RESEARCH PAPER

Evaluation of Abdominal Aortic Calcification Among Hemodialysis Patients with Stage 5 Chronic Kidney Disease

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Abstract

Background: Vascular calcification is a common cardiovascular complication among patients with stage 5 chronic kidney disease undergoing maintenance hemodialysis.

Objective: To evaluate the prevalence, severity, and predictors of abdominal aortic calcification among hemodialysis patients with stage 5 chronic kidney disease.

Methods: This retrospective observational study was conducted at HBS Medical and dental college Islamabad from April 2024 to April 2025 and included 140 patients with stage 5 chronic kidney disease receiving maintenance hemodialysis. Abdominal aortic calcification was assessed on lateral lumbar radiographs using the Kauppila scoring system. Demographic, clinical, biochemical, cardiovascular, and dialysis-related factors were reviewed. Patients were categorized as having mild or no calcification and moderate-to-severe calcification.

Results: The mean age of patients was 57.6 ± 12.1 years, and 82 (58.6%) were male. Abdominal aortic calcification was present in 110 (78.6%) patients, including mild calcification in 44 (31.4%), moderate calcification in 39 (27.9%), and severe calcification in 27 (19.3%). The mean abdominal aortic calcification score was 7.9 ± 4.6. Patients with moderate-to-severe calcification were older (63.2 ± 11.3 vs. 52.6 ± 10.4 years; $p<0.001$), had longer dialysis duration (51.8 ± 22.4 vs. 34.8 ± 16.9 months; $p<0.001$), and demonstrated higher serum phosphate, calcium-phosphate product, intact parathyroid hormone, and C-reactive protein levels.

Conclusion: Abdominal aortic calcification was highly prevalent among patients with stage 5 chronic kidney disease undergoing maintenance hemodialysis.

Keywords: Abdominal aortic calcification; chronic kidney disease; hemodialysis; vascular calcification; hyperphosphatemia

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Introduction

Chronic kidney disease (CKD) is a significant worldwide public health problem, with an estimated

prevalence rate of 10-13% in the general adult population, and is correlated with high morbidity, mortality and cost of healthcare [1]. Maintenance hemodialysis (MHD) is a therapy used by patients with stage 5 chronic kidney disease (CKD stage 5), and is associated with significantly higher rates of cardiovascular risk than in the general population. Nearly half of all dialysis patients die of cardiovascular disease, and there is a need to be aware of valid predictors of cardiovascular disease in this high-risk group [2]. In the advanced CKD population, the role of vascular calcification as a major cause of cardiovascular morbidity is important. Now, VASC is known as an actively regulated process of pathological calcification instead of a passive degenerative process, and has been associated with vascular smooth muscle cell osteogenic transformation, chronic inflammation, oxidative stress, mineral metabolism disturbances, and imbalance between VASC promoters and inhibitors [3]. These mechanisms lead to increased arterial stiffness, rise in PWV, decrease in vascular compliance, and lead to adverse cardiovascular outcomes. Abdominal aortic calcification (AAC) is one of the most frequent forms of medial and intimal vascular calcifications found in maintenance hemodialysis patients [4]. Calcification of the abdominal aorta is a sign of generalized systemic vascular disease and is an emerging surrogate marker for generalized atherosclerosis and cardiovascular risk. There are several studies that have shown that the severity of AAC is tightly linked to coronary artery calcification, peripheral arterial disease, cerebrovascular disease and cardiovascular death [5]. Vascular calcification is particularly seen in patients with stage 5 CKD, due to severe metabolic disturbances of calcium and phosphorus. There is a progressive mineralization of arteries that is mediated by hyperphosphatemia, secondary hyperparathyroidism, elevated calcium-phosphate product, abnormalities in fibroblast growth factor-23, vitamin D deficiency, and reduced expression of endogenous calcification inhibitors [6]. Furthermore, increased vascular calcification occurs in this group due to chronic inflammation, oxidative stress, diabetes mellitus, hypertension, aging and exposure to chronic dialysis [7]. Since the early identification of the presence of AAC is important, it may enable cardiovascular risk stratification and inform intervention to slow the disease, with clinical implications. There are a number of imaging modalities available that are cheap and readily available, including lateral lumbar radiographs, abdominal radiography or computed tomography, which can be used for assessment of AAC and are suitable as a screening tool in routine nephrology practice [8].

