Association between Diastolic Dysfunction by Color Tissue Doppler Imaging and Vascular Calcification on Plain Radiographs in Dialysis Patients

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Key Words

Dialysis · Diastolic dysfunction · Echocardiography ·
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Abstract

Background/Aim: Diastolic dysfunction is frequently associated with left ventricular hypertrophy, which is indicative of future cardiovascular events. Vascular calcification (VC) is known to be associated with coronary artery disease in dialysis patients. The present study was to determine the interrelationship between LV diastolic dysfunction by tissue Doppler imaging and VC on plain radiographs in dialysis patients.

Methods: Fifty-six dialysis patients were recruited and VC scores were evaluated by plain radiographic film. The ratio of early diastolic transmitral inflow velocity (E) to early diastolic mitral annular velocity (E') was measured by tissue Doppler imaging. We defined diastolic dysfunction as an E/E' ratio >15 on tissue Doppler imaging. **Results:** Patients with diastolic dysfunction showed a higher percentage of coronary artery disease history, abdominal aortic calcification (AAC) scores ≥ 5 , high LV mass index, and high left atrium volume compared to patients without diastolic dysfunction. The E/E' ratio was significantly higher in patients with significant VC, VC scores of the pelvis and hands ≥ 3 , and AAC scores ≥ 5 on plain radiographs. AAC scores ≥ 5 were

considered an independent predictor of diastolic dysfunction. **Conclusion:** VC on plain radiographs is associated with the E/E' ratio and AAC scores ≥ 5 are important clues for LV diastolic dysfunction in dialysis patients.

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Introduction

The prevalence of left ventricular (LV) changes, especially LV hypertrophy, is high among patients with chronic kidney disease and end-stage renal disease [1]. The risk of heart failure is threefold higher in uremic patients with LV hypertrophy, LV dilatation, and systolic dysfunction on echocardiograph regardless of age, diabetes, and coronary artery disease (CAD) [2]. Diastolic dysfunction assessed by echocardiography is a common sequela of arterial hypertension, which usually occurs early even before the manifestation of systolic dysfunction. Arterial stiffness and diastolic LV dysfunction are interrelated and frequently found in patients with diabetes mellitus and essential hypertension [3, 4]. Increased arterial stiffness or high pulse pressure are also related to vascular calcification (VC) in dialysis patients [5]. Therefore, LV diastolic dysfunction is thought to be possibly associated with VC.

Cardiovascular disease is a major comorbid disease and a frequent cause of hospitalization in dialysis patients [6]. VC is associated with cardiovascular disease and has been shown to be an independent predictor of cardiovascular mortality in dialysis patients [7, 8]. VC scores of the pelvis and hands from plain radiographic film are independently associated with CAD in hemodialysis (HD) patients at the end of follow-up [9]. Kidney Disease Improving Global Outcomes suggested that a lateral lumbar spine radiograph can be used to detect VC and is a good predictor of coronary artery calcification [10]. A recent report showed that the prevalence of CAD is related to the presence of medial artery calcification in the feet on plain radiography [11]. However, there are no reports on the association between VC on plain radiographs and diastolic dysfunction in dialysis patients.

In this study, we hypothesized that there is a possible interrelationship between LV diastolic dysfunction by tissue Doppler imaging and VC on plain radiographs in dialysis patients. In addition, we evaluated which VC on plain radiographs is more useful for the assessment of diastolic dysfunction in dialysis patients.

Methods

Patients

Among 47 HD and 33 peritoneal dialysis (PD) patients who wanted to participate in this study, 56 dialysis patients (34 HD and 22 PD patients) were recruited from the Dong-A University Dialysis Center. All patients between the ages of 20 and 80 years were considered eligible for the study if they had received dialysis treatment for ≥ 12 months. Patients with a history of hospital admission within 3 months were excluded. The enrolled HD patients received regular HD 3 times weekly. Bicarbonate-based dialysate and polysulfone dialyzers (Fresenius, Bad Homburg, Germany) were used. The enrolled PD patients received 4 exchanges per day using a standard regimen (8 l/day). Systolic blood pressure and diastolic blood pressure were measured in the sitting position before HD and casual blood pressure was taken as the average of 3 consecutive measurements taken just before echocardiography in PD patients. Informed consent was obtained from all enrolled patients. This study was approved by the Dong-A University Hospital Institutional Review Board.

