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RESEARCH ARTICLE

Dehydration Prevention and Diagnosis: A Study in Long-Term Geriatric and Palliative Care

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Abstract

Background: Diagnosing dehydration in frail older persons is challenging.

Objective: In residents of long-term geriatric and palliative care to appraise which clinical signs and laboratory data are associated with dehydration.

Methods: Study Part I is a cross-sectional point of care assessment of data which might distinguish dehydrated from euhydrated subjects. Twelve potential markers of dehydration were evaluated: inadequate fluid intake, vomiting, diarrhea, bleeding, diuretic treatment, serum sodium, serum urea and creatinine, urea/creatinine ratio, estimated glomerular filtration rate, hemoglobin and serum albumin. Study Part II is a longitudinal survey of patients at risk of dehydration under changing clinical conditions. He clinical and laboratory data were prospectively followed and related to the patients' hydration state.

Results: By point-of-care assessment (Study Part I) no single clinical or laboratory parameter correlated with dehydration. On longitudinal survey (Study Part II), useful in the diagnosing of dehydration were patient history corroborated with clinical and laboratory parameters designed 'potential markers of dehydration'. Seven case studies illustrate a variety of scenarios under which dehydration may occur.

Conclusions: Diagnosing dehydration in residents of long-term geriatric and palliative care is challenging. Useful to this aim are the day-to-day examination of the patient by the same clinician, with or without the support of conventional 'laboratory markers of dehydration'. Overemphasis and dependence on laboratory markers may be mislead the physician.

Keywords

Dehydration diagnosis, Frailty, Hypernatremia, Hyperosmolality, Renal function tests

Abbreviations

BUN: Blood Urea Nitrogen; eGFR: estimated Glomerular Filtration Rate

Introduction

Dehydration is a general term used to describe any type of fluid loss. Loss of water and salt loss may occur concurrently or independently. Water is lost in the urine, feces, exhaled air, and skin by perspiration. Water loss is replenished by oral intake of fluids and food. The gastrointestinal tract normally absorbs up to 9 L of fluid from diet and endogenous secretions. Ninety percent of water is absorbed in the small bowel and the remainder in the large bowel. Water homeostasis is controlled by the sensation of thirst along with reabsorption of water in the kidneys. Thirst provides the ultimate defense against dehydration assuming the ability to access water. Reabsorption of water in the kidneys is regulated by the antidiuretic hormone, aldosterone and natriuretic peptides. Older adults are disposed to fluid and electrolyte loss due to a blunted thirst response, reduction in renal function, and their 10-15% less total body water [1-4].

Dehydration may occur under low food and fluid intake or under excessive fluid loss. Water intake may be deficient under conditions of disease, in elderly subjects with infirmity, cognitive deficits, altered mental status, dependent on others for their water requirements. Water intake may be deficient under poor fluid manage-

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ment also in hospitalized patients [2]. Excessive fluid loss may occur through vomiting, diarrhea, high output intestinal fistula, ileus (intestinal pooling), fever (sweat and increased insensible fluid loss by hyperventilation), polyuria (effect of diuretics, post-obstructive polyuria, diabetes mellitus, diabetes insipidus, salt losing nephropathy) [1-4]. Among older people living in nursing homes dehydration is highly prevalent. The most common risk factors for dehydration are advanced age, infections, end of life and dementia [5]. Certain medications may enhance the risk of dehydration and are among the modifiable risk factors, but the majority of dehydration risk factors are unmodifiable [5].

There are different patterns of dehydration, depending on the causes of volume loss [3]. "Dry dehydration" is secondary to a negative water balance, while "wet dehydration" results from water redistribution [3,6,7]. The hypernatremic-hyperosmotic variant of dehydration is prevalent in the older subjects, those who cannot experience thirst or respond to thirst due to impaired mental status, but hypernatremic-hyperosmotic dehydration also occurs in enteral fed patients who are not provided sufficient fluids, in patients needing parenteral hydration but not adequately supplied, sometimes in patients with uncontrolled diabetes mellitus or diabetics receiving SGLT2 medication, as well as in patients with uncontrolled diabetes insipidus [6]. The prevalence of hypernatremia among older subjects varies: 3.7% in older patients living in the community [4], 2% among older patients admitted to hospital [8] and 15% of older patients admitted to hospital developed hypernatremia during hospitalization [9]. In a long-term care facility 20% of residents (mean age 86 years) were diagnosed with current dehydration based on serum osmolality > 300 mOsm/L [10].

