Tzu Chi Medical Journal 2020; 32(3): 272–277

Original Article

Low serum adiponectin level is associated with central arterial stiffness in patients undergoing peritoneal dialysis

*Ti-Kang Chen[a,†], Yu-Chien Pan[b,†], Chih-Hsien Wang[a,b], Jia-Sian Hou[b], Bang-Gee Hsu[a,b]**

[a]School of Medicine, Tzu Chi University, Hualien, Taiwan, [b]Division of Nephrology, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, Hualien, Taiwan

[†]Both authors contributed equally to this work.

Submission : 15-Mar-2019
Revision : 29-Apr-2019
Acceptance : 11-Jun-2019
Web Publication : 02-Aug-2019

Abstract

Objective: Adiponectin has antidiabetic, anti-atherosclerotic, and anti-inflammatory functions and protects against vascular damage. Carotid-femoral pulse wave velocity (cfPWV) is a noninvasive method for measuring central artery stiffness, which is known to be associated with cardiovascular disease in peritoneal dialysis (PD) patients. This study was conducted to evaluate the relationship between central arterial stiffness and serum adiponectin levels in PD patients. **Materials and Methods:** Fasting blood samples were obtained from 60 PD patients, and the cfPWV value was measured using a validated tonometry system. In this study, cfPWV values of >10 m/s were used to define the high arterial stiffness group according to the European Society of Hypertension and the European Society of Cardiology guidelines. **Results:** Among 60 patients with PD, 19 patients (31.7%) were included in the high arterial stiffness group. When compared to those in the control group, the high arterial stiffness group patients were older ($P = 0.029$), had longer PD vintage ($P = 0.001$), higher diastolic blood pressures ($P = 0.030$), higher fasting glucose ($P = 0.014$), and lower serum adiponectin levels ($P = 0.001$). After multivariable logistic regression analysis, serum adiponectin (odds ratio, 0.612; 95% confidence interval: 0.426–0.879; $P = 0.008$) was identified as an independent predictor of arterial stiffness. The multivariable regression analysis also showed that the adiponectin level ($\beta = -0.408$; adjusted R^2 change = 0.183; $P < 0.001$) was negatively associated with cfPWV values in patients undergoing PD. **Conclusion:** Low serum adiponectin level is an independent marker of arterial stiffness in patients undergoing PD.

Keywords: *Adiponectin, Arterial stiffness, Carotid-femoral pulse wave velocity, Peritoneal dialysis*

Introduction

Arterial stiffness results from a progressive breakdown of elastic fibers in the aorta and large elastic arteries under the effects of aging and other risk factors [1]. The carotid-femoral pulse wave velocity (cfPWV) is considered the simplest, most noninvasive, robust, and reproducible method to detect arterial stiffness [2]. The 2013 European Society of Hypertension and the European Society of Cardiology (ESH/ESC) guidelines list cfPWV values >10 m/s as influencing cardiovascular (CV) prognosis [3]. Moreover, the Association for Research into Arterial Structure and Physiology Society considers the cfPWV value a useful vascular biomarker for primary and secondary CV disease prevention [4]. Higher cfPWV values also predict CV disease and death in patients undergoing peritoneal dialysis (PD) [5].

Adiponectin, an adipocyte-specific protein, neutralizes the proinflammatory effects launched by tumor necrosis factor-α and modulates the development of atherosclerotic lesions on the arterial wall [6]. Moreover, low serum levels of adiponectin in relation to those of other adipokines are associated with obesity and metabolic syndrome [7-9]. Serum adiponectin levels decreased continuously after starting PD due to body weight, visceral, and subcutaneous fat mass increased [10]. Other study also notes that an increase in the percentage of fat mass in body weight and a decrease in the percentage of lean body mass in body weight by dual-energy X-ray absorptiometry examination are positively associated with adiponectin level during a 3-year follow-up in PD patients [11]. Moreover, *in vitro* studies, reactive oxygen species induced by

