Determination and Validation of Aortic Calcification Measurement from Lateral Bone Densitometry in Dialysis Patients

Nigel D. Toussaint,∗† Kenneth K. Lau,‡ Boyd J. Strauss,†§ Kevan R. Polkinghorne,*† and Peter G. Kerr*†

*Department of Nephrology, †Department of Radiology, and §Clinical Nutrition and Metabolism Unit, Monash Medical Centre, Clayton, Victoria, Australia; and ‡Department of Medicine, Monash University, Clayton, Victoria, Australia

Background and objectives: Vascular calcification (VC) contributes to increased cardiovascular (CV) disease in dialysis patients and is inversely correlated with bone mineral density (BMD). Screening for VC may determine patients at greater CV risk and bone densitometry may have dual role in assessing VC as well as BMD. The aim of this study was to determine measurement of VC using dual-energy x-ray absorptiometry (DXA) with correlation to gold standard computed tomography (CT).

Design, setting, participants, & measurements: Forty hemodialysis patients had abdominal aortic CT and lateral DXA of lumbar spine to determine aortic VC and BMD. Semiquantitative measurement of aortic VC from lateral DXA was determined using previously validated 24- and 8-point scales and correlated with aortic VC with CT. Anteroposterior (AP) and lateral DXA-reported BMD was compared with BMD from L2 through L4 with CT.

Results: Patients, 70% men, 38% diabetic, had median age 58.5 yr. Aortic VC was present in 94% with CT and 68% on lateral DXA. For 24- and 8-point scores, intraclass correlation coefficients for intrarater agreement were 0.93 and 0.88, respectively. DXA-measured VC correlated with CT. Sensitivity and specificity for CT aortic VC > 500 HU was 50 and 86%, respectively, for DXA VC > 6 on a 24-point scale. Lateral DXA-reported BMD significantly correlated with BMD from CT, but AP DXA did not.

Conclusions: Lateral DXA may be useful because images may provide concurrent assessment of aortic calcification as well as more accurate lumbar spine BMD, avoiding some of the limitations of AP DXA.


Cardiovascular (CV) disease is the leading cause of mortality in patients with chronic kidney disease (CKD) on dialysis (CKD 5D) (1–3) and nontraditional risk factors such as vascular calcification (VC) contribute considerably to this problem (4,5). Studies using electron-beam tomography (EBT) have reported increased coronary artery calcification in CKD compared with the general population, with the predominant differences being earlier age of onset and greater distribution and extent of VC in CKD (6–8). VC is associated with all-cause and CV mortality in CKD 5D (5,9) and screening methods to assess the degree of VC could potentially be worthwhile in general clinical practice given the high prevalence and functional significance (10). Detection using imaging modalities may allow accurate risk stratification and changes in treatment to address the extent of complications, and VC scores derived from EBT have been shown to add incremental prognostic information to traditional risk factors for the prediction of CV events and mortality in the general population and in CKD (11–13).

The presence of abdominal aortic calcification is a marker of both subclinical atherosclerotic disease and arteriosclerosis, and is also an independent predictor of CV morbidity and mortality (14,15). Several noninvasive methods are available to detect and measure the degree of aortic VC. Computed tomography (CT) constitutes the gold standard for quantification of VC and, being the most effective and widely available with reproducible measurements, is also useful for monitoring progression as well as assessing the effect of therapeutic strategies to modify progression (16,17) (Figure 1). Lateral lumbar radiographs can also accurately detect aortic calcification and may even distinguish between intimal and medial calcification (9). These simple measures are inexpensive and have been demonstrated to show good correlation with more sophisticated CT (18).