Clinical signs of dehydration include a dry mouth, inelastic skin, sunken eyes, though these features are not specific but in the extreme phase. Few symptoms may be present until sodium level exceeds 160 mmol/L [2,6,11]. Among laboratory features, hemoconcentration translates into hypernatremia, hyperosmolality, increased hematocrit and increased serum albumin; hypovolemia-induced impairment of renal function may produce a urea: creatinine ratio > 40. Neither is specific nor sensitive for the diagnosis of dehydration [11,12]. On the other hand, symptoms and signs caused by dehydration are often attributed, mistakenly, to other causes. In the absence of a validated hydration assessment tool dehydration is often under diagnosed. For now, skilled use by an experienced clinician of the patient history, physical examination, and certain laboratory values are the best means for diagnosing dehydration [13,14]. Most studies of dehydration diagnosis came from acute hospital settings [11,14]. It is unknown whether data from those studies are applicable to geriatric long-term and palliative care. The present study aimed to answer the question. Study Part I is as a cross-sectional appraisal of clinical and laboratory data which might distinguish dehydrated from euvolemic patients. Study Part II is a longitudinal survey of patients considered to be at risk of dehydration. To this aim, changing clinical features and laboratory data were confronted with the physicians' intuition of dehydration.

Study Part I. Comparison of Clinical and Laboratory Data in Dehydrated Vs. Euvolemic Patients: Cross-Sectional Assessment

Objective: To assess clinical signs and laboratory data associated with dehydration in residents of long-term geriatric and palliative care.

Methods: All residents who were institutionalized on study day for comprehensive nursing or palliative care were screened for being suitable to the study. Residents who satisfied inclusion criteria, i.e. availability of all the data listed under 'study parameters' were included. Excluded were patients in end-of-life condition and those who needed urgent referred to an acute care hospital. The following data were labeled 'study parameters': inadequate fluid intake (based on estimated fluid balance) [1], vomiting (twice or more on the day preceding study-day and needing parenteral administration of fluid), diarrhea (three or more stools on the day preceding study-day), bleeding (needing blood transfusion on the day preceding study-day), ongoing diuretic treatment, serum sodium, serum urea, serum creatinine, serum urea: creatinine ratio, estimated glomerular filtration rate, hemoglobin and serum albumin. The patient's hydration status - dehydrated or euvolemic - was judged according to clinical best standard, i.e. based on skilled clinician's impression making use of the patient history, clinical context, fluid balance, changes on physical examination, and shifts in laboratory data [13,14]. Patients diagnosed to be dehydrated constitute group A and patients considered to be euvolemic constitute group B. The point prevalence of 'study parameters' was compared between the two groups. Statistical analysis used the Stata Statistical Software Release 13 (StataCorp LP, College Station, TX). Normally distributed data were presented as means and standard deviations (SD) and the independent samples t-test was used to assess for statistically significant differences. Chi squared analysis was used to assess for statistically significant differences between categorical variables. $P < 0.05$ was considered statistically significant.

Results: Sixty-four out of 79 residents satisfied the inclusion criteria. Their clinical background was divers within the spectrum of dementia, pressure sores, tracheostomy, heart failure, chronic respiratory failure, end-stage cancer, diabetes mellitus, arterial hypertension and mild renal failure (Table 1). Accordingly, the disease- oriented treatments were diverse, including opiates, antiemetics, laxatives, insulin, bronchodilators, antihypertensives, diuretics and antidepressant medications. Fifty-one residents were classified euvolemic

Table 1: Patient's clinical background.