Access this article online

Quick Response Code:

Website: www.tcmjmed.com

DOI: 10.4103/tcmj.tcmj_67_19

*Address for correspondence:
Dr. Bang-Gee Hsu,
Division of Nephrology, Hualien Tzu Chi Hospital,
Buddhist Tzu Chi Medical Foundation, 707,
Section 3, Chung-Yang Road, Hualien, Taiwan.
E-mail: geelily@tzuchi.com.tw

How to cite this article: Chen TK, Pan YC, Wang CH, Hou JS, Hsu BG. Low serum adiponectin level is associated with central arterial stiffness in patients undergoing peritoneal dialysis. Tzu Chi Med J 2020; 32(3): 272-7.

conventional glucose-based PD dialysate fluid contribute to downregulate the adiponectin secreted from adipocytes [12]. Low serum adiponectin level is an independent predictor of CV events, and mortality among patients undergoing hemodialysis and PD [13,14]. CV disease is a leading cause of death in PD patients [15]. Low serum adiponectin level and arterial stiffness are also associated with future CV disease in PD patients. Therefore, it is important to explore this central arterial stiffness and serum adiponectin levels in PD patients. This study is aimed to assess the association between the serum adiponectin level and central arterial stiffness by measuring cfPWV values in PD patients.

Materials and methods

Patients

We recruited 60 patients undergoing PD at the Hualien and Dalin Tzu Chi Hospitals from June 2015 to October 2016. All patients underwent regular PDs for ≥3 months. Trained staff measured blood pressures (BPs) of all patients in the morning using standard mercury sphygmomanometers with appropriate cuff sizes after instructing the patient to sit for at least 10 min. We averaged the values for systolic BP (SBP) and diastolic BP (DBP) taken three times at 5-min intervals for our analysis. The Protection of Human Subjects Institutional Review Board of Tzu Chi University and Hospital approved the study, which was conducted under the tenets of the Helsinki Declaration (IRB103-136-B). All patients signed informed consents before participating in the study. We excluded patients if they presented an acute infection, malignancy, acute myocardial infarction, pulmonary edema, or heart failure at the time of blood sampling, or if they refused to sign the informed consent. Among the patients, 45 received continuous ambulatory PD (CAPD, Dianeal, Baxter Healthcare, Taiwan), with 3–5 dialysate exchanges per day, while 15 other patients underwent 4–5 dialysate exchanges each night with an automated device (automated PD). We obtained values for the weekly fractional clearance index for urea (weekly Kt/V), peritoneal Kt/V, total clearance of creatinine, peritoneal clearance of creatinine, and residual renal creatinine clearance (Clcr) from medical records.

Anthropometric analysis

We measured all anthropometric factors three times: in the morning, after overnight fasting, and without dialysate in the abdominal cavity. The trained staff measured body weights with patients in light clothing and without shoes to the nearest 0.5 kg, and the height was measured to the nearest 0.5 cm. We calculated the body mass indexes as weight (kg) divided by height squared (m^2) [16,17].

Biochemical investigations

Biochemical tests were determined from morning samples taken after overnight fasting for 8–10 h before the dialysis exchange. The fasting blood samples (approximately 5 mL) were immediately centrifuged at 3000 ×g for 10 min. Serum samples were stored at 4°C and used for biochemical analyses within 1 h of collection. Serum levels of blood urea nitrogen, creatinine, fasting glucose, albumin, total cholesterol, triglyceride, total calcium, and phosphorus were measured using an autoanalyzer (Siemens Advia 1800, Siemens Healthcare GmbH, Henkestr, Germany) [16,17]. Serum adiponectin (SPI-BIO, Montigny le Bretonneux, France) and intact parathyroid hormone (iPTH) levels (Diagnostic Systems Laboratories, Texas, USA) were measured using a commercially available enzyme immunoassay or enzyme-linked immunosorbent assays, respectively [18,19].

