COMPARATIVE STUDY OF DUAL ENERGY X-RAY ABSORPTIOMETRY SCAN AND CONVENTIONAL RADIOGRAPHY IN EARLY DETECTION OF RENAL OSTEODYSTROPHY

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ABSTRACT

BACKGROUND

Renal osteodystrophy is a part of broad spectrum of disturbances in mineral and bone metabolism, which are prevalent in Chronic Kidney Disease (CKD) and lead to serious and debilitating complications unless these abnormalities are addressed and treated at an early stage. Therefore, by this study, we try to compare Dual X-ray Absorptiometry (DXA) scan and conventional radiography in their ability to detect such lesions early and characterise them.

MATERIALS AND METHODS

Our study was a comparative study conducted over a period of one year. The subjects in our study were the newly diagnosed CKD patients of stage III, stage IV and stage V without any renal replacement therapy (renal transplant/dialysis) or any recent or intercurrent illness. 52 such patients were selected and they were evaluated by doing conventional radiographs and DXA scan of specific sites (lumbosacral spine, pelvis including femur and hands including radius).

RESULTS

At the lumbosacral spine, DXA revealed reduced bone density in 50% of which 40% had osteopenia and 10% had osteoporosis. At the pelvis, DXA was positive in 52% cases at femur of which 42% had osteopenia and 10% had osteoporosis. At forearm in the radius, DXA was positive in 62% cases of which 45% had osteopenia and 17% had osteoporosis. Conventional radiography revealed abnormality in 21% of the subjects at LS spine, 19% in pelvis and 26.9% in hands.

CONCLUSIONS

1. DXA studies of the radius are most appropriate for evaluation of bone mineral density in predialysis CKD patients.
2. In conventional radiography studies, the most sensitive site for radiographic abnormality is hand in predialysis CKD patients. Reduced bone density is the most common abnormal finding on conventional radiographs.
3. Though DXA has overall higher sensitivity than conventional radiography in identifying reduced bone mineral density in CKD, the specific features of renal osteodystrophy is better done by conventional radiography.

KEYWORDS

Chronic Renal Disease, Predialysis, Renal Osteodystrophy, DXA, Conventional Radiographs, Osteopenia, Osteoporosis.

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BACKGROUND

Chronic kidney disease is defined as kidney damage or Glomerular Filtration Rate (GFR) <60 mL/min./1.73 m2 for three months or more irrespective of the cause. Disturbances of bone and mineral metabolism are common during the course of CKD and lead to serious and debilitating complications unless these abnormalities are addressed and treated at the early stage.

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Renal osteodystrophy is a common complication of chronic kidney disease and is part of a broad spectrum of disorders of mineral metabolism that occurs in this clinical setting. It occurs early and progresses as the kidney function deteriorates. This term should be used exclusively to define the bone morphology associated with CKD.[1,2] The term CKD-Mineral and Bone Disorder (CKD-MBD) is used to describe a broader clinical syndrome that develops as a systematic disorder of mineral and bone metabolism in CKD.

The abnormalities of renal osteodystrophy may manifest as a high bone turnover disease, a dynamic bone disease or as mixed renal osteodystrophy.

More commonly, there is reduced bone mass, which increases the risk of bone fracture. Dual energy x-ray absorptiometry is one of the noninvasive methods by which the bone mass can be estimated.

On imaging, renal osteodystrophy combines the findings of osteomalacia, hyperparathyroidism and bone sclerosis.[3]

- Osteoporosis.
- Secondary hyperparathyroidism- Bone resorption especially subperiosteal resorption is a common and highly specific finding. Bone resorption causes cortical thinning and overall loss of bone density (osteopenia/osteoporosis). Intracortical tunnelling can also be seen. Brown tumours are another manifestation seen as well-defined lytic lesions that may occur in any bone.
- Osteomalacia- Identified by the presence of pseudofractures with evidence of generalised osteopenia.
- Osteosclerosis- Reason for this is not clear. Proposed to be due to excessive deposition of osteoid that may inhibit osteoclastic activity and increased serum calcium-phosphate product may cause precipitation of mineral in this osteoid.[4] In spine, this is seen as osteosclerosis near vertebral body end plates yielding a 'rugger jersey' appearance.
- Soft tissue calcification (vascular and periarticular)- is another prominent feature of renal osteodystrophy.
- Insufficiency fractures occur due to a combination of osteomalacic, osteoporotic, hyperparathyroid and aluminium toxicity changes in the bones.
- Aluminium toxicity- presents as fractures particularly of ribs (2, 3 and 4), pseudofractures and osteopenia related to osteomalacia. It occurs in patients taking phosphates with aluminium salts as binders. It causes encephalopathy and bone changes.