Patient data	Clinically euvolemic (no 51)	Likely dehydrated(no 13)
Age-years	70.3 (SD 12.9)	71.8 (SD 10.8)
Male gender %	63	61
Pressure sores %	41	69
Malignant neoplasm %	25	0
Cachexia %	29	69
Sarcopenia %	37	31
Diabetes mellitus %	27	38
Congestive heart failure %	12	15
COPD %	8	15
Dementia CDR > 1	67	69
Tracheostomy %	47	31
Oral feeding %	49	38
Enteral tube feeding %	51	54*
Systoblic blood pressure (mmHg)	117 (SD 14)	123 (SD 19.6)
Diastolic blood pressure (mmHg)	64.3 (SD 8.9)	66 (SD 5.9)

*Two enteral fed patients had begun oral feeding in parallel.

Table 2: Clinical indicators of possible dehydration.

Patient data	Clinically euvolemic (no 51)	Likely dehydrated (no 13)
Oral fluid intake < 1000 cc (%)	28	31
Diuretic treatment (%)	21	31
Diarrhea (%)	0	23
Vomiting (%)	0	8
Bleeding (%)	0	15

Intergroup differences not significant at $p < 0.05$.

and 13 residents were classified dehydrated. The latter group comprised two patients with liver cirrhosis-associated chronic hepatorenal syndrome, one patient with decompensated liver cirrhosis, two patients in palliative care for terminal stage carcinoma, three patients in palliative care for advanced foot gangrene (amputation refused by patient or proxy), two patients with congestive heart failure and sepsis, one patient who refused feeding, one patient with severe epistaxis and temporary discontinuation of nasogastric tube feeding, one-patient with decompensated type 2 diabetes mellitus (blood sugar 520 mg/Dl). The clinical background of the patients in the two groups differed but not to a statistically significant level (Table 1). Among the candidate clinical parameters of possible dehydration the following were more prevalent in patients classified dehydrated: diuretic treatment, diarrhea, vomiting and bleeding; however, small numbers turned down statistical significance (Table 2). All candidate laboratory markers of dehydration were equally represented in the two groups (Table 3).

Conclusions: Candidate markers of dehydration were similarly represented in the group of likely euvolemic and the group of likely dehydrated subjects. No single point-of-care clinical feature or laboratory test correlated with the clinicians' intuition of dehydration.

Study Part II. Longitudinal Survey of Patients at High Risk of Dehydration

Methods: Study Part II was a prospective longitudinal survey of residents in comprehensive geriatric care or palliative hospice care, those who were considered at high risk of dehydration. Inclusion criteria were the same as for Study Part I. Seven patients out of 15 candidates during a 6 months period satisfied the inclusion criteria. The patients were in our treatment for 42-180 days. Dehydration was diagnosed, as in Study Part I, based on the perception of experienced physicians knowing the patients well on direct, day-to-day follow-up. Clinical and laboratory data were prospectively followed and related to the concomitant hydration status. The concordance between the perceived hydration status and twelve candidate parameters of dehydration, the same as in Study Part I, was assessed prospectively.

Case summaries

Case 1: A 85-year-old woman with vascular dementia, respiratory failure, and tracheostomy was in long-term geriatric care. She suffered several episodes of diarrhea due to clostridium difficile enterocolitis.

Table 3: Candidate laboratory markers of dehydration.

Patient data	Clinically euvolemic (no 51)	Likely dehydrated (no 13)
Serum sodium mEq/L	137.2 (SD 3.2)	137.7 (SD 2.2)
Serum ureamg/Dl	53.8 (SD27)	54.5 (SD 18.9)
Serum creatinine mg/Dl	0.75 (SD 0.5)	0.73 (SD 0.28)
Serum urea creatinine ratio	79.3 (SD 35)	81 (SD 32/9)
Serum urea creatinine ratio > 49% of patients	82	89
eGFR*mL/min/1.73 m^2	92.1 (SD 28.9)	89 (SD 24.7)
Serum albumin g/Dl	3.2 (SD 0.4)	3.07 (SD 0.4)
Blood hemoglobin g/Dl	11.3 (SD 1.4)	10 (SD 1.7)
Hemoglobin recent increase** number of patients	2	2

*eFGR by CKD-EPI formula; **Hemoglobin increase by > 1 g/Dl intergroup differences are not significant at $p < 0.05$.