Carotid-femoral pulse wave velocity measurements

cfPWVs were measured transcutaneously by recording the pressure pulse waveform in the underlying artery using applanation tonometry (SphygmoCor system, AtCor Medical, Australia) as described [18,19]. These measurements were taken in the morning with patients in the supine position after a rest of at least 10 min in a quiet and temperature controlled room. Records were made simultaneously with an electrocardiogram (ECG) signal, which provided an *R*-timing reference. Pulse waves were recorded consecutively at two superficial artery sites. The carotid-femoral distance obtained by subtracting the carotid measurement site to sternal notch distance from the sternal notch to femoral measurement site distance. Integral software was used to process each set of the pulse wave, and ECG data to calculate the mean time difference between *R*-wave and pulse waves on a beat-to-beat basis, with an average of ten consecutive cardiac cycles. We calculated the cfPWV using the distance, and the mean time difference between the two recorded points. We set quality indices included in the software to ensure data uniformity. We used cfPWV values >10 m/s to classify patients into a high arterial stiffness group according to the ESH and of the ESC guidelines [3].

Statistical analysis

We tested data for normality using the Kolmogorov–Smirnov test. We expressed normally distributed data as the mean ± standard deviation, and used two-tailed Student's independent *t*-test for comparisons between patients. We expressed non-normally distributed data as medians and interquartile ranges. Comparisons between patients were performed using the Mann–Whitney U-test (fasting glucose, iPTH, residual renal Clcr, and adiponectin). We analyzed the data expressed as the number of patients using the Chi-square test. Since glucose, iPTH, residual renal Clcr, and adiponectin were not normally distributed, we transformed the collected data to base 10 logarithmic values to achieve normality. We tested variables that were significantly correlated with arterial stiffness in patients undergoing PD for independence by multivariable logistic regression analysis (age, PD vintage, fasting glucose, DBP, and adiponectin). We used simple regression analysis to evaluate the correlation between clinical variables and cfPWV values in patients undergoing PD, and tested variables that were significantly correlated with cfPWV values for independence using a multivariable forward stepwise regression analysis (age, PD vintage, log-glucose, and log-adiponectin). We performed all statistical analyses using the SPSS software for Windows (version 19.0; SPSS, Chicago, IL, USA). $P < 0.05$ was considered statistically significant.

Results

Table 1 presents the clinical characteristics of the 60 patients undergoing PD. Among these patients, 75%

Table 1: Clinical variables of the 60 patients on peritoneal dialysis with high or low arterial stiffness