Laboratory Measurements

Laboratory tests, including hemoglobin, calcium, phosphate, parathyroid hormone, alkaline phosphatase, C-reactive protein, total cholesterol, triglycerides, low-density lipoprotein-cholesterol, high-density lipoprotein cholesterol, blood urea nitrogen, and creatinine were obtained using fasting blood samplings. Additionally, HbA_{1c} was determined in diabetic patients. Blood samples and BMI were both taken before HD and before echocardiography in PD patients.

Vascular Calcification

We checked the plain radiographs of the feet, hands, pelvis, and lateral lumbar spine, and estimated the VC scores using previously reported methods. Abdominal aortic calcification (AAC) was graded using a previously reported system in which the location and severity of calcification deposits at each lumbar vertebral segment (L1–L4) were evaluated [12, 13]. These scores were summarized using two methods: (1) the composite score for anterior-posterior severity in which the scores of individual aortic segments both for the anterior and posterior walls were summed (maximum score of 24), and (2) the affected segment score was calculated as the total number of aortic segments showing any level of calcification indicated (maximum score of 4). It has been reported that an AAC ≥ 5 increases the risk of cardiovascular disease [14, 15]. VC scores of the pelvis and hands of the participants were evaluated in plain radiographic films. The radiographic films of the pelvis and hands were divided into four sections by two imaginary lines: a horizontal line over the upper limit of both femoral heads and a median vertical line over the vertebral column. The films of the hands were divided for each hand by a horizontal line over the upper limit of the metacarpal bones. The presence of linear calcifications in each section of the pelvis and the hand was counted as 1 and its absence as 0. The final score was the sum of all sections, ranging from 0 to 8. In a previous study, receiver operating characteristic curve analysis identified a VC score ≥ 3 as the best cutoff value associated with cardiovascular motility and cardiovascular events [9]. On radiographs of the feet, a score of 0 was assigned when medial artery calcification of the feet was absent, and a score of 1 was assigned when VC was present. Each VC serves as a useful predictor for cardiovascular disease. However, a study showed that VC evaluation on plain radiographs by only single method overlooked nearly 30% of other significant VC sites in PD and HD patients [16]. Therefore, we checked several plain radiographs and evaluated several VC sites on plain radiographs. We defined significant VC as any one finding among the following findings on plain radiographs: AAC score ≥ 5 , VC score of the hands and pelvis ≥ 3 , or medial artery calcification of the feet. This was performed by AXIOM Aristors MX/VX (SIEMENS, Erlangen, Germany) radiographic equipment with a digital imaging system [exposure conditions, 45–50 kVp (4 mAs)]. Two nephrologists independently decided VC scores on plain radiographs without any patient information. Consensus was reached on the interpretation of all radiographs.

Echocardiography

All enrolled patients were scanned with two-dimensional gray-scale imaging using a commercially available machine (Philips Sonos 5500, Andover, Mass., USA) to acquire the standard parasternal and apical images; these were used for the measurement of the cardiac dimensions and ejection fraction. HD patients were scanned by echocardiography after the first dialysis session of the week. The LV ejection fraction was obtained using a modified biplane Simpson's method from apical and four-chamber views. Measurements for M-mode-guided calculations of LV mass were taken at or just below the tip of the mitral valve with a paper speed of 50 mm/s. The LV mass was calculated using the modified American Society of Echocardiography cube formula and indexed by body surface area [17]. Using a pulsed-wave Doppler, mitral inflow profiles such as the peak

early (E-wave), late (A-wave) diastolic velocities, and E-deceleration time were measured according to previously recommended methods [18].

Tissue Doppler velocities of the mitral annulus were obtained from the apical 4-chamber view. A sample volume was placed consecutively at the lateral and medial mitral annulus. The ratio of early diastolic peak transmitral inflow velocity to early diastolic mitral annular velocity (E/E' ratio) was checked for estimation of LV filling pressure. An increase of this ratio is known to be correlated with the presence of diastolic dysfunction [19]. Based on other studies, we defined diastolic dysfunction as E/E' ratio >15 [20–22].

We counted the number of heart valve calcifications (range: 0–4) on echocardiography. Valve calcification was defined as bright echoes >1 mm on one or more valve cusps. All findings on echocardiography were interpreted by an experienced cardiologist who was blinded to the clinical and laboratory data.