Table 4: Markers of volume depletion.

Parameter	8.11/016	13.12	12.1.017	15.1	27.2
Blood pressure mmHg	149/61	127/57	125/57	126/67	137/54
Diarrhea	+	+	-	+	-
Hemoglobin g/Dl	12.5	10.1	10.4	9.5	11
S.Sodium mEq/L	135	137	134	136	135
Median glycemia mg/DL*	238	281	264	432	171
Serum osmolality	289	292	291	306	290
S. Creatinine mg/Dl	0.6	0.51	0.51	0.65	0.58
S. Bun mg/Dl	16	8	24	28	30
S. BUN: creatinine	27	16	47	43	51
eGFR mL	84	88	88	81	84
S. creat change** proportional		85	85	108	97
Feeding	Oral	Oral + enteral 1050 cc	Oral + enteral 1350 cc	Oral + enteral 1350 cc	Oral + enteral 1350 cc
Caloric intake	600	1400	1660	1660	1660

*Median of 3 tests on study day **Change relative to value on admission.

Dehydration with hyperosmolality, yet without hypernatremia, developed during diarrhea to which uncontrolled diabetes mellitus probably contributed. During a 4-month period under recurrences of diarrhea the levels of the blood pressure, serum sodium, creatinine and eGFR remained essentially unchanged. Only an increase in the BUN: Creatinine ratio > 20:*1* and hyperosmolality were consistent with dehydration (Table 4). Her treatment included oral vancomycin, enteral and parenteral hydration, and insulin to control glycemia. With resolution of the diarrhea, correction of the fluid status, and better control of diabetes the serum osmolality normalized but not the BUN: Creatinine ratio.

This patient had been at risk of dehydration because of fluid loss under diarrhea, often unsatisfactory oral fluid intake, osmotic diuresis due to hyperglycemia and, likely, age-related homeostenosis. When her BUN: Creatinine ratio became > 20:1, prerenal failure due to dehydration was diagnosed and the patient was treated accordingly. Other possibilities were also considered - increased urea production secondary to gastrointestinal bleeding, tissue breakdown, or glucocorticoid treatment [2,12] - but could be dismissed. The diagnosis of dehydration was also supported by an increase in serum osmolality (306 mOsm/l in January the 15th). Normal values for serum osmolality are 275 - 294 mOsm/L;values 295-300 mOsm/L are classified as impending dehydration; serum osmolality > 300 mOsm/L is consistent with dehydration. Of note, serum osmolality calculated with the equation of Fazekas, which was used in our study, is in good agreement with directly measured osmolality [15-17]. An unchanged natremia in this patient while the serum osmolality increased is explained by intestinal loss of sodium matching the volume loss. Such is observed when diarrhea is the primary cause of dehydration [7].

Case 2: A 72-year-old man in permanent unaware wakefulness state after traumatic brain injury was receiving supportive care inclusive enteral feeding. Frequent vomiting and temporary impediment to enteral feeding, an increased fluid loss during febrile events, a difficult to estimate net fluid intake occurred and were paralleled by increase in hemoglobin, serum creatinine, serum sodium, serum osmolality. These findings were

Table 5: Markers of volume depletion and predictors of renal risk.