Characteristics	All participants (*n*=60)	Control group (*n*=41)	High arterial stiffness group (*n*=19)	*P*
Age (years)	56.47±15.86	53.44±16.97	63.00±10.86	0.029*
Peritoneal dialysis vintage (months)	51.62±40.11	40.17±35.11	76.32±39.90	0.001*
Height (cm)	160.85±8.17	162.00±7.99	158.37±8.25	0.111
Body weight (kg)	63.29±14.40	62.84±13.32	64.25±16.85	0.727
BMI (kg/m^2)	24.63±4.18	24.24±3.98	25.47±4.59	0.291
Carotid-femoral PWV (m/s)	9.14±3.24	7.38±1.91	12.94±1.97	<0.001*
SBP (mmHg)	146.68±22.20	143.98±22.71	152.53±20.42	0.167
DBP (mmHg)	85.53±12.71	80.12±12.41	90.74±12.07	0.030*
TCH (mg/dL)	168.88±34.79	166.00±33.63	165.63±38.14	0.970
TG (mg/dL)	168.65±101.99	158.49±102.47	190.58±100.07	0.260
Fasting glucose (mg/dL)	105.50 (95.00-126.75)	101.00 (91.00-2.50)	112.00 (103.00-149.00)	0.014*
Albumin (mg/dL)	3.71±0.39	3.71±0.43	3.72±0.31	0.940
BUN (mg/dL)	58.85±18.62	61.07±18.90	54.05±17.52	0.176
Creatinine (mg/dL)	11.21±3.26	11.09±3.54	11.47±2.61	0.676
Total calcium (mg/dL)	8.93±1.21	8.82±1.29	9.18±1.01	0.283
Phosphorus (mg/dL)	5.24±1.46	5.35±1.47	5.02±1.45	0.484
iPTH (pg/mL)	248.58 (121.64-508.86)	250.00 (106.55-548.25)	229.20 (133.50-96.83)	0.994
Adiponectin (μg/mL)	11.32 (9.01-14.73)	12.39 (10.15-19.20)	8.11 (6.66-12.42)	0.001*
Weekly Kt/V	2.17±0.39	2.23±0.41	2.05±0.31	0.093
Peritoneal Kt/V	1.82±0.46	1.80±0.50	1.86±0.38	0.665
Total clearance of creatinine (L/week)	59.80±26.45	62.37±28.93	54.26±19.62	0.273
Peritoneal clearance of creatinine (L/week)	41.96±16.38	40.60±17.34	44.88±14.07	0.351
Residual renal Clcr (mL/min)	1.69 (0.00-0.98)	2.00 (0.00-5.55)	1.20 (0.00-5.70)	0.514
Women, *n* (%)	32 (53.3)	22 (53.7)	10 (52.6)	0.940
Diabetes, *n* (%)	26 (43.3)	17 (41.5)	9 (47.4)	0.668
Hypertension, *n* (%)	52 (86.6)	35 (85.4)	17 (89.5)	0.663
CAPD, *n* (%)	45 (75.0)	30 (73.2)	15 (78.9)	0.631
ACE inhibitor use, *n* (%)	3 (5.0)	3 (7.3)	0 (0.0)	0.226
ARB use, *n* (%)	30 (50.0)	21 (51.2)	9 (47.4)	0.781
β-blocker use, *n* (%)	22 (36.7)	16 (39.0)	6 (31.6)	0.578
CCB use, *n* (%)	34 (56.7)	23 (56.1)	11 (57.9)	0.896
Statin use, *n* (%)	15 (25.0)	9 (22.0)	6 (31.6)	0.423
Fibrate use, *n* (%)	3 (5.0)	1 (2.4)	2 (10.5)	0.181

Values for continuous variables are shown as mean±SD after analysis by Student's *t*-test; variables not normally distributed are shown as median and interquartile range after analysis by the Mann-Whitney U-test; values are presented as *n* (%), and analysis after analysis by the Chi-square test. *P<0.05 was considered statistically significant. The cfPWV values >10 m/s to classify patients into a high arterial stiffness group. PWV: Pulse wave velocity, CAPD: Continuous ambulatory peritoneal dialysis, Weekly Kt/V: Weekly fractional clearance index for urea, ACE: Angiotensin-converting enzyme, ARB: Angiotensin receptor blocker, CCB: Calcium channel blocker, BMI: Body mass index, cfPWV: Carotid-femoral pulse wave velocity, SD: Standard deviation, DBP: Diastolic blood pressures, SBP: Systolic blood pressures, TCH: Total cholesterol, TG: Triglyceride, BUN: Blood urea nitrogen, Clcr: Creatinine clearance, iPTH: Intact parathyroid hormone

used CAPD. Comorbid conditions included diabetes (*n* = 26; 43.3%) and hypertension (*n* = 52; 86.6%). The prescribed drugs included angiotensin-converting enzyme inhibitors (ACEi; *n* = 3; 5%), angiotensin receptor blockers (ARB; *n* = 30; 50%), β-blockers (*n* = 22; 36.7%), calcium channel blockers (CCB; *n* = 34; 56.7%), statins (*n* = 15; 25.0%), and fibrate (*n* = 3; 5%). We found no statistically significant differences in gender, PD model, and the use of ACEi, ARB, β-blockers, CCB, statins, or fibrate between the two groups. Nineteen patients undergoing PD (31.7%) formed the high arterial stiffness group. They were older (P = 0.029) and had longer PD vintage (P = 0.001), higher DBP (P = 0.030), higher fasting glucose (P = 0.014), and lower serum adiponectin level (P = 0.001) than the patients in the control group.

