The Measurement of Axillary Moisture for the Assessment of Dehydration among Older Patients

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Abstract

Purpose: Dry axilla can sometimes be found among dehydrated older patients. In this study, we measured the axillary moisture and assessed it as possible marker for dehydration.

Methods: Twenty-nine older patients admitted with acute medical conditions participated in this study. Dehydration was diagnosed by the calculated serum osmolality of greater than 295mOsm/L. The moisture of axilla was measured by a skin moisture impedance meter which was applied at the center of axilla of patients.

Results: 11 patients (7 males and 4 females) were diagnosed as dehydrated and 18 patients (10 males and 8 females) were diagnosed as non-dehydrated. The mean axillary moisture (33%) in the dehydrated group was significantly lower than that (42%) in the non-dehydrated group ($p<0.05$). The axillary moisture >=50% showed the sensitivity of 88%. The axillary moisture <30% showed the specificity of 91%. As for the physical signs, dry axilla had also moderate sensitivity and excellent specificity to detect dehydration.

Conclusions: The measurement of the axillary moisture could help assess dehydration. By using a skin moisture impedance meter, dehydration could be ruled out when the axillary moisture >=50%, while it could be ruled-in when

the axillary moisture is <30%.

Keywords: Dehydration; Dry axilla; Skin moisture; Stratum Corneum

1. Introduction

Dehydration is a common condition in the older patients and exposes them to the risk of delirium, renal failure, infection, falls, pressure ulcers and constipation (Eaton 1994; Wotton 2008). In recent US data, the economic burden associated with avoidable hospitalization due to dehydration in elderly patients was substantial, and the average total hospital charge was $7442 in hospitalized older patients with a principal diagnosis of dehydration (Xiao 2004). Even in 2009, dehydration is listed as one of the 20 most common diagnoses reported by US Agency for Healthcare Research and Quality (AHRQ).

The reason why the incidence of dehydration has not decreased for over a decade is that the way to find the symptoms of dehydration is not familiar with family and care persons at home and there are also difficulties to find out dehydration even in nursing home residents. The common physical signs of dehydration are dry axillary (Eaton 1994), dry mouth, sunken eyes, decreased skin turgor, and delayed capillary refill time (McGee 1999). These symptoms could be identified by healthcare professionals, while these could not be easily noticed by lay care persons at home and nursing homes.

The hydration state of the skin can be quantitatively evaluated in terms of conductance with impedance or capacitance methods. In the skin, its outer layer, the stratum corneum which directly faces the water-saturated epidermis at lower portion has the barrier function from the evaporation of water in the epidermis. The upper portion of the stratum corneum is much drier because it is exposed to ambient air and it is affected by sweating. The water content in upper portion of the stratum corneum can be evaluated by measuring its conductance (Tagami 1982; Rawlings 2004).

In this study, we measured the water content of the stratum corneum in the axillary area to find out the dry axilla as a simple detection tool for dehydration. In addition, we evaluated the relations between these water contents of the axilla measured by the device and physical signs as well as blood test results.

2. Materials and methods

2.1 Subjects and Setting

We studied patients aged 65 or older who were consecutively admitted with acute medical conditions. Patients excluded from the study were those with chronic kidney disease (CKD), since serum osmolality was used as the gold standard test for dehydration in this study and patients with CKD can show elevated serum osmolality in non-dehydrated states. The Mito Kyodo General Hospital Ethics Committee approved the protocol. Research staff obtained written informed consent to participate in the current study from patients who were able to provide informed consent. If patients were unable to provide the consent since they had consciousness disturbance or cognitive dysfunction, written informed consent was obtained from their designated representatives. Primary physicians had assessed whether patients had consciousness disturbance or cognitive dysfunction.

2.2 Measurements

Subjects were classified as dehydrated or not dehydrated according to the criteria with calculated serum osmolality above 295 mOsm/L of the initial blood test in their arrivals to our hospital (Mito Kyodo General Hospital). In the initial process of the evaluation, blood samples of patients were obtained for tests including total protein concentration (TP), albumin concentration (ALB), blood urea nitrogen concentration (BUN), creatinine concentration (Cr), uric acid concentration (UA), sodium concentration (Na), and blood glucose concentration (BG). BUN: Cr ratio (BUN/Cr) and osmolality were calculated. The calculated osmolality was performed with the equation below:

$$\text{Calculated osmolality} = 2\times Na^{+} + BG/18 + BUN/2.8$$

For the physical signs, dry axilla was examined by the bilateral axillary skins palpated by the physicians' second to fifth fingers. Sunken eyes were considered to be present when the bilateral eyeballs seemed abnormally sunken, which were assessed by the primary physicians for caring each patient. Decreased skin turgor was referred as the slow return of the anterior chest skin to its normal position after being pinched between the examiner's thumb and forefinger.