There are several radiologic scoring systems to measure the severity of AAC such as the Kauppila score which is based on the extent of calcification of the anterior and posterior wall of the abdominal aorta near the lumbar vertebrae [9]. The association of higher AAC scores with higher levels of arterial stiffness, LVH, ischemic heart disease, hospitalisation and both cardiovascular death and all-cause mortality has been consistently observed among dialysis patients [10]. The prevalence of AAC in the previous studies varied from 40% to more than 80% and was also dependent on patient age, dialysis duration, imaging modality, and scoring system used for the diagnosis of AAC [11]. Raised age, diabetes mellitus, hypertension, older dialysis vintage, hyperphosphatemia, elevated levels of parathyroid hormone and previous cardiovascular disease have consistently been shown to be the main determinants of severity of AAC [12]. In addition to the traditional cardiovascular risk factors, there are also metabolic abnormalities characteristic of CKD that contribute to the development of vascular calcification. Chronic retention of phosphate induces the osteogenic differentiation of vascular smooth muscle cells, and chronic inflammation and uremic toxins enhance the mineralization of the extracellular matrix [13]. The mechanisms identified have led to greater interest in early diagnosis and specific therapeutic strategies to alleviate vascular calcification and improve long term cardiovascular outcome. Although there is increased awareness about the prognostic importance of AAC, few data is available from the developing countries, especially in patients receiving maintenance hemodialysis (MHD). The prevalence and severity of vascular calcification may be affected by regional variations in mineral metabolism, dialysis techniques, nutritional status and cardiovascular risk profile [14]. Hence, assessing AAC in local dialysis population is crucial to enhance cardiovascular risk evaluation in dialysis patients and to tailor clinical management. Evaluation of aortic calcification in the abdomen could be a straightforward, low-cost, and repeatable way of determining those hemodialysis patients at a higher risk of cardiovascular disease. Routine use of AAC in the clinic may help to implement early intervention, optimizing mineral metabolism, blood pressure, phosphate management, and preventive measures for the cardiovascular system [15].

Objective

To evaluate the prevalence, severity, and predictors of abdominal aortic calcification among hemodialysis patients with stage 5 chronic kidney disease.

Methodology

This retrospective observational study was conducted at HBS Medical and dental college Islamabad from April 2024 to April 2025 and included 140 patients with stage 5 chronic kidney disease (CKD) receiving maintenance hemodialysis. The study included patients 18 years of age or older with stage 5 chronic kidney disease (CKD) who had been on maintenance hemodialysis for at least three months and who had had abdominal radiography or lateral lumbar radiography for evaluation of abdominal aortic calcification (AAC). Only patients with full clinical, laboratory and imaging records were included for analysis. Patients were excluded if they suffered from acute kidney injury, had a history of renal transplantation, an active malignancy, had an acute systemic infection, had severe liver disease, were pregnant, had incomplete imaging or laboratory data, or refused to allow medical records to be utilized for research.