After adjustment for factors significantly associated with arterial stiffness in the multivariable logistic regression analysis, the serum adiponectin level (odds ratio [OR]: 0.612; 95% confidence interval [CI]: 0.426–0.879; P = 0.008), age (OR: 1.145; 95% CI: 1.032–1.271; P = 0.011), PD vintage (OR: 1.035; 95% CI: 1.007–1.064; P = 0.014), and DBP (OR: 1.093; 95% CI: 1.007–1.186; P = 0.033) were identified as independent predictors of arterial stiffness in patients undergoing PD [Table 2].

Table 3 shows the correlation between cfPWV values and clinical variables among patients undergoing PD. Our simple regression analysis identified age (r = 0.336, P = 0.009), PD vintage (r = 0.324, P = 0.012), and log-transformed glucose (log-glucose, r = 0.282, P = 0.029) to be positively correlated, and serum log-adiponectin levels (r = −0.444, P < 0.001) to be negatively correlated with cfPWV values in patients undergoing PD. The multivariable forward stepwise linear regression analysis revealed that age (β = 0.284; adjusted R^2 change = 0.070; P = 0.010), PD vintage (β = 0.301; adjusted R^2 change = 0.087; P = 0.006),

and serum log-adiponectin levels (β = −0.408; adjusted R^2 change = 0.183; $P < 0.001$) were independent predictors of cfPWV values in patients undergoing PD.

Discussion

Our results showed that older age, longer PD vintage, higher DBP, and lower serum adiponectin levels were higher among patients undergoing PD in the arterial stiffness group. Older age, longer PD vintage, and lower serum adiponectin levels were positively correlated with cfPWV values in patients undergoing PD. The multivariable logistic regression analysis identified age, PD vintage, DBP, and serum adiponectin level as independent predictors of arterial stiffness in patients undergoing PD.

Table 2: Multivariable logistic regression analysis of the factors correlated with arterial stiffness among 60 patients on peritoneal dialysis

Variables	OR	95% CI	*P*
Adiponectin (μg/mL)	0.612	0.426-0.879	0.008*
Age (years)	1.145	1.032-1.271	0.011*
Peritoneal dialysis vintage (months)	1.035	1.007-1.064	0.014*
DBP (mmHg)	1.093	1.007-1.186	0.033*

We analyzed data using a multivariable logistic regression analysis for age, peritoneal dialysis vintage, diastolic blood pressure, fasting glucose, and adiponectin. *P<0.05 was considered statistically significant DBP: Diastolic blood pressures, OR: Odds ratio, CI: Confidence interval, TG: Triglyceride, BUN: Blood urea nitrogen, iPTH: Intact parathyroid hormone

Aging modifies the structures of blood vessels and leads to impaired endothelial function and arterial stiffening [20]. cfPWV values have been noted to increase with advancing age [21]. Older age is also positively associated with cfPWV values in patients undergoing PD [5]. Vascular arterial wall aging is characterized by a decrease in elastic fibers and increase in collagen concentration, leading to increased arterial stiffness [22]. Increased arterial stiffness leads to elevate central BP, as well as elevated SBP and DBP [23]. Our results showed that older patients undergoing PD had higher DBP in high arterial stiffness, and older age was positively associated with cfPWV values. After adjusting the covariates in our patients undergoing PD, older age, and DBP are also risk factors for the development of arterial stiffness.