OBJECTIVES

1. To identify and examine the frequency and severity of skeletal changes in chronic kidney disease by measurement of Bone Mineral Density (BMD) by Dual X-Ray Absorptiometry (DXA) scan.
2. The role of conventional radiography in detection of patterns of bone changes in the patients of chronic kidney disease.
3. Comparison between the findings of Dual X-Ray Absorptiometry (DXA) scan and conventional radiography as a modality in early detection of bone changes in chronic kidney disease.

MATERIALS AND METHODS

In our study, a cross-sectional study was conducted between February 2007 and July 2008 in the Department of Radiodiagnosis in collaboration with Department of Nephrology and Department of Rheumatology, Institute of Postgraduate Medical Education and Research (IPGMER) Kolkata, India.

Total 52 subjects of mean age 49.5±12.3 yrs. ranging from 21 to 75 yrs. participated in the study.

The only inclusion criteria we used was newly-diagnosed Chronic Kidney Disease (CKD) patients of stage III, stage IV and stage V without any renal replacement therapy or any intercurrent illness.

Subjects with acute renal failure or any medical conditions or medications known to influence bone metabolism were excluded from the study. Postmenopausal women were also excluded from the study.

A brief clinical history was taken from the selected subjects. Conventional x-ray of lumbosacral spine (AP and lateral views), pelvis including both hip joints (AP view) and magnified view of both hands (PA view) were done.

BMD was then measured by DXA Scan. BMD was measured at lumbar spine (L1 to L4), both femoral necks and both radius and was expressed as exact values in gm/cm2, Z-score and T-score. BMD results were then interpreted according to WHO criteria as follows-

T-score- 1 to -2.5 = Osteopenia.

T-score <-2.5 = Osteoporosis.

Statistical Analyses

Data analyses was done using Statistica version 6.0 (Tulsa, OK, USA; StatSoft Inc., 2001) and SPSS version 11.5 (Chicago, IL USA; SPSS Inc., 2002) software.

The descriptive statistic and cross tabulation results were analysed by Kappa statistic (test of general agreement) and Fisher's exact test (paired) (test of significance).

P value <0.05 was considered significant according to Fisher's exact test.

Kappa coefficient was interpreted as per Landis and Koch's interpretation.

OBSERVATION AND RESULTS

In our study, we had total of 52 subjects out of which CKD stage III comprised 23%, stage IV was 33% and stage V was 44% with mean age 49±12.38 yrs. Thus, we found that in chronic kidney disease, most of the patients presented at an advanced stage of their disease process.

In our study, we subjected our study population to both Conventional radiography and DXA and then compared the results to test the diagnostic utility of both imaging modalities.

At the lumbosacral spine, DXA revealed reduced bone density in 50% (26) of the study population of which 40% had osteopenia and 10% had osteoporosis. The mean BMD at LS spine was 1.0838±0.17 gm/cm^2 (ranging from 0.492 to 1.456 gm/cm^2) and mean T-score was -1.075±1.23. Of these, 3 were in CKD stage III, 9 in stage IV and 14 in stage V, whereas conventional radiography revealed abnormality in 21% of the subjects. Of these, 1 patient was in CKD stage III, 3 patients in stage IV and 7 patients in stage V. All the cases positive on conventional radiography revealed reduced bone density on DXA except for one patient who showed osteosclerosis at the end plates of vertebral bodies in conventional radiography suggesting rugger jersey spine. This latter, patient didn't show any abnormality on DXA. Thus, it was found that overall DXA detects more abnormalities than conventional radiographs, but is less sensitive in picking the sclerotic lesions where conventional radiography takes the upper hand.

At the pelvis, DXA was positive in 52% cases at femur of which 42% had osteopenia and 10% had osteoporosis. The mean BMD at right femur was 0.9562±0.16 gm/cm^2 and at left femur was 0.9495±0.15 gm/cm^2. The mean T score at

right femur and left femur was -0.9423±1.22 and 0.9096±1.158, respectively. Conventional radiography was positive in only 19% cases and all of them had positive DXA. Eight patients showed features suggesting reduced bone density, one patient showed reduced bone density along with pseudofracture suggesting osteomalacia and one patient showed insufficiency fracture at neck of femur (right) along with cortical erosion at symphysis pubis. All 10 patients who were positive on conventional radiography showed reduced bone density in DXA. Additionally, 17 more patients were detected by DXA.