A relationship exists between increasing VC and loss of bone mineral density (BMD), with recent experimental studies revealing the mechanisms that link these two processes (19). In the general population and in CKD there is an association between CV mortality and osteoporosis (20,21), and BMD has been shown to be inversely associated with VC (6,22–24). It is difficult to diagnose osteoporosis in dialysis patients because a low BMD may result from many abnormalities that constitute the spectrum of renal osteodystrophy (25,26). Dual-energy x-ray absorptiometry (DXA), commonly used to measure BMD in the general population, may be helpful in CKD 5D although should not be used in isolation to make a diagnosis of osteo-
porosis. This technique utilizes two x-ray beams that are projected through soft tissue and through bone and soft tissue, with the difference in absorption between the two beams used to calculate the BMD. Because this is a two-dimensional rather than a volumetric measurement, calcifications in the path of the x-ray beam, such as a calcified aorta overlying the lumbar spine or lumbar spine osteophytes, can lead to artifactually elevated BMD readings in anteroposterior (AP) views (27–30). Although it has been suggested that quantitative CT should probably be used to assess BMD of lumbar vertebrae in CKD given limitations of DXA, lateral bone densitometry may also be useful to provide an accurate measurement, avoiding the overestimation in BMD with aortic calcification seen with AP DXA views (31,32).

Lateral spine images obtained with bone densitometry (similar to plain lateral radiographs) can also detect abdominal aortic calcification with reasonable good sensitivity and specificity (33)(Figure 2). Few studies have assessed the measurement of aortic calcification from bone densitometry images in the general population (33–35), and no study to date has reported this finding in CKD. The aim of this study was to determine and validate measurement of aortic calcification using DXA in a cohort of 40 prevalent hemodialysis (HD) subjects. We hypothesize that lateral DXA imaging with assessment of aortic VC may offer the opportunity to greater establish CV risk at little more time or expense when bone densitometry is performed for measurement of BMD. We also aim to compare differences in vertebral BMD between AP DXA and lateral DXA and correlate these measurements with lumbar spine BMD calculated from abdominal CT.

**Materials and Methods**

**Study Subjects**

Forty subjects were recruited between June 2007 and March 2008 from outpatient clinics, private consulting rooms, and satellite dialysis centers by nephrologists at Monash Medical Centre, Clayton, Australia. The cohort selected were HD patients willing to participate in a randomized controlled clinical trial assessing the differences in VC between calcium carbonate and lanthanum carbonate over an 18-mo period (Australian Clinical Trials Registry No. ACTRN12607000046404). Inclusion criteria were ages 18 to 80 and being established on HD for at least 3 mo. The local ethics committee approved the protocol and all subjects gave written consent. The trial is currently in progress and results presented in this study are an analysis of baseline data.

**CT**

We analyzed noncontrast CT scans of the abdominal aorta of 40 HD patients, from which VC scores based on the Hounsfield unit (HU) measurement of the aortic wall calcifications were determined. CT scans were performed using GE medical systems Lightspeed 16 multislice spiral CT scanner (120 kVp, 75 mAs, and 1.375 pitch). Images were acquired in a spiral mode with the patient lying supine. The scanning range was from T12 to L4 vertebral levels. The images were reconstructed to 10 mm thickness for viewing on the workstation. HU of any VC in the aorta were determined by a single radiologist who was blinded to the patient demographics, BMD data, and lateral DXA VC scoring. The number of calcifications and the highest HU of calcification in the infrarenal abdominal aorta were recorded. In a separate setting, HU of all VC in the exact anterior and posterior locations of the aortic walls were measured. The highest HU of the anterior and posterior aortic wall calcifications of each subject were recorded. Assessment of the BMD of L2 to L4 of all 40 subjects was also performed by measuring and averaging the HU of the cancellous bone of the mid-vertebral bodies. Because all patients were scanned under the same scanning parameters in the same CT scanner, the HU of the vertebral bodies measured would be directly proportional to the bone mineralization content within the vertebrae. All measurements were recorded for correlation.

**BMD**

BMD was assessed by AP and lateral DXA scans. Absolute BMD values, Z-scores, and T-scores (number of SD below the BMD of a younger reference group) for lumbar spine (L2 to L4) were reported...
and mean scores for all subjects were calculated. The lateral DXA images of the lumbar spine were obtained in the lateral decubitus position and were used to determine both BMD and VC. The DXA scan used was a GE-Lunar Prodigy (General Electric Medical Services, Australia) with the same densitometer used for all patients for accurate comparisons.

