Original Article

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

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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. 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 (β = −0.408; adjusted R² 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...
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 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 (m²) [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          | 76.3±39.90                         | 0.001*|
| Height (cm)           | 160.8±8.17              | 162.0±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/m²)           | 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            | 12.9±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 (0.00-9.98)       | 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 R² change = 0.070; P = 0.010), PD vintage (β = 0.301; adjusted R² 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.

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 dialysis 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 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.

| Table 3: Correlation between carotid-femoral pulse wave velocity levels and clinical variables among 60 peritoneal dialysis patients |
|-----------------|-----------------|--------|--------|-----------------|-----------------|--------|--------|
| Variables       | Simple regression | Carotid-femoral pulse wave velocity (m/s) | Multivariable regression |
|                 | $r$   | $P$   | $\beta$ | 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/m²)     | 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.

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**Conflicts of interest**

There are no conflicts of interest.

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