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NEPHROLOGY - ORIGINAL PAPER

Arm circumference: its importance for dialysis patients in the obesity era

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Abstract
Purpose The purposes of this study were to investigate the association between arm circumference and body mass index (BMI) and to discuss problems, mainly arm circumference and cuff size mismatch, that could affect the reliability of home blood pressure monitoring (HBPM) among peritoneal dialysis (PD) and hemodialysis (HD) patients.
Methods 525 PD and 502 HD patients from 16 centers were included in the study. A two-part questionnaire was used to gather information from the participants. Arm circumferences were categorized into four groups according to the British Hypertension Society cuff size recommendations.
Results Mean BMI and arm circumference of all participants were 25.0 kg/m^2 and 27.6 cm, respectively.

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There was a significant correlation between BMI and arm circumference. The mean BMI and arm circumference values were higher in PD patients than in HD patients. Requirement of a large-sized adult cuff was more common among PD patients compared to HD patients (14 % vs 8 %, $p = 0.002$).
Conclusions Since HBPM is a useful tool for clinicians to improve BP control, nephrologists should be aware of the problems related to HBPM in dialysis patients and take an active role to increase the reliability of HBPM.

Keywords Arm circumference · Cuff · Hemodialysis · Home blood pressure monitoring · Obesity · Peritoneal dialysis

Introduction

Hypertension is a common cardiovascular risk factor among the hemodialysis (HD) and peritoneal dialysis (PD) patients [1–3], and failure to achieve the target blood pressure (BP) is a frequent problem among them. Home blood pressure monitoring (HBPM) is one of the measures having a great potential to improve hypertension control rates [4–6]. Although 24-h ambulatory BP monitoring (ABPM) can provide additional information, the main advantages of HBPM are its availability, cost, reproducibility, and acceptability. In addition, home BP measurements have been shown to predict target organ damage and cardiovascular outcomes among chronic kidney disease (CKD) patients [3, 7], and reimbursement of a home sphygmomanometer by national health organizations and insurance companies was recommended for hypertensive subjects [4] and HD patients [8].

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An accurate and appropriate device, strict adherence to the manufacturer's instructions, proper patient preparation, patient training, and correct BP measurement technique are the essentials of reliable HBPM [4–6]. The "ideal" cuff should have a bladder length that is 80 % of arm circumference, and there are two different standards for cuff size based on the American Heart Association (AHA) and British Hypertension Society (BHS) recommendations [5, 9]. Upper arm circumference limit for standard or normal adult cuff size according to AHA and BHS standards are 34 cm and less than 33 cm, respectively. Inappropriate cuff size is one of the factors causing inaccurate BP measurement [10] in which the readings can be higher than those of actual BP with a small-sized cuff [4–6]; therefore, arm circumference-cuff size conformity is very important, particularly in obese patients. Obesity is a common and increasing social problem predisposing chronic disabilities including kidney disease. The purposes of this study were to investigate the association between arm circumference and body mass index (BMI) and to discuss the problems, mainly arm circumference and cuff size mismatch, that could affect the reliability of HBPM among PD and HD patients.

Patients and methods

525 PD and 502 HD patients from 16 centers were included in the study. Exclusion criteria were being younger than 18 years and having any acute circumstances affecting upper extremities including recent intravenous cannulation. A two-part questionnaire was used to gather information from the participants. The first part included basic clinical questions such as age, gender, underlying renal disease, comorbid diseases, type of dialysis treatment, duration of current renal replacement therapy, and history of previous renal replacement therapies. The presence of an arteriovenous fistula (AVF), conditions that could affect arm circumference, location and type of vascular access, and preferred or used upper arm for BP measurement were asked in the second part.

The mid-arm circumference (midpoint of the acromion and the olecranon) was measured with a plastic tape on bare extremities. In case of a condition affecting arm circumference (functioning vascular access, vascular obstruction, plegia, fracture, neuropathy, etc.), contralateral upper arm was used for arm circumference measurement. If an upper extremity did not have a condition affecting arm circumference, arm circumference was measured from both arms, but only right arm circumference was included in the study unless the patient preferred left arm for BP measurement. Arm circumference was not measured in patients whose BP had to be measured from thigh due to vascular or other causes.

Arm circumferences were categorized into four groups according to BHS cuff size recommendations [9]: small adult/child (<23 cm), standard adult (<33 cm), large adult (<50 cm), and adult thigh cuff (<53 cm).