Abdominal aortic calcification on lateral DXA images was assessed using previously validated 8- and 24-point aortic calcification scales (34,36). Two investigators blinded to CT calcification data and patient demographics independently assessed all subjects. For the 24-point scale, calcified deposits in the aorta adjacent to each lumbar vertebra from L1 to L4 were assessed using the midpoint of the intervertebral space above and below the vertebrae as the boundaries (36). Lesions were graded as follows: 0, no aortic calcific deposits; 1, small scattered calcific deposits less than one-third of the longitudinal wall of the aorta; 2, one-third or more, but less than two-thirds calcified; 3, two-thirds or more calcified. The scores, obtained separately for the anterior and posterior wall, result in a range from 0 to 6 for each vertebral level and 0 to 24 for the total score.

An 8-point scale has more recently been described and validated (34). This scoring system estimates the total length of calcification of the anterior and posterior aortic walls in front of vertebrae L1 to L4 as 0 if no calcification is seen, 1 if the aggregate length of calcification is equal to the height of one vertebrae or less, 2 if that length is more than one but less than or equal to the heights of two vertebrae, 3 if that length is more than two but less than or equal to the heights of three vertebrae, and 4 if the aggregate length of calcification is more than the height of three vertebrae. Both the anterior and posterior walls are scored from 0 to 4, and the total score range is 0 to 8.

Clinical Characteristics

Medical charts were reviewed for clinical history, dialysis information and medications, and supplemented with information obtained directly from patients. Weight and height were measured to calculate the body mass index. Patients were considered to have a history of coronary artery disease if there was previous abnormal cardiac investigation or a history of myocardial infarction or angina. Patients were considered to have peripheral vascular disease if there was a history of intermittent claudication, leg ulceration, or previous abnormal peripheral angiography or Doppler ultrasound. Medications were recorded, including phosphate binders, vitamin D analogues, antihypertensive agents, and cholesterol-lowering agents.

Statistical Analyses

Results are expressed as mean ± SD, median (and range), or frequency (and proportion). To test intrarater agreement, DXA images were reread by the same reader (NT) 1 wk later blinded by previously measured scores. Intraclass correlation coefficients (ICC) were calculated for assessing agreement between readings. Univariate associations between VC (measured by CT and DXA) and BMD (measured by CT and DXA) were explored using linear regression. We also ascertained sensitivity, specificity, likelihood ratios, negative predictive values, and area under the curve for lateral DXA VC to predict various CT aortic calcification scores, with VC divided into tertiles to obtain scores of 0, ≥500, and ≥800 from CT and of 0, 1 to 5, and ≥6 from lateral DXA. A P-value of <0.05 was considered to be statistically significant. Intercooled Stata 10.0 (StataCorp, College Station, TX, US) was used for all statistical analyses.

Results

The demographics and clinical characteristics of the enrolled subjects studied are presented in Table 1. Subjects were predominantly men (70%) with a median age 58.5 yr (range 26 to 80). Thirty-eight percent were diabetic, and 62.5% of subjects had a history of hypertension. Diabetes mellitus was the main cause of CKD 5D (35%), with GN the next most common (25%). The median time on HD was 38.5 mo with most subjects dialyzing 12 h/wk. Laboratory values, including serum markers of mineral metabolism and inflammation, are displayed in Table 2. Serum phosphate levels were elevated (mean 2.00 mmol/L) as all subjects had ceased all phosphate binders for 1 wk before venesection as part of the randomized controlled trial protocol. Mean 25-hydroxy vitamin D level was 47.2 nmol/L (N = 75 to 250), with 80% of patients being vitamin D deficient.

