic metabolic acidosis. *Crit Care Med* 30: 259-261. [[Crossref](#)]
19. Prough D, Bidani A (1995) Hyperchloremic metabolic acidosis is a predictable consequence of intraoperative infusion of 0.9% saline. *Anesthesiology* 90: 1247-1249. [[Crossref](#)]
20. Wilkes N, Woolf R, Mutch M, Mallett, Peachey T, et al. (2001) The effects of balanced versus saline-based hetastarch and crystalloid solutions on acid-base and electrolyte status and gastric mucosal perfusion in elderly surgical patients. *Anesth Analg* 93: 811-816. [[Crossref](#)]
21. Hagihara A, Hasegawa M, Abe T, Wakata Y, Nagata T, et al. (2013) Prehospital lactated ringer's solution treatment and survival in out-of-hospital cardiac arrest: a prospective cohort analysis. *PLoS Med* 10: 1001394. [[Crossref](#)]
22. Orbegozo Cortés D, Rayo Bonor A, Vincent JL (2014) Isotonic crystalloid solutions: a structured review of the literature. *Br J Anaesth* 112: 968-981. [[Crossref](#)]
23. Waters J, Gottlieb A, Schoenwald P, Popovich M, Sprung J, et al. (2001) Normal saline versus lactated Ringer's solution for intraoperative fluid management in patients undergoing abdominal aortic aneurysm repair: an outcome study. *Anesth Analg* 93: 817-822. [[Crossref](#)]
24. Wu B, Hwang J, Gardner T, Repas K, Delee R, et al. (2011) Lactated Ringer's solution reduces systemic inflammation compared with saline in patients with acute pancreatitis. *Clin Gastroenterol Hepatol* 9: 710-717. [[Crossref](#)]
25. Tavernier B, Faivre S, Bourdon C (2010) Hyperchloremic acidosis during plasma expansion. *Transfusion Alternatives in Transfusion Medicine* 11: 3-9.
26. Williams E, Hildebrand K, McCormick S, Bedel M (1999) The effect of intravenous lactated Ringer's solution versus 0.9% sodium chloride solution on serum osmolality in human volunteers. *Anesth Analg* 88: 999-1003. [[Crossref](#)]