Body weight was measured after drainage of peritoneal dialysate with an empty abdomen or after a HD session. Body mass index was calculated by dividing a patient's weight in kilograms by the patient's height in meters squared and assessed as follows: BMI < 18.5, underweight; BMI of 18.5–24.9, normal; BMI of 25.0–29.9, overweight; BMI of 30–39.9, obese; BMI ≥ 40, morbid obese. All subjects were informed about the study.

The Student's *t* test, chi-square test, and Pearson test were used for statistical analysis where appropriate and a p value less than 0.05 was considered as statistically significant.

Results

The basic characteristics of the patients were shown in Table 1.

605 patients had vascular access surgery to create an AVF (400 on left arm, 48 on right arm, and 157 on both arms). Any condition affecting their arm (28 on left arm, 13 on right arm, and 6 on both arms) other than vascular access attempt was present in 47 patients. 473 patients had a functional AVF (376 on left arm, 94 on right arm, and 3 on both arms). Vascular access for HD patients were left AVF ($n = 318$), right AVF ($n = 83$), internal jugular catheter ($n = 43$), subclavian catheter ($n = 39$), and other vascular routes ($n = 19$). Fifty-two PD patients had functional AVF (10 %). Blood pressure was measured from right arm in 582 cases, left arm in 170 cases, both arms in 268 cases, and thigh in 7 cases.

Mean BMI and arm circumference of all participants were 25.0 kg/m^2 (range, 14.1–55.7) and 27.6 cm (range, 15.9–47), respectively. There was a significant correlation between BMI and arm circumference (Fig. 1). The mean BMI and arm circumference values were higher in PD patients than in HD patients, 25.6 versus 24.3 kg/m^2 ($p < 0.001$) and 28.0 versus 27.2 cm ($p = 0.002$) respectively. The mean BMI were significantly higher in female patients than in male patients (25.4 vs 24.6 kg/m^2, respectively, $p = 0.03$), but mean arm circumferences were close in both genders (27.61 vs 27.63 cm). Table 2 shows mean body mass index and mid-arm circumference values according to gender and the dialysis modality. There were significant correlations between BMI and arm circumference in all groups (Figs. 2, 3, 4, 5).

160 (16 %) of 1,020 patients had a BMI of larger than or equal to 30. Arm circumference was 33 cm or greater in 114 (11 %) of the patients who needed a large-sized adult cuff. Requirement of a large adult size cuff was more common among overweight and obese patients (Table 3). Majority of the obese and morbid obese patients required large adult size cuff (Table 3). Requirement of a large-sized adult cuff was more common among PD patients compared to HD patients (14 vs 8 %, $p = 0.002$) (Table 4) and among

Table 1 Basic characteristics of the patients according to dialysis modality

Feature	PD[a] patients ($n = 525$)	HD[b] patients ($n = 502$)
Age (mean, years)	48.0	53.7
Gender (male/female)	257/268	276/226
Duration of current dialysis therapy (mean, months)	53	64
Hypertension (*n*, %)	371 (71 %)	318 (63 %)
Diabetes mellitus (*n*, %)	117 (22 %)	119 (24 %)
Previous renal transplantation (*n*, %)	37 (7 %)	34 (7 %)
Previous HD therapy (*n*, %)	263 (50 %)	–
Previous PD therapy (*n*, %)	–	75 (15 %)

[a] Peritoneal dialysis,
[b] Hemodialysis

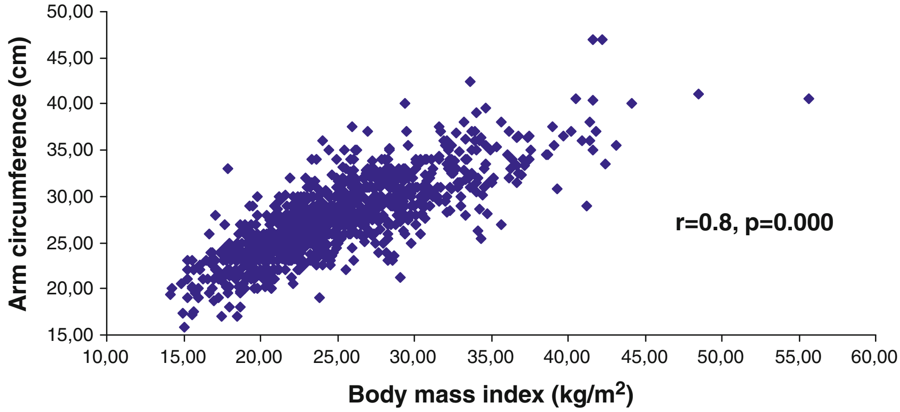

Fig. 1 The relationship between body mass index and arm circumference

Table 2 Mean body mass index (BMI) and mid-arm circumference (MAC) values according to gender and the dialysis modality