At the physical examination for patients, physician measured the moisture of the skin at the center of axilla in the supine position with a skin moisture meter (Macros Corporation). It automatically shows the capacitance of the stratum corneum in terms of percentage in 2 seconds after application of a probe on the skin where there are no hircus. This measuring technique is common measure approach as a sensor of measuring the moisture of the skin using the correlation between the moisture in protein and permittivity. The measurement accuracy is under 2%. The lower percentage of capacitance indicates the drier axilla.

2.3 Statistical analysis

Regarding sample size, based on our preliminary unpublished data, we expected that dehydrated patients had 30% of skin moisture and non-dehydrated patients had 60% and thus we considered the expected sample size was about 15 patients for each group by alpha error of 0.05 and statistical power of 0.50. A BUN/Cr ratio greater than 25, the concentration of serum sodium ion greater than 145 mEq/L, and the concentration of serum uric acid greater than 7 mg/dL are usually employed as the aid for dehydration diagnosis. Thus, we compared the axillary moisture of patients based on these cutoffs of blood test results. All statistical analyses were carried out with Student's unpaired t test or an analysis of variance (ANOVA) where appropriate by using the SPSS version 18.0 for Windows (SAS Institute, Cary, NC, USA). A two-tailed P value less than 0.05 was regarded as significant.

3. Results

3.1 Patients

Twenty nine patients (17 men and 12 women) were recruited during the study period. The patients diagnosed as dehydrated were 7 males aged 84.0 ± 4.2 and 4 females aged 85.0 ± 7.5. The patients diagnosed as non-dehydrated were 10 males aged 83.3 ± 6.4 and 8 females aged 89.5 ± 5.3. In the dehydrated group, the chief complaints of their concomitant diseases were fever, dyspnea, diarrhea, anorexia, disturbance of consciousness, edema, abdominal pain, and dizziness. In the non-dehydrated group, the chief complaints of their concomitant diseases were fever (10 patients), liver dysfunction (2 patients), and others (dyspnea, vomiting, disturbance of consciousness, cough, hemiplegia, and fatigue).

The mean axillary moistures were 33% and 42% for the dehydrated group and the non-dehydrated group, respectively ($P<0.05$). In the dehydrated group, dry axilla was detected in 6/15 patients, whereas 1/14 patients in the non-dehydrated group (Table 1). The average moisture with dry axilla was 27%, which was significantly lower than that without dry axilla (41%, $P<0.01$).

Sunken eyes were detected in 5 patients out of 15 in the dehydrated group, while the sign was detected only in one patient in the non-dehydrated group. The mean moisture with sunken eyes was 30%, which was significantly lower than that of patients without sunken eyes (39%, $P<0.05$). Four patients showed decreased skin turgor in dehydrated group, while 3 patients with decreased skin turgor were found in non-dehydrated group. The average moisture with decreased skin turgor was 36%, which was slightly lower than that of the patients without the sign (38%).

3.2 Comparison of axillary moisture in respect to discharge conditions

Regarding discharge outcomes, 36% of patients in the dehydrated group died during the hospitalization, while 17% in the non-dehydrated group died. The average moisture among patients died during the hospitalization was 32%, which was significantly lower than the moisture of 37% among patients alive at discharge ($P<0.05$).

3.3 Comparison of axillary moisture with dehydration scales based on blood tests

The comparison of axillary moisture with dehydration scales based on blood tests is shown in Table 2. Patients with BUN/Cr >25 had the mean moisture of 34%, which was significantly lower than that of 38% in patients with BUN/Cr <=25. The axillary moisture among patients with serum Na >145mEq/L was 31%, which was also significantly lower compared with other patients (37%, $P<0.01$). As for uric acid concentration, there was no significance for axillary moistures of patients between those with >7 mg/dL and <= 7 mg/dL.

3.4 The cutoff value of the axillary moisture for the dehydration assessment

The sensitivity and specificity of each cutoff value was examined as an assessment of dehydration (Table 3). The sensitivity showed 88% with 50% or greater values of axillary moisture. The specificity indicated 91% with less than 30% of axillary moisture. ROC (Receiver Operating Characteristic) curve was indicated in Figure 1.

4. Discussion

In the present study, we demonstrated that the moisture of axilla could indicate the hydration state. Based on our results, dehydration could be ruled out when the axillary moisture is 50% or greater, while dehydration could be ruled in when the axillary moisture is less than 30%. In addition, we found that there were significant correlations between the axillary moisture and laboratory test results commonly used for dehydration diagnosis such as BUN/Cr ratio and serum sodium concentration.