Statistical Analysis

Data are presented as means $\pm$ SD except for dietary consumption data which are expressed as means $\pm$ SE. The non-parametric Mann-Whitney U test was used to compare numerical data between patients with and without significant calcification. Fisher's exact test was used to compare dichotomous data between patients with and without significant calcification. A Mann-Whitney U test was used to compare numerical data and Fisher's exact test was used to compare dichotomous data between patients with an E/E' ratio ≤ 15 and patients with an E/E' ratio >15. Correlation analyses were performed using Spearman's rank test. Multiple linear regression analysis using the backward elimination method was applied to determine the factors independently associated with the E/E' ratio on tissue Doppler imaging since E/E' ratio was a continuous variable. We included age, LV mass index, left atrium (LA) volume, CAD history, significant VC, AAC scores ≥ 5 , and VC scores of the hand and pelvis ≥ 3 as independent factors for linear regression analysis. Logistic regression analysis was also used for analysis to determine the factors independently associated with diastolic dysfunction since diastolic dysfunction was a dichotomous variable. We included age, CAD history, significant VC, AAC scores ≥ 5 , VC scores of hand and pelvis ≥ 3 , and number of antihypertension medications as independent factors for logistic regression analysis. We selected clinical variables for logistic regression analysis because these variables were related with VC or diastolic dysfunction. $p < 0.05$ was considered significant. All statistical calculations were performed with SPSS software, version 16.0 (SPSS Inc., Chicago, Ill., USA).

Results

Characteristics of Patients According to Significant VC

The study population consisted of 56 dialysis patients with a mean duration of renal replacement therapy of 38.9 ± 28.7 months. The group consisted of 22 men and 34 women, with a mean age of 55.2 ± 10.2 years and a mean E/E' ratio of 10.6 ± 4.2 . The clinical and biochem-

ical characteristics of patients according to the presence of significant VC are summarized in table 1.

The prevalence of diabetes and CAD history were significantly higher in patients with significant VC than in those without significant VC. The E/E' ratio and LV mass index were higher in patients with significant VC than in those without significant VC (11.7 ± 4.5 vs. 8.9 ± 3.0 , $p = 0.031$; 119.7 ± 27.2 vs. 93.8 ± 45.8 g/m², $p = 0.031$). The serum high-density lipoprotein cholesterol level was significantly lower and the C-reactive protein level was significantly higher in patients with significant VC than in those without significant VC. The prevalence of diastolic dysfunction was 23.5% (8 patients) in patients with significant VC and 4.5% (1 patient) in patients without significant VC.

Characteristics of Patients According to Diastolic Dysfunction

Of the 56 patients, 47 patients (83.9%) had an E/E' ratio ≤ 15 and 9 patients (16.1%) had an E/E' ratio >15. The clinical and biochemical characteristics of patients according to the presence of diastolic dysfunction are summarized in table 2. Patients with diastolic dysfunction showed higher percentages of CAD history, AAC scores ≥ 5 , and high LV mass index and LA volume compared to patients without diastolic dysfunction. Patients with diastolic dysfunction took a lot more antihypertensive medications and showed lower ejection fraction compared to patients without diastolic dysfunction.

E/E' Ratio According to VC Sites on Plain Radiographs

The E/E' ratio was significantly higher in patients with significant VC compared to those without significant VC ($p = 0.015$). The E/E' ratio was significantly higher in patients with VC scores of the pelvis and hands ≥ 3 , and with AAC scores ≥ 5 compared to patients with VC scores of the pelvis and hands <3, and with AAC scores <5. There was no significant difference in E/E' ratios according to the presence of arterial media calcification on the feet (fig. 1). The E/E' ratio was positively correlated with significant VC ($r = 0.325$, $p = 0.015$), AAC scores ≥ 5 ($r = 0.396$, $p = 0.003$), and VC scores of the pelvis and hands ≥ 3 ($r = 0.342$, $p = 0.010$), but was not related with arterial media calcification on the feet (table 3).