Glucose-based PD dialysate fluid can produce glucose degradation products and advanced glycation end products (AGEs) that aggravated vascular changes and the development of CV events [24]. Plasma AGE concentration was significantly associated with cfPWV values in men and in patients with diabetes or prediabetes [25]. The results of the present study showed that higher fasting glucose was noted in the

Table 3: Correlation between carotid-femoral pulse wave velocity levels and clinical variables among 60 peritoneal dialysis patients

Variables	Carotid-femoral pulse wave velocity (m/s)				
	Simple regression		Multivariable regression		
	r	*P*	β	Adjusted R^2 change	*P*
Women	−0.001	0.992	-	-	-
Diabetes mellitus	0.168	0.200	-	-	-
Hypertension	−0.053	0.686	-	-	-
Age (years)	0.336	0.009*	0.284	0.070	0.010*
Peritoneal dialysis vintage (months)	0.324	0.012*	0.301	0.087	0.006*
Height (cm)	−0.116	0.378	-	-	-
Body weight (kg)	0.042	0.769	-	-	-
BMI (kg/m^2)	0.114	0.387	-	-	-
SBP (mmHg)	0.065	0.624	-	-	-
DBP (mmHg)	0.071	0.588	-	-	-
TCH (mg/dL)	0.023	0.862	-	-	-
TG (mg/dL)	0.158	0.229	-	-	-
Log-glucose (mg/dL)	0.282	0.029*	-	-	-
Albumin (mg/dL)	0.009	0.947	-	-	-
BUN (mg/dL)	−0.081	0.539	-	-	-
Creatinine (mg/dL)	−0.046	0.727	-	-	-
Total calcium (mg/dL)	0.149	0.257	-	-	-
Phosphorus (mg/dL)	−0.169	0.197	-	-	-
Log-iPTH (pg/mL)	−0.006	0.966	-	-	-
Log-adiponectin (μg/mL)	−0.444	<0.001*	−0.408	0.183	<0.001*
Weekly Kt/V	0.141	0.281	-	-	-
Peritoneal Kt/V	0.059	0.655	-	-	-
Total clearance of creatinine (L/week)	0.048	0.716	-	-	-
Peritoneal clearance of creatinine (L/week)	0.114	0.384	-	-	-
Log-residual renal clcr (mL/min)	−0.128	0.329	-	-	-

*P<0.05 was considered statistically significant. Data of glucose, iPTH, and adiponectin levels showed skewed distributions, and therefore log-transformed before analysis. We analyzed data using the simple regression analyses or multivariable stepwise linear regression analysis (for age, peritoneal dialysis vintage, log-glucose, and log-adiponectin). Kt/V: Fractional clearance index for urea, DBP: Diastolic blood pressures, SBP: Systolic blood pressures, BMI: Body mass index, TCH: Total cholesterol, TG: Triglyceride, BUN: Blood urea nitrogen, Clcr: Creatinine clearance, iPTH: Intact parathyroid hormone

high arterial stiffness group compared to those in the control group. Increased PD vintage has been associated with structural (fibrosis, angiogenesis, and hyalinizing vasculopathy) and functional (increased peritoneal solute transfer rate and ultrafiltration failure) changes [15]. Glucose-based PD dialysate fluid increased the body weight, visceral and subcutaneous fat mass also decreased adiponectin production in patients with long-term PD used [10-12]. A clinical study also noted increases in cfPWV values after 2-year follow ups in patients undergoing PD [26]. We also found that patients undergoing PD with longer PD vintage had with higher cfPWV values that were positively associated with arterial stiffness after multivariable logistic regression analysis.

Intraperitoneal inflammation, hypoalbuminemia, and metabolic risk factors (dyslipidemia, insulin resistance, metabolic syndrome, and weight gain) are associated to systemic glucose absorption from the glucose-based dialysate in patients undergoing PD [15]. Peritoneal membrane damage by chronic inflammation and angiogenesis are the most common complications in patients undergoing PD, and adipokines also modulate these effects [27]. Adiponectin has anti-inflammatory, anti-atherosclerotic, and insulin-sensitizing activities and protects against the development of metabolic disorders and their related vascular damage [28]. Clinical studies have shown that serum adiponectin levels are independent predictors of peripheral arterial stiffness measured by brachial-ankle pulse wave velocity in hypertensive patients with metabolic syndrome and that is negatively associated with cfPWV values in healthy men, kidney transplant patients, and patients undergoing chronic hemodialysis [9,18,19,29]. In this study, we also found the serum adiponectin levels to be negatively associated with cfPWV values among our patients. After adjusting for a variety of confounding factors in the multivariate logistic regression analysis, we identified the serum adiponectin level as an independent predictor of arterial stiffness in patients undergoing PD.