Type of dialysis	Male BMI (kg/m^2)/MAC (cm)	Female BMI (kg/m^2)/MAC (cm)
Hemodialysis	24.1/27.2	24.6/27.2
Peritoneal dialysis	25.2/28.1	26.0/27.9

female patients compared to male patients (14 vs 9 %, $p = 0.02$) (Table 5).

Table 6 shows percentage of patients requiring a large-sized adult cuff according to gender and the dialysis modality. Female hemodialysis patients required more commonly a large-sized adult cuff compared to male hemodialysis patients (12 vs 6 %, $p = 0.03$).

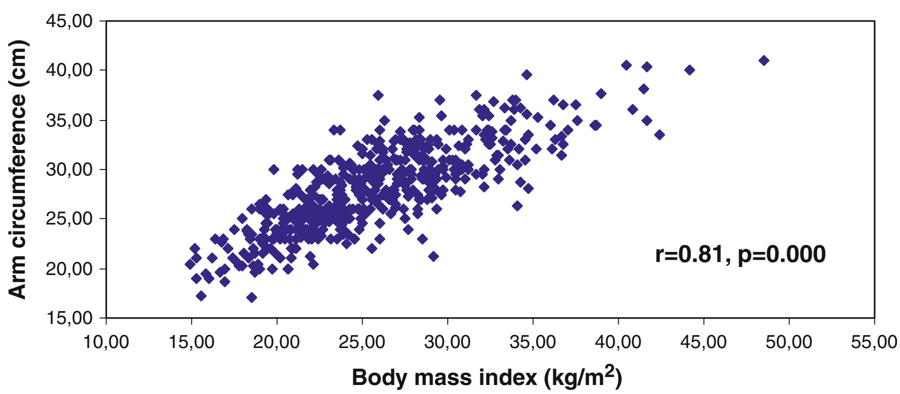

Fig. 2 The relationship between body mass index and arm circumference in peritoneal dialysis patients

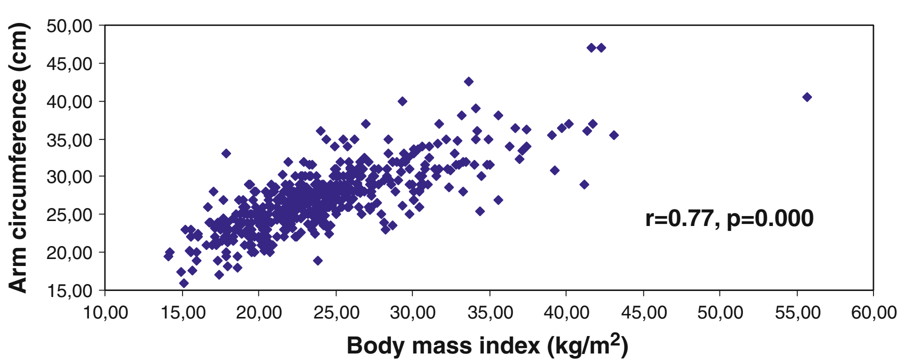

Fig. 3 The relationship between body mass index and arm circumference in hemodialysis patients

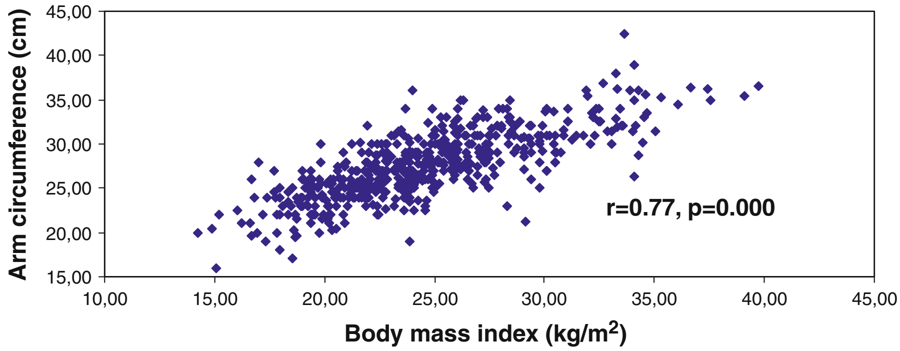

Fig. 4 The relationship between body mass index and arm circumference in male patients