Factors Associated with E/E' Ratio and Diastolic Dysfunction

The E/E' ratio was positively correlated with LV mass index ($r = 0.351$, $p = 0.009$), LA volume ($r = 0.608$, $p <$

Table 1. Characteristics of study population according to significant vascular calcification

Characteristics	Total	Significant vascular calcification		p
		positive (n = 34)	negative (n = 22)	
Age, years	55.5 ± 10.2	57.1 ± 9.7	53.2 ± 10.8	0.167
Male, n (%)	22 (39.3)	13 (38.2)	9 (40.9)	1.000
Diabetes, n (%)	28 (50)	22 (64.7)	6 (27.3)	0.006
CAD history, n (%)	13 (23.2)	13 (38.2)	0 (0)	0.001
HD/PD, n	34/22	22/12	12/10	0.577
Dialysis duration, months	38.9 ± 28.7	41.2 ± 31.1	35.2 ± 24.7	0.449
BMI	23.4 ± 3.3	23.6 ± 3.3	23.1 ± 3.3	0.603
Systolic BP, mm Hg	146.0 ± 26.4	148.0 ± 27.3	142.7 ± 25.2	0.397
Diastolic BP, mm Hg	79.6 ± 14.0	78.4 ± 15.3	81.6 ± 11.6	0.526
LV mass index, g/m ²	114.0 ± 27.5	119.7 ± 27.2	93.8 ± 45.8	0.031
Ejection fraction, %	57.6 ± 9.5	56.2 ± 11.2	59.8 ± 5.7	0.259
Left atrium volume, ml	64.4 ± 21.5	67.9 ± 20.5	60.1 ± 22.4	0.210
Deceleration time, ms	247.6 ± 67.6	241.0 ± 60.4	254.9 ± 75.65	0.521
E/E' ratio	10.6 ± 4.2	11.7 ± 4.5	8.9 ± 3.0	0.031
Hemoglobin, g/dl	10.4 ± 1.0	10.5 ± 1.0	10.23 ± 1.1	0.735
PTH, pg/ml	330.3 ± 284.7	287.7 ± 249.6	408.3 ± 333.4	0.117
Calcium, mg/dl	8.7 ± 0.7	8.8 ± 0.6	8.5 ± 0.8	0.142
Phosphorous, mg/dl	4.8 ± 1.4	4.7 ± 1.4	4.9 ± 1.4	0.692
Creatinine, mg/dl	9.9 ± 2.9	9.7 ± 3.1	10.2 ± 2.6	0.486
ALP, IU/l	343.9 ± 232.0	286.9 ± 135.9	426.5 ± 310.8	0.115
Cholesterol, mg/dl	163.2 ± 43.0	158.1 ± 34.0	171.1 ± 54.1	0.276
HDL, mg/dl	40.7 ± 10.8	38.3 ± 10.2	44.1 ± 10.9	0.034
LDL, mg/dl	88.4 ± 35.9	80.8 ± 25.7	99.4 ± 45.5	0.256
Triglyceride, mg/dl	154.5 ± 100.0	166.2 ± 115.4	137.1 ± 70.1	0.410
Albumin, g/dl	3.9 ± 0.3	3.9 ± 0.3	3.9 ± 0.4	0.467
CRP, mg/dl	0.4 ± 0.9	0.6 ± 1.1	0.2 ± 0.4	0.001

BP = Blood pressure; PTH = parathyroid hormone; BUN = blood urea nitrogen; ALP = alkaline phosphatase; HDL = high-density lipoprotein cholesterol; LDL = low-density lipoprotein cholesterol; CRP = C-reactive protein.

0.001), and CAD history ($r = 0.291$, $p = 0.029$). Age, LA volume, and AAC scores ≥ 5 were independent predictors of a higher E/E' ratio in multiple linear regression analysis (table 4). AAC scores ≥ 5 [Exp (B) = 8.89, 95% CI: 1.36–48.51, $p = 0.012$], CAD history [Exp (B) = 6.09, 95% CI: 1.33–27.83, $p = 0.020$], and number of antihypertensive medications [Exp (B) = 2.32, 95% CI: 1.16–4.65, $p = 0.017$] were risk factors for diastolic dysfunction in logistic regression analysis. AAC scores ≥ 5 [Exp (B) = 8.04, 95% CI: 1.29–50.23, $p = 0.026$] and number of antihypertensive medications [Exp (B) = 2.30, 95% CI: 1.07–4.97, $p = 0.034$] were independent predictors of diastolic dysfunction in multiple logistic regression analysis (table 5).