Data Collection

After obtaining approval from the Institutional Ethical Review Committee, the information was obtained from the electronic medical records of the hospital, from the records of the dialysis unit, from the laboratory records, from the radiology reports and from the discharge summaries with the use of a standardized data collection form.Demographic variables included in the analysis were dialysis vintage, age, gender, BMI, smoking status, duration of dialysis, frequency of dialyses, presence of diabetes mellitus, hypertension, dyslipidaemia, previous cardiac disease and current medication, which included phosphate binders, vitamin D analogues, calcimimetics and antihypertensive agents.Laboratory parameters recorded prior to dialysis in the event of dialysis use were hemoglobin, serum creatinine, blood urea nitrogen, serum calcium, serum phosphate, calcium-phosphate product, intact parathyroid hormone (iPTH), serum albumin, alkaline phosphatase, C-reactive protein, lipid profile, serum vitamin D, estimated glomerular filtration rate (eGFR).cAbdominal aortic calcification was assessed radiographically on lateral lumbar radiographs and was scored according to the Kauppila Abdominal Aortic Calcification Score where calcification was graded on the anterior and posterior wall of abdominal aorta, next to L1 to L4. Patients were divided into three groups: no calcification, mild, and moderate and severe calcification, according to the total AAC score. The main outcome was the presence and extent of abdominal aortic calcification in patients with stage 5 chronic kidney disease (CKD) undergoing maintenance hemodialysis. Secondary outcomes were the relationship of aortic calcification with age, sex, history of cardiovascular disease, history of hospitalization, diabetes mellitus, hypertension, dialysis duration, serum calcium, phosphate, calcium-phosphate product, parathyroid hormone, and inflammatory markers.

Statistical Analysis

SPSS version 26.0 was used to analyze the data. The continuous variables were reported as mean ± standard deviation and the categorical variables were reported as frequencies and percentages. Comparisons of continuous variables were performed by independent t-tests or one-way ANOVA tests based on the severity of the abdominal aortic calcification, and Chi-square or Fisher's exact tests were used for categorical variables. Pearson or Spearman correlation analysis was used to evaluate the correlation between Abdominal aortic calcification score and laboratory parameters. Statistically significant variables from univariate analysis were used to create a multivariable logistic regression model to identify independent predictors of moderate to severe abdominal aortic calcification. Odds ratios (ORs) with 95% confidence intervals (CIs) were computed and a p-value of ≤0.05 was deemed to be statistically significant.

Results

The 140 hemodialysis patients had a mean age of 57.6 ± 12.1 years, and 82 (58.6%) were male. Hypertension was the most common comorbidity, affecting 108 (77.1%) patients, followed by diabetes mellitus in 64 (45.7%), dyslipidemia in 56 (40.0%), and previous cardiovascular disease in 38 (27.1%). The mean dialysis duration was 42.8 ± 21.6 months. Mean hemoglobin was 9.8 ± 1.4 g/dL, serum phosphate was 5.9 ± 1.2 mg/dL, corrected calcium was 8.8 ± 0.7 mg/dL, and intact PTH was 458.7 ± 214.3 pg/mL.

Table 1: Baseline Demographic, Clinical, and Dialysis Characteristics of Hemodialysis Patients (N = 140)

Variable	n (%) / Mean ± SD
Age (years)	57.6 ± 12.1
Male	82 (58.6)
Female	58 (41.4)
Body mass index (kg/m²)	25.8 ± 4.3
Diabetes mellitus	64 (45.7)

Hypertension	108 (77.1)
Dyslipidemia	56 (40.0)
Previous cardiovascular disease	38 (27.1)
Dialysis duration (months)	42.8 ± 21.6
Hemodialysis sessions/week	2.8 ± 0.5
Hemoglobin (g/dL)	9.8 ± 1.4
Serum phosphate (mg/dL)	5.9 ± 1.2
Corrected serum calcium (mg/dL)	8.8 ± 0.7
Intact PTH (pg/mL)	458.7 ± 214.3

Abdominal aortic calcification was present in 110 (78.6%) patients. Mild calcification was observed in 44 (31.4%), moderate calcification in 39 (27.9%), and severe calcification in 27 (19.3%), while 30 (21.4%) had no calcification.