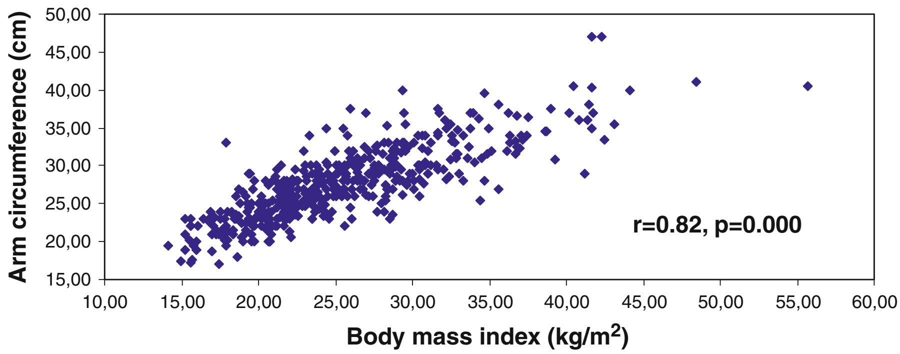

Fig. 5 The relationship between body mass index and arm circumference in female patients

Table 3 Required cuff size according to body mass index status

Body mass index status	Cuff size			Total
	Small (*n*)	Standard (*n*)	Large *n* (%)	
Underweight	50	27	0	77
Normal	58	433	5 (1 %)	496
Overweight	2	257	28 (10 %)	287
Obese	0	78	66 (46 %)	144
Morbid obese	0	1	15 (94 %)	16
Total	110	796	114 (11 %)	1,020

Table 4 Required cuff size according to the patients' dialysis type ($p = 0.002$)

Dialysis type	Cuff size			Total
	Small (*n*)	Standard (*n*)	Large *n* (%)	
Peritoneal dialysis	44	409	72 (14 %)	525
Hemodialysis	66	387	42 (8 %)	495
Total	110	796	114 (11 %)	1,020

Table 5 Required cuff size according to the patients' gender ($p = 0.02$)

Gender	Cuff size			Total
	Small (*n*)	Standard (*n*)	Large *n* (%)	
Male	50	433	48 (9 %)	531
Female	60	363	66 (14 %)	489
Total	110	796	114 (11 %)	1,020

Table 6 The percentage of patients requiring a large-sized adult cuff according to gender and the dialysis modality

Type of dialysis	Male	Female
Peritoneal dialysis, $p = 0.22$	13 %	15 %
Hemodialysis, $p = 0.03$	6 %	12 %

There were significant correlations between BMI and arm circumference across different subgroups, and *r* values are shown in Table 7. The percentages of patients requiring a large-sized adult cuff were 16 % ($p = 0.006$) and 12 % ($p = 0.02$) among diabetic and hypertensive patients, respectively.

Table 7 *r* Values between body mass index and arm circumference across different subgroups

Group	*r*	*p* value
Diabetes mellitus		
Present	0.755	<0.001
Absent	0.795	<0.001
Hypertension		
Present	0.802	<0.001
Absent	0.78	<0.001
Age groups		
<30 years	0.748	<0.001
30–39 years	0.711	<0.001
40–49 years	0.789	<0.001
50–59 years	0.793	<0.001
≥60 years	0.748	<0.001
Duration of dialysis treatment		
1–24 months	0.784	<0.001
25–48 months	0.826	<0.001
49–72 months	0.803	<0.001
>72 months	0.781	<0.001

Discussion

Obesity predisposes to diabetes mellitus and hypertension, two commonest causes of CKD worldwide; therefore, it is a predisposing factor for CKD as well. Beyond that, it is an independent risk factor for development and progression of renal damage [11]. The risen prevalence of obesity increased the mean arm circumference of the whole population including hypertensive subjects [12]. Weight gain is a well-known complication of PD, and obesity is more common among both PD and HD patients compared to 10–20 years ago as a result of current worldwide epidemic. Most of the studies investigating BMI among dialysis patients are interested in undernourishment rather than in obesity. Measurement of triceps skin fold and calculation of mid-arm muscle circumference are useful parameters in the evaluation of lean body mass and body composition [13–15]. The BHS and AHA cuff size recommendations [5, 9] categorize arm circumferences into four groups and do not mention about different tissue types; therefore, triceps skin fold thickness and mid-arm muscle circumference were not used in our study. Possible effects of changes in triceps skin fold thickness and mid-arm muscle circumference on blood pressure readings need further investigation.