Table 1. Characteristics of patients studied (n = 40)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Median (Range) or Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>58.5 (26 to 80)</td>
</tr>
<tr>
<td>Gender (Male)</td>
<td>28 (70)</td>
</tr>
<tr>
<td>Race (Caucasian)</td>
<td>37 (92.5)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>26.5 (18.2 to 40)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>15 (37.5)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>13 (32.5)</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>4 (10)</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>11 (27.5)</td>
</tr>
<tr>
<td>HT</td>
<td>25 (62.5)</td>
</tr>
<tr>
<td>Cause of CKD5</td>
<td></td>
</tr>
<tr>
<td>diabetes mellitus</td>
<td>14 (35)</td>
</tr>
<tr>
<td>GN</td>
<td>10 (25)</td>
</tr>
<tr>
<td>HT/renovascular reflux</td>
<td>4 (10)</td>
</tr>
<tr>
<td>othera</td>
<td>6 (15)</td>
</tr>
<tr>
<td>Length of HD (mo)</td>
<td>38.5 (3 to 204)</td>
</tr>
<tr>
<td>H/wk of HD</td>
<td>12 (12 to 15)</td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
</tr>
<tr>
<td>current</td>
<td>4 (10)</td>
</tr>
<tr>
<td>former</td>
<td>21 (52.5)</td>
</tr>
<tr>
<td>Medications</td>
<td></td>
</tr>
<tr>
<td>vitamin Db</td>
<td>26 (65)</td>
</tr>
<tr>
<td>ACE inhibitors</td>
<td>6 (15)</td>
</tr>
<tr>
<td>ARB</td>
<td>6 (15)</td>
</tr>
<tr>
<td>statinsc</td>
<td>21 (52.5)</td>
</tr>
<tr>
<td>ESA</td>
<td>36 (90)</td>
</tr>
<tr>
<td>Native AVF</td>
<td>39 (97.5)</td>
</tr>
<tr>
<td>Previous parathyroidectomy</td>
<td>7 (17.5)</td>
</tr>
<tr>
<td>Previous transplant</td>
<td>7 (17.5)</td>
</tr>
</tbody>
</table>

Other includes polycystic kidney disease, vasculitis, and obstructive nephropathy.

Active vitamin D, all patients on oral calcitriol.

Cholesterol-lowering HMG-CoA reductase inhibitors.

HT, hypertension; CKD5, chronic kidney disease stage 5; HD, hemodialysis; ACE, angiotensin-converting enzyme; ARB, angiotensin II receptor blockers; ESA, erythropoietin stimulating agents; AVF, arterio-venous fistula.
Ninety-four percent of subjects had evidence of abdominal aortic calcification with CT (Table 3). Mean aortic VC score was 520.9 ± 286.1 HU (range 0 to 1164.4). Mean anterior and posterior aortic calcification scores were 298.2 and 401.8 HU, respectively (combined 700.4 HU). Aortic VC was seen in 67.5% of lateral DXA images, with mean VC scores of 4.80 ± 5.73 and 2.03 ± 1.91 using the 24- and 8-point scales, respectively (Table 4). Frequency distributions of VC from DXA for the two measurement scales are shown (Figure 3). ICC for intrarater agreement (test-retest reliability) of aortic VC with DXA is shown in Table 4. There was good correlation for both 24- and 8-point scales with ICC 0.93 (95% confidence interval 0.87 to 0.96) and 0.88 (95% confidence interval 0.79 to 0.93), respectively.

Correlation between VC measured from DXA and CT

There was good correlation for measurements of aortic VC between lateral DXA and CT, using both the 24- and 8-point scales (r = 0.58, P < 0.001 and r = 0.57, P < 0.001, respectively; Table 5). This was consistent for anterior and posterior aortic VC measurements independently.

Table 6 shows the sensitivity, specificity, likelihood ratios, and area under the curve for lateral DXA aortic VC scores in the prediction of aortic calcification with CT for aortic VC ≥ 500 and ≥ 800. The likelihood ratio of aortic VC ≥ 500 was 2.37 and 3.50 for subjects with lateral DXA VC of 1 to 5 and ≥ 6, respectively (24-point scale). The negative predictive values of a lateral DXA VC score of 0 for CT aortic VC scores ≥ 500 and ≥ 800 were 76.9 and 92.3%, respectively, for both 24- and 8-point scales.
8-point scales. The area under the curve for DXA scores was above 0.80 for predicting CT-measured aortic VC ≥500, indicating good discriminatory value.