Discussion

Aortic arch calcification volume measured by multi-detector computed tomography was known to be an independent risk factor for LV diastolic dysfunction, which was estimated as the E/E' ratio in a previous study [5]. Our present study also demonstrated that significant VC on plain radiographs was associated with E/E' ratio, and AAC scores ≥ 5 on plain radiograph were closely associated with LV diastolic dysfunction in dialysis patients. The development and progression of diastolic dysfunction is a multifactorial process. The known predisposing factors for diastolic dysfunction include old age, obesity, hypertension, and diabetes. It has been demonstrated that VC results in hemodynamic alterations such as reduced compliance of large arteries and autonomic dys-

Table 2. Comparison of clinical, laboratory and echocardiographic characteristics according to diastolic dysfunction

	E/E' ratio ≤15 (n = 47)	E/E' ratio >15 (n = 9)	p
Age, years	54.9±10.4	58.7±8.8	0.218
Male, n (%)	18 (38.3)	4 (44.4)	0.727
Diabetes, n (%)	22 (46.8)	6 (66.7)	0.469
CAD history, n (%)	8 (17.4)	5 (55.6)	0.026
Dialysis duration, months	37.4±28.7	46.4±28.7	0.354
BMI	23.5±3.1	22.8±4.1	0.696
Systolic BP, mm Hg	144.5±28.2	154.3±7.9	0.149
Diastolic BP, mm Hg	79.7±13.5	79.3±17.9	0.785
Pulse pressure, mm Hg	65.5±23.4	75.0±15.5	0.236
Valve calcification	0.8±0.8	0.8±1.0	0.795
Significant VC, n (%)	26 (55.3)	8 (88.9)	0.074
VC of feet, n (%)	19 (40.4)	4 (44.4)	1.000
VC of hand and pelvis ≥3, n (%)	17 (37.0)	5 (55.6)	0.459
AAC ≥5, n (%)	13 (28.3)	7 (77.8)	0.008
LV mass index, g/m ²	109.4±25.3	137.4±26.1	0.013
Ejection fraction, %	59.1±7.5	49.4±14.2	0.021
Left atrium volume, ml	59.2±17.6	87.4±23.1	0.002
E, cm/s	63.4±16.3	94.3±21.0	<0.001
E', cm/s	7.2±2.0	5.2±1.1	0.001
E/E' ratio	9.2±2.5	18.1±2.4	<0.001
Hemoglobin, g/dl	10.4±1.0	10.4±1.3	0.800
Creatinine, mg/dl	10.0±2.8	9.3±3.5	0.441
Cholesterol, mg/dl	165.4±46.0	151.6±24.1	0.585
HDL, mg/dl	41.1±11.2	38.0±6.9	0.652
LDL, mg/dl	90.5±38.1	76.1±16.1	0.395
Triglyceride, mg/dl	155.6±101.5	148.0±96.7	0.952
Albumin, mg/dl	3.9±0.3	4.0±0.3	0.805
CRP, mg/dl	0.4±1.0	0.4±0.4	0.078
Number of anti-HT medication	2.43±1.5	3.9±0.8	0.005

BP = Blood pressure; HDL = high-density lipoprotein cholesterol; LDL = low-density lipoprotein cholesterol. CRP = C-reactive protein; HT = hypertension.

Table 3. Correlation between E/E' ratio and related parameters

	r	p
Age, years	0.259	0.054
CAD history	0.291	0.029
Dialysis duration, months	0.036	0.794
LV mass index, g/m ²	0.351	0.009
Left atrium volume	0.608	<0.001
Ejection fraction, %	-0.191	0.159
Significant VC	0.325	0.015
Feet calcification	0.138	0.310
Hand and pelvis calcification ≥3	0.342	0.010
AAC ≥5	0.396	0.003
Valve calcification	0.090	0.526

Table 4. Independent factors associated with E/E' ratio

Variables	Standardized coefficient	t	p
Age	0.304	2.791	0.008
LA volume	0.536	4.932	0.000
AAC scores ≥5	0.296	2.637	0.012

Multiple linear regression analysis was used for analysis.
LA = Left atrium.

Table 5. Independent factors associated with diastolic dysfunction

Variables	Exp (B)	CI	p
AAC scores ≥5	8.04	1.29–50.23	0.026
Number of anti-HT medication	2.30	1.07–4.97	0.034

Logistic regression analysis was used for analysis. HT = Hypertension.

function [23]. In addition, pulse wave velocity as a determinant of LV hypertrophy was highly associated with not only VC, but also E/E' ratio in dialysis patients [5, 24]. Therefore, frequently detected VC in dialysis patients may have an effect on the development and progression of diastolic dysfunction. Blood pressure was not found to be related with diastolic dysfunction or E/E' ratio in this study. However, considering the number of antihypertensive medications, it can be assumed that blood pressure is related with the development and progression of diastolic dysfunction. It is of note that significant VC on

plain radiographs and the numbers of antihypertensive medications give clues to possible diastolic dysfunction in dialysis patients.