Parameter	27.11.2016	11.12	26.12	30.1.2017	12.3
Blood pressure mmHg	124/70	125/63	125/64	134/75	145/80
Hemoglobin g/Dl	10.8	11.9	12.6	11.2	10.6
s.sodium mEa/L	139	142	146	140	139
Blood sugar mg/Dl	140	198	108	142	130
Serum osmolality	295	305	307	297	292
S.Creatinine mg/Dl	0.52	0.66	0.66	0.53	0.53
S.BUN mg/Dl	27	30	27	26	20
S.BUN: creatinine ratio	52	45	41	49	38
eGFR mL	107	97	97	106	106
S.creat change* mg/dL		0.14	0.14	0.01	0.01
S.creat change* %		127	127	107	107
Enteral feeding attempted mL	1300	1300	1300	1300	1300
Caloric intake attempted kcal	1450	1450	1450	1450	1450

*Change relative to value on admission.

consistent with dehydration (Table 5). Other potential markers of dehydration –the blood pressure, BUN, BUN: creatinine ratio - were not affected. On antibiotic treatment, parenteral hydration and metoclopramide as needed, the patient's general state improved, and the laboratory abnormalities were corrected. The diagnosis of dehydration was straightforward: a negative fluid balance, hemoconcentration, altered renal function (though minimal), and restitution to normal of the relevant parameters by fluid administration supported the diagnosis.

Case 3: An 84-year-old man with end-stage Alzheimer's disease was admitted to our institution for treatment of stage 3 pressure ulcers. An incident urinary retention was relieved by insertion of a bladder catheter. In the following, postobstructive polyuria occurred along with sepsis, dehydration and hypernatremia. Under antibiotic treatment and parenteral hydration there was temporary improvement, but a vicious circle of sepsis, renal failure and hypernatremia led to the patient's demise.

Case 4: A 44-year-old woman with breast cancer metastatic to the brain, bones and liver was admitted for palliative hospice care. Metastatic tumor to the spine was the cause of paraplegia and a neurogenic bladder. Her medication included transcutaneous fentanyl 100 mcg/hour, mirtazapine 30 mg/day and bisacodyl 10 mg/day. Repeated obstructions and of an indwelling urinary catheter occurred, followed by post-obstructive polyuria up to 4000 mL/day. Dehydration was expected to ensue and could be prevented by appropriate parenteral hydration. During her short hospitalization the serum sodium and osmolality, urea, creatinine, serum urea: creatinine ratio, and estimated glomerular filtration rate remained within the normal range.

Case 5*:* A 62-year-old man received palliative care for advanced esophageal carcinoma. In his patient, frequent vomiting (unrelieved by metoclopramide), unbalanced oral intake and inconstant acceptance of parenteral hydration were premises for dehydration to occur. Yet, clinical signs of dehydration were not perceived and values of the serum sodium, urea, creatinine, serum urea: creatinine ratio, and estimated glomerular filtration rate remained within the normal range, with near normal serum osmolality (297 mOsm/L).

Case 6: A 46-year-old man in unaware wakefulness state subsequent to traumatic had injury, subdural hemorrhage, cardiac arrest and anoxic brain damage was admitted to for life support. He received enteral nutrition and respiratory care through tracheostomy. The patient's daily medications were phenytoin sodium 200 mg, levetiracetam 1500 mg and bisacodyl 10 mg. During hospitalization in neurosurgery, intensive care and subsequently in palliative care the diuresis was about 3000 mL/day. Hypernatremia was a constant finding in the range of 148-156 mEq/L, urine osmolality was 248 mOsm/L. The clinical setting - polyuria associated with hypernatremia after traumatic brain injury - was suggestive of central diabetes insipidus [18]. The diagnosis was confirmed by normalization of the serum sodium, serum osmolality and diuresis under desmopressin treatment. Awareness to diabetes insipidus as the possible cause of hypernatremia when associated with polyuria may be important, though rarely met in geriatric care.

Case 7: An 84-year-old woman with end-stage Alzheimer's disease was admitted for treatment of stage 3 and 4 pressure sores. She was reluctantly receiving oral feeding. The patient's medications were transcutaneous fentanyl 25 mcg/hour, vitamin D 1000 U/day and bisacodyl 10 mg/day. Unwillingness by the patient's apotropos to accept enteral feeding predisposed her to dehydration, which actually developed during an acute febrile illness, and was associated with hypernatremia.