**Table 4. Prevalence and mean scores of aortic calcifications from DXA (and intraclass correlation coefficients)**

<table>
<thead>
<tr>
<th>Scale</th>
<th>Score</th>
<th>Investigator 1</th>
<th>Investigator 1a</th>
<th>ICC (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24-point</td>
<td>Prevalence</td>
<td>67.5%</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anterior</td>
<td>2.18 ± 3.06</td>
<td>2.27 ± 3.39</td>
<td>0.921 (0.86 to 0.96)</td>
</tr>
<tr>
<td></td>
<td>Posterior</td>
<td>2.63 ± 2.89</td>
<td>2.50 ± 3.08</td>
<td>0.912 (0.85 to 0.95)</td>
</tr>
<tr>
<td></td>
<td>A-P</td>
<td>4.80 ± 5.73</td>
<td>4.78 ± 6.36</td>
<td>0.931 (0.87 to 0.96)</td>
</tr>
<tr>
<td>8-point</td>
<td>Prevalence</td>
<td>67.5%</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anterior</td>
<td>0.95 ± 1.04</td>
<td>0.95 ± 1.07</td>
<td>0.826 (0.71 to 0.91)</td>
</tr>
<tr>
<td></td>
<td>Posterior</td>
<td>1.08 ± 1.00</td>
<td>0.98 ± 1.00</td>
<td>0.846 (0.74 to 0.92)</td>
</tr>
<tr>
<td></td>
<td>A-P</td>
<td>2.03 ± 1.91</td>
<td>1.90 ± 1.99</td>
<td>0.879 (0.79 to 0.93)</td>
</tr>
</tbody>
</table>

aTest retest reliability: assessed 1 wk later.

Median values for A-P scores were 3 and 2 for 24- and 8-point, respectively.

A-P, combined anterior and posterior; ICC, intraclass correlation coefficient.

**Figure 3. Frequency distributions of (A) 24-point and (B) 8-point scores from lateral DXA images (n = 40)**

Mean T-scores with DXA were 0.48 ± 1.71 for lumbar spine (L2 to L4) measured AP and −1.16 ± 1.93 using lateral lumbar images (Table 3). Using the latter method, 20 patients (50%) had T-scores less than −1.0, with 12 (30%) having T-scores less than −2.5 (WHO osteoporotic range). The mean femoral neck T-score for the cohort (−1.73 ± 1.21) was more consistent with the mean lateral DXA lumbar T-score (r = 0.42, P = 0.007) than with AP DXA scores (r = 0.34, P = 0.01).

Lumbar BMD was also measured using CT scans with HU of L2 to L4 vertebrae reported. The combined BMD with CT was 652.8 ± 216 HU, and with linear regression there was good correlation with lumbar T-scores from the lateral DXA (r = 0.54, P < 0.001) but no significant association with those from AP DXA (Table 7). There was a trend toward a significant positive association between AP lumbar spine T-scores and aortic calcification on linear regression (r = 0.30, P = 0.064), whereas lateral spine T-scores and aortic calcification were nonsignificantly associated (P = 0.78).

**Discussion**

Studies in CKD 5D report 80 to 85% of prevalent dialysis patients and 60% of incident patients have some degree of coronary artery or aortic VC as determined by CT (8,37). In our study, 94% of the prevalent HD cohort had aortic VC with CT, with 68% having documented VC with lateral DXA views. We demonstrate that lateral DXA images, intended to detect vertebral BMD, can reliably identify patients with abdominal aortic calcification in the region corresponding to L1 to L4. We also report the ability to provide semiquantitative measurement of VC, with good correlation between aortic VC scores measured by CT.

