The Relationship Between Nocturnal Polyuria and the Distribution of Body Fluid: Assessment by Bioelectric Impedance Analysis

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Purpose: Increased nocturnal urinary volume is closely associated with nocturia. We investigated the relationship between nocturnal polyuria and the variation of body fluid distribution during the daytime using bioelectric impedance analysis.

Materials and Methods: A total of 34 men older than 60 years were enrolled in this study. A frequency volume chart was recorded. Nocturnal polyuria was defined as a nocturnal urine volume per 24-hour production of greater than 0.35 (the nocturnal polyuria index). Bioelectric impedance analysis was performed 4 times daily at 8 and 11 a.m., and 5 and 9 p.m. using an InBody S20 body composition analyzer (BioSpace, Seoul, Korea).

Results: A significant difference was found in mean ± SEM 24-hour urine production per fat-free mass between the groups with and without nocturnal polyuria (17.8 ± 1.4 vs 7.7 ± 0.9 ml/kg). The increase in fluid in the legs compared with the volume at 8 a.m. was significantly larger at 5 p.m., while there was no difference in the arms or trunk. Nocturnal urine volume significantly correlated with the difference in fluid volume in the legs ($r = 0.527$, $p = 0.0019$) and extracellular fluid volume ($r = 0.3844$, $p = 0.0248$) between the volumes at 8 a.m. and 9 p.m.

Conclusions: Overproduction of urine per fat-free mass leads to nocturnal polyuria. Extracellular fluid accumulates as edema in the legs during the day in patients with nocturnal polyuria. The volume of accumulated extracellular fluid correlates with nocturnal urine volume. We suggest that leg edema is the source of nocturnal urine volume and decreasing edema may cure nocturnal polyuria.

Key Words: urinary bladder, nocturia, circadian rhythm, extracellular fluid, electric impedance

Abbreviations and Acronyms

ANP = atrial natriuretic peptide
BIA = bioelectric impedance analysis
BNP = brain natriuretic peptide
Cr = creatinine
DSM = direct segmental multifrequency
ECF = extracellular fluid
FVC = frequency volume chart
ICF = intracellular fluid
NP = nocturnal polyuria
NPI = NP index
NUV = nocturnal urinary volume

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Study received institutional review board approval.

NOCTURIA is among the most bothersome of all urological symptoms.[1,2] Nocturia is mainly caused by decreased nocturnal bladder capacity and NP. When high grade bladder outlet obstruction induces detrusor overactivity, nocturia often manifests due to decreased voided volume in elderly men with lower urinary tract symptoms.[3] The 4 principal factors associated with nocturia, including nocturnal polyuria, decreased nocturnal bladder capacity, mixed polyuria and global polyuria, may be easily differentiated by mathematical analysis of FVCs.[4] Therefore, NP must be clarified before starting treatment for nocturia.

The causes of NP are a circadian defect of secretion or action of antidiuretic hormone, congestive heart failure, autonomic dysfunction, sleep apnea syndrome, renal insufficiency, etc.[5] NP is often too difficult to treat

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because to our knowledge the main cause has not yet been determined. NP is overproduction of urine during the night, affecting quality of life, and the material of urine should be water accumulated in the body.

We hypothesized that in patients with NP surplus water accumulates in some segment of the body from morning through evening, which is excreted as urine during the night. To evaluate this hypothesis we investigated the circadian variation in body water distribution using BIA. BIA is suitable for studying nocturia as a quality of life disease because it is noninvasive and can be easily repeated. We also performed blood examination to assess the background of our patients with NP.

MATERIALS AND METHODS

A total of 34 male inpatients older than 60 years were enrolled in this study. Any patients who had a history of heart disease, diabetes mellitus with a fasting blood glucose of 200 mg/dl or more, serum Cr greater than 1.5 ng/dl, hydronephrosis, post-void residual urine volume greater than 50 ml, urinary incontinence that influenced the exact measurement of urinary volume or active urinary tract infection, habitual diuretic or lithium use, or a 24-hour urinary production that exceeded 40 ml/kg body weight were excluded from study. Patients ate the same meals as served in the hospital, which included about 1,100 ml water and less than 10 gm NaCl per day. They ingested only pure water to relieve thirst. The purpose and method of this study were approved by our institutional review board and fully explained to the patients, who then provided informed consent.