This case is illustrative of the frequently met situation in long-term geriatric care: dehydration and hypernatremia occurring in patients who are unable to express thirst. Seven case histories illustrate a spectrum of conditions and settings predisposing residents of geriatric or palliative care to dehydration. Awareness to the problem and close observation of the patients by dedicated physicians was important in preventing dehydration or timely diagnosis.

Discussion

Most research concerning diagnosis and treatment of dehydration come from acute hospital settings [1,3,11-13]. Results of the published studies and the present observations bear similarity, though specifics in frail a population with comorbidities in our study had an imprint on the manifestations of dehydration. In the present Study Part I, no symptom or laboratory test on its own was sensitive and specific enough to permit early diagnosis of dehydration (Table 2 and Table 3), as also concluded by others [12,13]. It is the clinical context that made the better to prevent dehydration or for timely dehydration diagnosis [13,14], as illustrated in Study Part II.

The challenge to prevent dehydration and, when it occurs, the difficulty in early diagnosis is widely recognized. Normal vital signs do not exclude a state of volume depletion [1,3,11-14], an understanding confirmed in the present work. Minor consequences of volume depletion - cognitive impairment (may be difficult to recognize in a demented person), delirium, lethargy, tachycardia, hyperpnea - each indicate deterioration in general, but none is specific for dehydration. A blood pressure lower than at baseline may be due to dehydration, but the cause may be infection or a variety of other causes. Orthostatic hypotension while supine blood pressure is unaltered may be a hint to volume loss. The blood pressure should be measured supine and after standing or sitting upright for 5 minutes. A decrease in systolic pressure of 20 mmHg or a decrease in diastolic pressure of 10 mmHg, especially when associated with dizziness or light-headedness, are consistent with the diagnosis of orthostatic hypotension [19]. Yet, bedbound persons might be unable to undergo a standard orthostatic test. Acute renal failure, and acute coronary event, cerebral ischemia, seizures, coma, acidosis, coagulopathy may be caused by dehydration, aggravated by dehydration [20-25] or be unrelated to dehydration. Among biochemical tests there also is no gold standard measure of the hydration status.

Older persons should be considered at risk of low-intake dehydration and be encouraged to consume adequate amounts of fluids [4]. However, studies investigating modifiable factors to increase fluid intake and reduce dehydration in people living in long-term care showed little achievement [26,27]. Any aggravation of an older person's general state may be significant in triggering a search for possible causes, including volume loss. When the diagnosis of dehydration is uncertain, the response to a fluid challenge can be helpful. This is done by infusion of 500 mL of normal saline over 1 to 3 hours. In patients with a normal cardiac reserve, the effect of a fluid challenge may be monitored by evaluating the pulse, blood pressure, and urine output [12-14,27,28]. In the setting of a hospital emergency department, two measures derived by ultrasound have proved to be useful for the diagnosis of dehydration in elderly people: the caval index and the expiratory diameter of the inferior vena cava [29].

There are limitations to the present work. The cross-sectional study is first of this kind, as far as I know in the setting of geriatric and palliative care. Small patient numbers may have turned down the statistical significance of diuretic treatment, diarrhea, vomiting and bleeding in patients classified dehydrated (Part I). Hence, we consider the present work a pilot investigation. Data of this work may be used to calculate the sample size when planning larger studies.

The present study supports the need for improved awareness to the problem: knowing the patients who are chronically predisposed to dehydration, being alert to causes of acute volume loss, to symptoms and signs that may be caused by dehydration though unspecific, knowing the contribution and limitations of laboratory tests to the diagnosis of dehydration. In high risk situations it may be necessary to track the patient's fluid balance and provide a fluid load upon suspicion of dehydration, to expose the causes of volume loss and tailor management accordingly. Hospitalist skills are significant. No consultation by telephone can replace the dedicated physician who is seeing the patient day by day.

Conclusion

Diagnosing dehydration in older adults is challenging due to a lack of specific symptoms and signs, which often are erroneously attributed to other causes. Corroboration of the patient history, physical examination findings on a day to day follow-up by the physician, and skilled use of laboratory tests are essential for preventing dehydration and early dehydration diagnosis, as illustrated on longitudinal survey.

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