Table 2: Distribution of Abdominal Aortic Calcification and Laboratory Characteristics

Variable	n (%) / Mean ± SD
No abdominal aortic calcification	30 (21.4)
Mild calcification	44 (31.4)
Moderate calcification	39 (27.9)
Severe calcification	27 (19.3)
Mean AAC score	7.9 ± 4.6
Serum phosphate (mg/dL)	5.9 ± 1.2
Calcium-phosphate product (mg²/dL²)	52.4 ± 11.8
Intact PTH (pg/mL)	458.7 ± 214.3
C-reactive protein (mg/L)	9.6 ± 4.2
Serum albumin (g/dL)	3.7 ± 0.5

Patients with moderate-to-severe calcification were older than those with mild or no calcification (63.2 ± 11.3 vs. 52.6 ± 10.4 years; p<0.001) and had a longer dialysis duration (51.8 ± 22.4 vs. 34.8 ± 16.9 months; p<0.001).

Table 3: Comparison Between Patients With Mild/No Calcification and Moderate/Severe Calcification

Variable	Mild/No AAC (n=74)	Moderate/Severe AAC (n=66)	p-value
Age (years), Mean ± SD	52.6 ± 10.4	63.2 ± 11.3	<0.001
Dialysis duration (months), Mean ± SD	34.8 ± 16.9	51.8 ± 22.4	<0.001
Diabetes mellitus, n (%)	26 (35.1)	38 (57.6)	0.008
Previous cardiovascular disease, n (%)	13 (17.6)	25 (37.9)	0.006
Serum phosphate (mg/dL)	5.4 ± 1.0	6.4 ± 1.1	<0.001
Calcium-phosphate product (mg²/dL²)	48.3 ± 9.4	57.0 ± 11.6	<0.001
Intact PTH (pg/mL)	392.6 ± 181.5	532.8 ± 226.9	<0.001
C-reactive protein (mg/L)	7.9 ± 3.5	11.5 ± 4.3	<0.001

Age above 60 years was the strongest independent predictor of moderate-to-severe abdominal aortic calcification (AOR=4.58, 95% CI: 1.92–10.92; p<0.001). Dialysis duration over 36 months, serum phosphate above 5.5 mg/dL, diabetes mellitus, elevated intact PTH, and previous cardiovascular disease were also significant independent predictors, indicating that both traditional cardiovascular risks and CKD-related mineral abnormalities contributed to calcification severity.

Table 4: Multivariable Logistic Regression Analysis of Predictors of Moderate-to-Severe Abdominal Aortic Calcification

Predictor	Adjusted OR	95% CI	p-value
Age >60 years	4.58	1.92–10.92	<0.001
Dialysis duration >36 months	3.86	1.64–9.07	0.002
Diabetes mellitus	2.94	1.28–6.77	0.011
Serum phosphate >5.5 mg/dL	3.42	1.47–7.95	0.004
Elevated intact PTH	2.76	1.18–6.47	0.019
Previous cardiovascular disease	2.51	1.06–5.96	0.036