Age was an independent factor, but diabetes was not an independent factor correlated with the AAC score on lateral lumbar spine radiographs [14, 16]. In contrast, diabetes was a consistent independent factor, but age was not associated with a VC score of the hands and pelvis ≥3 on plain radiographs and medial artery calcification of the feet on plain radiographs in dialysis patients [9, 16]. Based on these results, different demographic factors and

Fig. 1. Comparison of the E/E' ratio according to the VC sites.

conditions may be partially related to the formation of VC according to location and size of the artery. AAC on lateral lumbar spine radiographs is definitely associated with LV diastolic dysfunction and E/E' ratio, but VC of the feet was not related with LV diastolic dysfunction in our present study. The VC score of the hand and pelvis may predict diastolic dysfunction based on the E/E' ratio. However, VC score of the hand and pelvis as a predictor of diastolic dysfunction is less significant than AAC scores based on our study. The significance of VC as a predictor of diastolic dysfunction is also dependent on the location and size of the artery. AAC indicates large artery calcification, VC of the hand and pelvis indicates large and peripheral artery calcification, and VC of the feet signify peripheral artery calcification. It is of note that an AAC score ≥ 5 on plain radiograph compared to other VC sites is the most reliable marker for prediction of the presence of diastolic dysfunction and higher E/E' ratio without echocardiography.

The noninvasive assessment of LV filling pressure without cardiac catheterization can be an important clinical tool. An E/E' ratio >15 is a reliable marker for predicting LV end-diastolic pressure >15 mm Hg in the end-stage renal disease population [21]. In addition, patients with an E/E' ratio >15 can be classified as having elevated filling pressure and diastolic dysfunction [22]. An

E/E' ratio <8 suggests normal filling pressure. With an E/E' ratio in the range of 8–15, LV diastolic dysfunction can be assessed by additional information. Therefore, in this study, we defined definite diastolic dysfunction according to an E/E' ratio >15 or ≤ 15 . An E/E' ratio >15 was a better predictor for mortality than classic clinical and echocardiographic data in end-stage renal disease patients [25]. Meanwhile, combining transmitral flow velocity with annular velocity (E/E' ratio) has been proposed as the single best tool for assessing LV filling pressure and the prognostic significance of an increased E/E' ratio has been established in several studies [26]. The clinical significance of AAC scores ≥ 5 on plain radiographs should be emphasized because AAC scores ≥ 5 on plain radiographs were shown to be an important independent factor for an E/E' ratio >15 and E/E' ratio in this study.

LV diastolic dysfunction is the important determinant for the incidence of cardiovascular events [27]. In the present study, patients with an E/E' ratio >15 showed lower ejection fraction and a higher percentage of CAD history compared to patients with an E/E' ratio <15 . Pulsed Doppler transmitral velocities can be used for assessing LV diastolic function, but this parameter is known to be preload-dependent [28, 29]. Therefore, volume status of dialysis patients may affect assessment of diastolic

function. On the contrary, the E/E' ratio has been proposed as a new method because it is relatively preload-independent [30, 31]. Thus, using the E/E' ratio compared to only using transmitral velocities is much more correct for evaluation of LV diastolic function. Furthermore, a high E/E' ratio was reflecting chronic LA and LV volume overload by showing correlation of LA volume and LV mass index in the present study.

The main limitations of our cross-sectional study are the small number of patients evaluated and the observational nature of the study. In addition, all parameters were measured at one time point and invasive measurement of LV filling pressure was not performed simultaneously. Therefore, VC is just a hint for considering the presence of a possible LV diastolic dysfunction and this study does not prove that VC is the cause of LV diastolic dysfunction. The interpretation of the current study was also limited because data were derived from a very small

sample size including only 9 patients with diastolic dysfunction. Despite these limitations, to the best of our knowledge, this study is the first to show an association between diastolic dysfunction and VC evaluated by plain radiographs.

In conclusion, a higher E/E' ratio, which is a predictor of cardiovascular events and diastolic dysfunction, can possibly be anticipated by checking and evaluating for significant VC, especially AAC and VC of the hand and pelvis in dialysis patients. Furthermore, an AAC score ≥ 5 is an independent predictor of LV diastolic dysfunction defined by $E/E' > 15$ in dialysis patients.

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