EBT and CT are highly reliable research tools, being more sensitive and providing quantitative calcification measurement; however, both are expensive and deliver a substantial dose of radiation. Given the prognostic significance of VC, it has been suggested that simple in-office measurements and assessments might be substituted for these more sophisticated radiologic techniques (38). Plain lateral x-rays have been reported to be effective in detecting aortic VC with acceptable accuracy in HD (18), and one study comparing lateral DXA images to lateral
spine x-rays in postmenopausal women reported good correlation (ICC 0.80 and 0.76 for 24-point and 8-point scoring system, respectively) (34). In our study we also highlight the potential for utilizing lateral DXA, in a HD population with greater VC than the general population, to detect and semi-quantitatively measure aortic calcification.

We assessed the criterion validity of VC measurement from lateral DXA and demonstrated good correlation with the gold standard CT VC measurement. Although this was not surprising, given that the different radiologic methods are both measuring the same parameter, agreement between them was relatively low and the degree of VC with CT, in fact, explains less than 35% of the variability in the DXA measurement. However, the high negative predictive values of a lateral DXA VC score of zero for high aortic VC scores with CT support the possibility of using this method for VC screening to potentially influence management. We also report good reproducibility of VC scores from lateral DXA in our study with excellent intrarater ICC, both for the 24- and 8-point scales.

Several issues should be noted with the use of DXA scans to measure VC. One issue is that technicians performing the investigation need to be informed to include the abdominal aortic region in the lateral view for adequate images. Determining if aortic VC is present on lateral DXA is made difficult with the presence of ribs and the iliac crest, and this may explain the decreased prevalence of VC with DXA compared with CT detection. Aortic VC can also be difficult to visualize with lateral DXA images in obese subjects, in which vertebral bodies are even sometimes difficult to see. However, in our study there were no differences in VC scores with DXA with respect to differences in BMI levels. Lateral DXA images, like plain radiographs, are also only qualitative and do not allow for accurate assessment of temporal changes in VC.

Radiographic findings of abdominal aortic calcification have been shown to be significantly predictive of heart failure, ischemic heart disease, stroke, and overall CV disease incidence and mortality in the general population and in CKD (15,39–42). Recently, abdominal aortic VC scores on baseline lateral DXA images, intended for vertebral fracture assessment in elderly women, were associated with subsequent myocardial infarction.
or stroke over a 4-yr period, independent of clinical CV disease risk factors (35). Therefore, imaging studies to detect subclinical CV disease, such as using lateral DXA to detect aortic VC, may be useful to improve identification of CKD 5D patients who may benefit from more aggressive treatment of risk factors such as stricter control of abnormal mineral metabolism, avoidance of calcium-based phosphate binders, or earlier renal transplantation. However, the predictive validity of VC measurement from lateral DXA in CKD patients for CV morbidity and mortality has not been assessed.

In addition to VC measurement, we also assessed the use of multislice spiral CT scans to measure lumbar spine BMD with HU scoring. Comparison of CT BMD scores with lateral DXA revealed good correlation, unlike with AP DXA images, because the lateral DXA avoids any superimposed aortic calcification, which can confound and exaggerate the BMD measurement with the AP DXA. The rationale for BMD determination in CKD 5D, however, is questionable, because low BMD probably represents a spectrum of renal osteodystrophy, and not just osteoporosis, in this population. The role of DXA, normally used to diagnose osteoporosis in the general population, is therefore not clear in dialysis patients and the single best diagnostic tool for bone abnormalities is quantitative double tetracycline-labeled bone histomorphometry.

DXA may still be helpful in advanced CKD because low BMD and resultant fracture rates increase with CKD progression. Early studies reported that in the dialysis population, DXA assessing hip and lumbar spine BMD was not associated with fractures and that quantitative CT scans, assessing cortical bone, were more beneficial because CKD5 patients have a selective decrease in cortical density not identified by standard DXA (43,44). However, a recent meta-analysis reported that BMD determined by DXA was lower in patients with CKD5 who had fractures than those without fractures (45). This was an unadjusted association and only showed a significant difference in fractures for BMD measured at the spine and radius (not at the femoral neck), but suggested that DXA may have a role in CKD5 for predicting fracture risk. Lateral DXA is non-invasive, has low radiation exposure, is relatively inexpensive compared with CT, and therefore may have a dual role in determining vertebral BMD, subsequent fracture risk, and aortic VC.