Discussion

In this retrospective study of 140 patients with stage 5 chronic kidney disease (CKD) on maintenance hemodialysis, the authors found a high prevalence of vascular calcification, with almost 40% of the patients with some degree of abdominal aortic calcification (AAC). Moderate to severe calcification was associated with older age, longer dialysis duration, diabetes mellitus, higher serum phosphate, higher levels of intact parathyroid hormone (PTH) and previous cardiovascular disease. The results underscore the significant extent of vascular calcification in eKD and underscore the importance of this marker of cardiovascular risk. There were 57.6 ± 12.1 years of age, 58.6% male patients in the study population. Some of the most common comorbidities were hypertension (77.1%) and diabetes mellitus (45.7%). The duration of the maintenance hemodialysis was 42.8 ± 21.6 months, which indicated that the population had been exposed to the uremia and mineral metabolism disorders for a long duration. A previous study also found that the patients on long-term hemodialysis were mostly middle aged elderly with high prevalence of cardiovascular risk factors including hypertension and diabetes that have been shown to play a major role in the vascular calcification [16]. 78.6% of the patients were found to have abdominal aortic calcification, of which almost half (46.9%) had moderate and severe calcification. A considerable burden of vascular calcification was seen with AAC score being 7.9 ± 4.6. The presence of aortic calcification has also been shown to be prevalent in previous studies of maintenance hemodialysis patients, and usually ranges from 60% to 80%, thus showing that vascular calcification is one of the most common cardiovascular complications associated with advanced chronic kidney disease. In comparison by calcification severity, the patients that had moderate to severe AAC were significantly older and had had a much longer duration of dialysis than patients with mild or no calcification. Diabetes mellitus and history of cardiovascular disease were also higher among patients with advanced calcification. In line with this, previous studies have also demonstrated that progressive arterial mineralization occurs during ageing due to progressive vascular damage, and that exposure to dialysis for a longer period of time leads to an increased risk of calcification as a result of chronic exposure to uremic toxins, chronic inflammation and calcium-phosphate disturbances [17]. In the present study, metabolic disorders were significantly related to AAC. Patients with moderate to severe calcification had significantly higher levels of serum phosphate, calcium-phosphate product and intact PTH levels than those with minimal calcification. These results confirm the well recognised association of chronic kidney disease-mineral and bone disorder (CKD-MBD) with vascular calcification. Previous studies have also shown that hyperphosphatemia can induce osteogenic differentiation of vascular smooth muscle cells, and that secondary hyperparathyroidism can worsen the calcium deposition and vascular stiffening in arteries.

Inflammatory markers also seemed to play a role in vascular calcification with C-reactive protein levels being significantly elevated and higher in patients with advanced AAC. Osteogenic signaling pathways, endothelial dysfunction and oxidative stress contribute to progressive arterial calcification by chronic inflammation within the vascular wall. The previous studies have also shown strong relationships between inflammatory markers and the incidence of vascular calcification and progression of vascular calcification in patients on maintenance dialysis [18]. Multivariable logistic regression showed that only age >60 years was a strong independent risk factor for moderate to severe AA calcium deposition. Other factors that were independently associated with advanced calcification were longer dialysis time, higher serum phosphate, diabetes mellitus, higher intact PTH, and prior cardiovascular disease. Advanced age is one of the strongest factors linked to vascular calcification as chronic vascular injuries and metabolic disturbances over time affect the elasticity of the arteries and lead to calcium deposition. The clinical significance of the association of diabetes mellitus with severe aortic calcification found in this study is significant. Oxidative stress, chronic inflammation and accelerated atherosclerosis are all downstream effects of chronic hyperglycemia that lead to vascular mineralization. Earlier studies have also found that diabetes mellitus is one of the most important risk factors for vascular calcification and cardiovascular death in ESKD patients [19]. In a similar way, the link between longer dialysis time and higher levels of calcification highlights the aggravation of chronic uremia and mineral imbalance. For maintenance hemodialysis patients who receive dialysis for a longer duration, there is continuous retention of phosphate, persistent secondary hyperparathyroidism, and continuous exposure to inflammatory mediators which gradually increase vascular calcification. Dialysis vintage was also found to be an independent predictor of the calcification of the abdomen and coronary arteries in previous studies of stage 5 chronic kidney disease [20]. This study was limited by its retrospective, single-center design and moderate sample size, which may restrict generalizability. Reliance on existing records may have introduced incomplete documentation and residual confounding. Abdominal aortic calcification was assessed using plain radiography rather than computed tomography,

and long-term cardiovascular events, calcification progression, and mortality were not evaluated.

Conclusion

Abdominal aortic calcification was highly prevalent among stage 5 chronic kidney disease patients receiving maintenance hemodialysis, affecting 78.6% of the study population. Older age, prolonged dialysis duration, diabetes mellitus, hyperphosphatemia, elevated intact parathyroid hormone, and previous cardiovascular disease independently predicted moderate-to-severe calcification. Routine assessment of abdominal aortic calcification may provide a simple and practical approach for cardiovascular risk stratification.

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