At the first examination blood count, standard chemistry panel, brain natriuretic peptide determination and urinalysis were routinely evaluated. Post-void residual urine volume and hydronephrosis were assessed by ultrasonography.

Frequency Volume Chart

NUV was defined as the total amount of urine voided between 10 p.m. and 6 a.m., including the first voided volume after arising from bed according to our previously recorded method.[6] All patients were requested to void urine at 10 p.m. and 6 a.m. We defined NP as NUV/24-hour production 0.35 or greater (NPI).[1]

Bioelectric Impedance Analysis

Patients underwent BIA 4 times daily at 8 a.m., 11 a.m., 5 p.m. and 9 p.m. using an InBody S20 body composition analyzer with InBody 3.0 software (BioSpace). Resistance of the arms, trunk and legs was measured in fasting patients at a frequency of 1, 5, 50, 250, 500 and 1,000 kHz. This instrument uses 8 tactile electrodes, of which 2 are in contact with the thumb and middle finger of each hand, and 2 are in contact with the bilateral aspects of the ankle joint of each foot. The patient lies supine, and body weight and height are input into the analyzer. As controlled by a microprocessor, the sequence of measurements then proceeds. An alternating current of less than 100 μA at 1 kHz or less than 500 μA at another frequency of intensity is applied between 2 electrodes to measure each part (arms, trunk and legs) of impedance, as previously described by Bedogni et al.[7] InBody S20 measures each part of water based on the assumption that each part is a cylinder. Body water in the cylinder can be calculated using the equations, resistance/length and volume = area $\times$ length. BIA can measure body water and fat-free mass because the resistance of body compositions differs depending on the amount of water. The accuracy of BIA has been demonstrated in previous studies.[7,8] Patients were instructed to keep the stomach and bladder empty, avoid exercise, recline for at least 5 minutes before BIA and lie quietly during BIA to make the measurement more precise.

Statistical Analysis

For statistical analysis the Mann-Whitney U test, 2-way ANOVA and Bonferroni's post test were used for intergroup comparisons with $p < 0.05$ considered statistically significant. Prism® 5 was used to perform the Mann-Whitney U test and multivariate analysis.

RESULTS

Patient Characteristics

A total of 34 male inpatients were enrolled in this study and all were eligible for qualification. NP was diagnosed in 15 patients with an NPI of greater than 0.35. Significant differences were found in NUV, NPI and 24-hour production per fat-free mass but not in patient age, body weight, body mass index, fat mass, fat-free mass, 24-hour water intake (except meals served in the hospital, which included about 1,100 ml water daily), 24-hour urine production, 24-hour production per body weight and blood examination data, including Na, Cl, total protein, hematocrit, Cr and BNP, between the NP and nonNP groups according to the NPI definition (see table).

Circadian Variation of Body Fluid Distribution by Nocturnal Polyuria Index Definition

Mean total body fluid was greater in the nonNP group than in the NP group all day. However, the mean increase in body fluid compared with the fluid volume at 8 a.m. was larger in the NP group than in the nonNP group, although the difference was not significant. Analyzing the segmental distribution of fluid revealed that the increased fluid in the legs compared with the volume at 8 a.m. was significantly larger at 5 p.m., while there was no difference in the arms or trunk (fig. 1).

The increase in ECF compared with the volume at 8 a.m. was significantly larger at 9 p.m. in the NP group vs the nonNP group. However, the ICF volume was not significantly different between the groups at any time (fig. 2).

Correlation Between Nocturnal Urinary Volume and Fluid Distribution

NUV from 10 p.m. to 6 a.m. significantly correlated with the difference between fluid volumes at 8 a.m. and 9 p.m. in the legs ($r = 0.527$, $p = 0.0019$), and