There are several limitations in our study. First, our study design was cross sectional, in a single center, and with a small sample size. Second, the medications used in patients undergoing PD could have potentially affected the serum adiponectin levels or cfPWV values in this study. Third, one study noted that central arterial stiffness was associated with residual renal function in PD patients [30]. However, we did not find the association between residual renal function and central arterial stiffness or cfPWV values in this study. Further studies are required to confirm our findings in the future.

Conclusion

Older age, longer PD vintage, and hypoadiponectinemia seem to be positively correlated with cfPWV values in patients undergoing PD. Meanwhile, adiponectin, age, PD vintage, and DBP may be independent risk factors for arterial stiffness in patients undergoing PD.

Financial support and sponsorship

This study was supported by a grant from the Ministry of Science and Technology, Taiwan (MOST-104-2314-B-303-010).

Conflicts of interest

There are no conflicts of interest.

References

1. Palombo C, Kozakova M. Arterial stiffness, atherosclerosis and cardiovascular risk: Pathophysiologic mechanisms and emerging clinical indications. Vascul Pharmacol 2016;77:1-7.
2. Tomiyama H, Yamashina A. Non-invasive vascular function tests: Their pathophysiological background and clinical application. Circ J 2010;74:24-33.
3. Mancia G, Fagard R, Narkiewicz K, Redón J, Zanchetti A, Böhm M, et al. 2013 ESH/ESC guidelines for the management of arterial hypertension: The task force for the management of arterial hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). J Hypertens 2013;31:1281-357.
4. Vlachopoulos C, Xaplanteris P, Aboyans V, Brodmann M, Cífková R, Cosentino F, et al. The role of vascular biomarkers for primary and secondary prevention. A position paper from the European society of cardiology working group on peripheral circulation: Endorsed by the Association for Research into Arterial Structure and Physiology (ARTERY) society. Atherosclerosis 2015;241:507-32.
5. Xu T, Xie J, Zong X, Wang W, Ren H, Chen N. Pulse wave velocity: A valuable predictor for cardio-cerebrovascular disease and death in PD patients. Blood Purif 2015;40:203-8.
6. Katsiki N, Mantzoros C, Mikhailidis DP. Adiponectin, lipids and atherosclerosis. Curr Opin Lipidol 2017;28:347-54.
7. Nigro E, Scudiero O, Monaco ML, Palmieri A, Mazzarella G, Costagliola C, et al. New insight into adiponectin role in obesity and obesity-related diseases. Biomed Res Int 2014;2014:658913.
8. Wang ZV, Scherer PE. Adiponectin, the past two decades. J Mol Cell Biol 2016;8:93-100.
9. Chen MC, Lee CJ, Yang CF, Chen YC, Wang JH, Hsu BG. Low serum adiponectin level is associated with metabolic syndrome and is an independent marker of peripheral arterial stiffness in hypertensive patients. Diabetol Metab Syndr 2017;9:49.
10. Choi SJ, Park MY, Kim JK, Hwang SD. The 24-month changes in body fat mass and adipokines in patients starting peritoneal dialysis. Perit Dial Int 2017;37:290-7.
11. Xu X, Tian X, Chen Y, Yang ZK, Qu Z, Dong J. Associations of adiponectin, leptin levels, and the change of body composition in patients on peritoneal dialysis: A prospective cohort study. Perit Dial Int 2018;38:278-85.
12. Huh JY, Seo EY, Lee HB, Ha H. Glucose-based peritoneal dialysis solution suppresses adiponectin synthesis through oxidative stress in an experimental model of peritoneal dialysis. Perit Dial Int 2012;32:20-8.
13. Abdallah E, Waked E, Nabil M, El-Bendary O. Adiponectin and cardiovascular outcomes among hemodialysis patients. Kidney Blood Press Res 2012;35:247-53.
14. Tung CW, Hsu YC, Shih YH, Lin CL. Association of adiponectin with high-sensitivity C-reactive protein and clinical outcomes in peritoneal dialysis patients: A 3.5-year follow-up study. PLoS One 2015;10:e0141058.
15. Mehrotra R, Devuyst O, Davies SJ, Johnson DW. The current state of peritoneal dialysis. J Am Soc Nephrol 2016;27:3238-52.
16. Tsai JP, Lee CJ, Wang CH, Lai YH, Lin YL, Hsu BG. Inverse association of long-acting natriuretic peptide with metabolic syndrome in peritoneal dialysis patients. Int J Clin Exp Pathol 2016;9:8634-41.
17. Lin YL, Lai YH, Wang CH, Kuo CH, Liou HH, Hsu BG. Triceps skinfold thickness is associated with lumbar bone mineral density in peritoneal dialysis patients. Ther Apher Dial 2017;21:102-7.
18. Hou JS, Wang CH, Lai YH, Lin YL, Kuo CH, Subeq YM, et al. Negative correlation of serum adiponectin levels with carotid-femoral