In our study, the densitometry images obtained were dual-energy images to assess BMD of lateral vertebrae as well as aortic VC, as opposed to previous published studies involving single-energy densitometers for vertebral fracture assessment and aortic VC (33–35); therefore this is the first study to show concurrent validity for this technique. DXA delivers "high-resolution" lateral spine images and can also offer a potential practical alternative to plain radiographs for clinical vertebral fracture analysis. The advantages of using lateral DXA over conventional plain x-rays are its minimal radiation exposure and high-speed image acquisition, but one disadvantage is that upper thoracic vertebrae cannot be evaluated in a substantial number of patients because of poor imaging quality.

In the general population and CKD, there is a strong inverse relationship between BMD levels and VC (6, 22–24, 46); however, in our study we showed a trend toward a significant positive association between AP DXA-reported BMD and aortic VC. As described earlier, this likely artifactual association occurs because AP DXA beams, projected blindly through the body, are likely absorbed by dense VC in the aorta rather than the spine, therefore leading to falsely elevated BMD readings. Lateral DXA are probably more beneficial in patients with a greater extent of aortic VC, such as in CKD, by providing more accurate lumbar spine BMD measurements. In our study, lumbar BMD measured by lateral DXA was more consistent with femoral neck BMD.

Although there is a reported correlation between increasing VC and loss of BMD, we did not find an inverse relationship between VC and BMD in our study. In a previous study of 49 dialysis patients who underwent x-ray to determine both coronary calcification scores and vertebral bone mass, there was a significant inverse correlation between these parameters (6). Despite both CT and DXA being used for measurements of VC and BMD in our study, this relationship was not evident and may be related to the smaller sample size or our assessment of aortic instead of coronary artery calcification. There was a strong positive relationship between aortic VC and increasing age, but no association with serum markers of mineral metabolism (data not shown).

Of interest, vitamin D deficiency was highly prevalent in our study, with 80% of HD patients documented to have 25-hydroxy vitamin D levels below the normal range. This finding is consistent with reported studies in CKD 5D (47,48), and 25-hydroxy vitamin D deficiency has been shown to correlate poorly with other components of mineral metabolism and be associated with increased early mortality (47). However, there was no correlation in our study between vitamin D levels and VC (data not shown).

There were a few limitations in our study. The study was observational and there were small patient numbers. No intraobserver variability was determined by repeated measurement of VC from CT however the investigator reporting VC and BMD did so independently without knowledge of results of the other tests and demographic details. Also, as our study is cross-sectional it does not directly show how detection of aortic VC on lateral DXA images predicts incident CV events in the dialysis population. Further studies would be required to determine the value of lateral DXA to demonstrate VC, as a surrogate marker, in predicting CV morbidity and mortality.

Conclusion
Screening methods to assess the degree of VC could potentially be worthwhile in general clinical practice given the high prevalence and functional significance of these structural changes. Detection may allow accurate risk stratification and changes in treatment, because VC rarely regresses once developed. Abdominal aortic calcification scored semiquantitatively with lateral lumbar spine x-rays has been shown to be predictive of CV disease incidence and mortality independent of other clinical risk factors. We report that lateral imaging from DXA scans, similar to lateral x-rays, may have dual benefit in CKD 5D because they can more accurately detect vertebral BMD and...
simultaneously detect abdominal aortic calcification with good sensitivity and specificity. AP DXA has limitations in CKD 5D, with artifactual increased vertebral BMD measurements from concurrent detection of aortic VC. We have demonstrated that lateral DXA is a more reliable measure of BMD and correlates better with hip DXA and vertebral BMD with CT. Lateral DXA is low cost, has low risk to patients, and may be helpful as part of the screening process for VC in dialysis patients.

Acknowledgments

Nigel D. Toussaint is supported by a National Health and Medical Research Council (NHMRC) Grant (Australia).

Disclosures

None.

References