Since increased weight leads to a larger mean arm circumference in the affected subjects, overweight and obese patients often require automated home sphygmomanometers with large- or extra large-sized cuffs. To our knowledge, the frequency of dialysis patients requiring large- or extra large-sized cuffs was not investigated before, and according to the BHS recommendations, 14 and 8 % of PD and HD patients need a large-sized cuff, respectively. The number of patients requiring large-sized cuff would be less, if we used AHA standards which recommend normal adult size for patients having an arm circumference of 27–34 cm, but most of the devices in the market have a 22–23- to 32–33-cm cuff [16, 17]. As shown in the Fig. 1, the greater the BMI, the greater the arm circumference. Therefore, in the nations where obesity is more common compared to Turkey [18], it is reasonable to expect that the number of dialysis patients requiring large- or extra large-sized cuffs would increase. For example, Ricks et al. [19] evaluated BMI of 109,605 HD patients in the United States of America, and 29, 21, and 5 % of the patients were overweight, obese and morbid obese, respectively. If our data were extrapolated to this patient group, 17 % of the patients would require large-sized cuffs.

Factors affecting reliability of HBPM is not limited to arm circumference-cuff size mismatch in dialysis patients. Both extremities were not appropriate for BP measurement due to vascular causes in 7 patients whose BP had to be measured from thigh. Fortunately, the presence of non-functioning arteriovenous grafts and fistulas in the ipsilateral arm does not alter BP readings significantly [20]; otherwise, much more than 7 patients would require BP measurement from thigh.

Choice of an appropriate sphygmomanometer is crucial for HBPM. Automated devices were recommended for HBPM by relevant guidelines [4, 6], and they mostly rely on oscillometric method which can affect BP readings in CKD. Standard validation protocols [21–23] are objective guides for nephrologists who want to recommend an accurate device to their patients. The validation protocols are for the general adult population, and it should not be assumed that a device that has been validated in the general population will be accurate in special circumstances, such as obesity, elderly, children, normal pregnancy, pre-eclampsia, end-stage renal disease, and arrhythmias. The basis of additional validation testing for elderly population was increased arterial stiffness with aging [24], which is common among dialysis patients [25]. Arterial stiffness can influence the correspondence between readings taken by mercury sphygmomanometers and oscillometric devices [5, 26]. To date, only 2 home sphygmomanometers have been validated for CKD patients, one for HD [26] and one for predialysis CKD patients [27]. Two studies confirmed the importance of the issue [28, 29]. Semret et al. [28] found that the oscillometric measurement was accurate for systolic BP but underestimated the auscultated diastolic BP. Czarkowski et al. [29] evaluated the same oscillometric monitor and reported that although the monitor met accuracy requirements for systolic BP, it failed on diastolic BP. There is only one oscillometric ambulatory BP monitor validated among HD patients [20].

Although wrist diameter is minimally affected by obesity, the variation in the wrist circumference is much less than that of the arm, and wrist devices are popular, three specific guidelines [4, 6, 30] and two relevant Web sites [31, 32] have recommended upper arm devices in preference to wrist devices. New wrist sphygmomanometers have a potential to change these recommendations, but a validated wrist device for CKD patients is not available currently.

We did not enquire control of hypertension and ownership of home sphygmomanometers in our study. Almost all hypertensive patients in the developed countries have a home sphygmomanometer [4, 33, 34], and the prevalence of a home device was 47 % among hypertensive subjects in a developing country [35]. Therefore, it can be expected that most of the dialysis patients would possess a sphygmomanometer for HBPM in many countries. Given the rarity of validated devices on the market [16, 36–38] achievement of an appropriate device could be off chance for dialysis patients. Since HBPM is a useful tool for clinicians to improve dialysis patient care by increasing hypertension control rate, nephrologists should be aware of problems related to HBPM in dialysis patients and take an active role to increase the reliability of HBPM.

Conflict of interest There is no conflict of interest.

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