pulse wave velocity in patients treated with hemodialysis. Biol Res Nurs 2018;20:462-8.

19. Ho CC, Hsu BG, Yin WY, Ho GJ, Chen YC, Lee MC. Serum adiponectin is a negative predictor of central arterial stiffness in kidney transplant patients. Scand J Clin Lab Invest 2016;76:264-9.
20. Xu X, Wang B, Ren C, Hu J, Greenberg DA, Chen T, et al. Age-related impairment of vascular structure and functions. Aging Dis 2017;8:590-610.
21. Kohn JC, Lampi MC, Reinhart-King CA. Age-related vascular stiffening: Causes and consequences. Front Genet 2015;6:112.
22. Nanayakkara S, Marwick TH, Kaye DM. The ageing heart: The systemic and coronary circulation. Heart 2018;104:370-6.
23. Safar ME. Arterial stiffness as a risk factor for clinical hypertension. Nat Rev Cardiol 2018;15:97-105.
24. Grantham CE, Hull KL, Graham-Brown MP, March DS, Burton JO. The potential cardiovascular benefits of low-glucose degradation product, biocompatible peritoneal dialysis fluids: A review of the literature. Perit Dial Int 2017;37:375-83.
25. Liu CY, Huang QF, Cheng YB, Guo QH, Chen Q, Li Y. A comparative study on skin and plasma advanced glycation end products and their associations with arterial stiffness. Pulse (Basel) 2017;4:208-18.
26. Szeto CC, Kwan BC, Chow KM, Leung CB, Law MC, Li PK. Prognostic value of arterial pulse wave velocity in peritoneal dialysis patients. Am J Nephrol 2012;35:127-33.
27. Shi J, Yu M, Sheng M. Angiogenesis and inflammation in peritoneal dialysis: The role of adipocytes. Kidney Blood Press Res 2017;42:209-19.
28. Sabbatini AR, Fontana V, Laurent S, Moreno H. An update on the role of adipokines in arterial stiffness and hypertension. J Hypertens 2015;33:435-44.
29. El Khoudary SR, Barinas-Mitchell E, White J, Sutton-Tyrrell K, Kuller LH, Curb JD, et al. Adiponectin, systolic blood pressure, and alcohol consumption are associated with more aortic stiffness progression among apparently healthy men. Atherosclerosis 2012;225:475-80.
30. Caliskan Y, Ozkok A, Akagun T, Alpay N, Guz G, Polat N, et al. Cardiac biomarkers and noninvasive predictors of atherosclerosis in chronic peritoneal dialysis patients. Kidney Blood Press Res 2012;35:340-8.