The implications of our results may be very important regarding early diagnosis and intervention for dehydration among older people. In a Japanese study, about 10% of older patients admitted to several hospitals in Japan were shown to be involved with low to moderate levels of dehydration in addition to other concomitant disease conditions (Takehisa 2010). It suggested that dehydration could not be easily found out even if caring people pay attention to the dehydration. From our results, in the dehydrated group, 36% of the patients died during the hospitalization, whereas 17% of the patients died in the non-dehydrated group. This result is similar to the previous report in 1991 that 50% of older people Medicare beneficiaries hospitalized with dehydration died within a year of admission (Warren 1994). If dehydration in older people could be diagnosed earlier by using a simple and non-invasive device even in home or nursing homes, earlier hospitalization and rehydrating intervention could be employed for these vulnerable patients and might lower their mortality.

Dehydration is the result of a fluid imbalance and inadequate circulating volume from either the consumption of too little fluid associates with the lack of thirst or due to a loss of too much fluid associates with the lack of condensation ability of urine in kidney (Wilson 1999). This can cause the increase in plasma sodium concentration, serum osmolality, and capillary refill time. This also affects the ability of sweating (Levitt 1992) and saliva production. The degree of dehydration is correlated with the percentage of total body water lost and also with changes in signs and symptoms classified as mild to severe dehydration. Total body water is estimated by bioelectrical impedance analysis with electrode placements to an area of the body (ankle to knee), but it is also confounded with obesity (Yamada 2009). Thus, we focused on the relation between dehydration and dry axilla and measured the water content of the stratum corneum in the axilla.

For correlation between laboratory data and axillary moisture, we employed the commonly used data for dehydration diagnosis (BUN/Cr>25, Na^+>145mEq, osmolality>295mOsm) as cutoffs for the groups to compare the axillary moistures. As for BUN/Cr>25 and Na^+>145mEq, the axillary moistures was significantly lower than those of non-dehydrated groups. From the results of Table 1 and 2, when axillary moisture is 25-30%, it might indicate mild dehydration. When axillary moisture is under 25%, it might indicate moderate or severe dehydration. For 30-50% of axillary moisture, dehydration could not be excluded because of its low sensitivity among those values. There might be some delayed time intervals between the initiation of intracellular dehydration (first space) and the onset of extracellular/extravascular dehydration (third space).

There are some limitations for the study. First, our sample size was relatively small and thus a larger study is needed to confirm our results. Second, since our study was conducted in patients admitted to a hospital, our results may be needed for the confirmation in a setting of home care or nursing homes.

In conclusion, the present study demonstrated that the measurement of the axillary moisture could indicate the mild to moderate dehydration as well as dehydration indexes such as osmolality and serum sodium concentration. Measuring the axillary moisture has the potentiality to be the simple tool for detecting dehydration at home and nursing homes.

Disclosure Statement

The authors have no competing financial interests.

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Table Legends

Table 1: Physical signs and axillary moisture in each patient

Table 2: **(a)** Mean axillary moisture of patients with BUN/Cr >25 and BUN/Cr <=25. **(b)** Mean axillary moisture of patients with Na^+>145 mEq and Na^+<=145 mEq. **(c)** Mean axillary moisture of the patients with UA >7 mg/dL and UA <=7 mg/dL. **(d)** Mean axillary moisture of patients with osmolality >295 mOsm/L and osmolality <=295 mOsm/L

Table 3: Cutoff values of the axillary moisture as the dehydration assessment

Figure 1: ROC curve of the moisture meter (TPF: True Positive Fraction, FPF: False Positive Fraction)

Table 1

Group	No.	Dry axilla	Sunken eyes	Decreased skin turgor	Moisture (%)
Dehydrated	1	+	-	-	29
	2	-	-	-	32
	3	+	+	-	14
	4	-	-	-	42
	5	-	+	+	39
	6	+	+	+	29
	7	-	-	-	36
	8	+	-	-	33
	9	-	-	-	33
	10	-	-	-	33
	11	-	-	-	37
	12	-	-	+	34
	13	+	+	+	31
	14	-	-	-	36
	15	+	+	-	34
Non-dehydrated	16	-	-	+	35
	17	-	-	-	53
	18	+	-	-	20
	19	-	-	-	33
	20	-	-	+	40
	21	-	-	-	43
	22	-	-	+	46
	23	-	-	-	83
	24	-	+	-	34
	25	-	-	-	48
	26	-	-	+	36
	27	-	-	-	40
	28	-	-	-	46
	29	-	-	-	32

+: detected

-: not detected

Table 2

	Laboratory data	Axillary moisture (%)	P value
(a)	BUN/Cr > 25	34	<0.05
	BUN/Cr <= 25	38	
(b)	Na+ > 145mEq/L	31	<0.01
	Na+ <= 145mEq/L	37	
(c)	UA > 7mg/dL	35	0.37
	UA <= 7mg/dL	34	
(d)	Osmolality >295 mOsm/L	33	0.18
	Osmolality <= 295 mOsm/L	35	

Table 3

Axillary moisture	30%	35%	40%	45%	50%
Sensitivity (%)	12	35	59	71	88
Specificity (%)	91	36	9	0	0

Fig. 1