At hand and radius, DXA was positive in 62% cases of which 45% had osteopenia and 17% had osteoporosis. Mean BMD at the right radius and left radius was 0.5194±0.07 gm/cm^2, respectively. The mean T score of right and left radius was -1.3135±1.16 and -1.198±1.07, respectively. Conventional radiography showed abnormalities in 26.9% cases and all of which showed reduced BMD on DXA. Most common finding was subperiosteal resorption and reduced bone density.

From the above data, we can see radius is the most sensitive site to detect bony changes in CKD patients by both conventional radiography and DXA in all stages of CKD.

The cross tabulation results assessed by Kappa statistic for overall study population, stage IV and stage V together and stage V separately revealed fair agreement of conventional radiography with DXA at all sites in all subgroups, but it was not strong enough to replace DXA.

Fischer's exact test also revealed statistically significant difference (p value <0.05) in all the subgroups at all sites. However, when we grouped stage III and stage IV patients together and analysed the data, then Fisher's exact test showed significant difference at radius (p value 0.0421) and was not significant at lumbosacral spine (p value 0.27) and pelvis including femurs (p value 0.0602). Thus, we see that radius is the most sensitive site for DXA in both early and late stage of chronic kidney disease.

Number of Cases				
CKD Stage	**Male**	**Female**	**Total**	**Percentage (%)**
Stage III	9	3	12	23
Stage IV	12	5	17	33
Stage V	16	7	23	44

Table 1. CKD Stage Distribution in Study Population (n=52)

Modalities	**DXA-LS Spine**			
Conventional Radiography-LS Spine	**Results**	**Negative**	**Positive**	**Total**
	Negative	25	16	41
	Positive	01	10	11
	Total	**26**	**26**	**52**

Table 2. Cross Tabulation of DXA vs. Conventional Radiography Results at Lumbosacral Spine (Stage III, IV and V) n =52

Modalities	**DXA-LS Spine**			
Conventional Radiography-LS Spine	**Results**	**Negative**	**Positive**	**Total**
	Negative	16	14	30
	Positive	01	09	10
	Total	**17**	**23**	**40**

Table 3. Cross Tabulation of DXA vs. Conventional Radiography Results at Lumbosacral Spine (Stage IV and V) n=40

Modalities	**DXA-LS Spine**			
Conventional Radiography-LS Spine	**Results**	**Negative**	**Positive**	**Total**
	Negative	09	07	16
	Positive	0	07	07
	Total	**09**	**14**	**23**

Table 4. Cross Tabulation of DXA vs. Conventional Radiography Results at Lumbosacral Spine (Stage V) n=23

Modalities	DXA-PF			
Conventional Radiography-PF	**Results**	**Negative**	**Positive**	**Total**
	Negative	25	17	42
	Positive	00	10	10
	Total	**25**	**27**	**52**

Table 5. Cross Tabulation of DXA vs. Conventional Radiography Results at Pelvis Including Femurs (CKD III, IV and V)

Modalities	DXA-PF			
Conventional Radiography-PF	**Results**	**Negative**	**Positive**	**Total**
	Negative	17	14	31
	Positive	00	09	09
	Total	**17**	**23**	**40**

Table 6. Cross Tabulation of DXA vs. Conventional Radiography Results at Pelvis Including Femurs (CKD IV and V)

Modalities	DXA-PF			
Conventional Radiography-PF	**Results**	**Negative**	**Positive**	**Total**
	Negative	08	08	16
	Positive	00	07	07
	Total	**08**	**15**	**23**

Table 7. Cross Tabulation of DXA vs. Conventional Radiography Results at Pelvis Including Femurs (CKD V)

Modalities	DXA-Hand			
Conventional Radiography-Hand	**Results**	**Negative**	**Positive**	**Total**
	Negative	20	18	38
	Positive	00	14	14
	Total	**20**	**32**	**52**

Table 8. Cross Tabulation of DXA vs. Conventional Radiography Results in Hands Including Radius (CKD III, IV and V)

Modalities	DXA-Hand			
Conventional Radiography-Hand	**Results**	**Negative**	**Positive**	**Total**
	Negative	13	15	28
	Positive	00	12	12
	Total	**13**	**27**	**40**

Table 9. Cross Tabulation of DXA vs. Conventional Radiography Results in Hands Including Radius (CKD IV and V)

Modalities	DXA-Hand			
Conventional Radiography-Hand	**Results**	**Negative**	**Positive**	**Total**
	Negative	06	08	14
	Positive	00	09	09
	Total	**06**	**17**	**23**

Table 10. Cross Tabulation of DXA vs. Conventional Radiography Results at Hands Including Radius (CKD V)

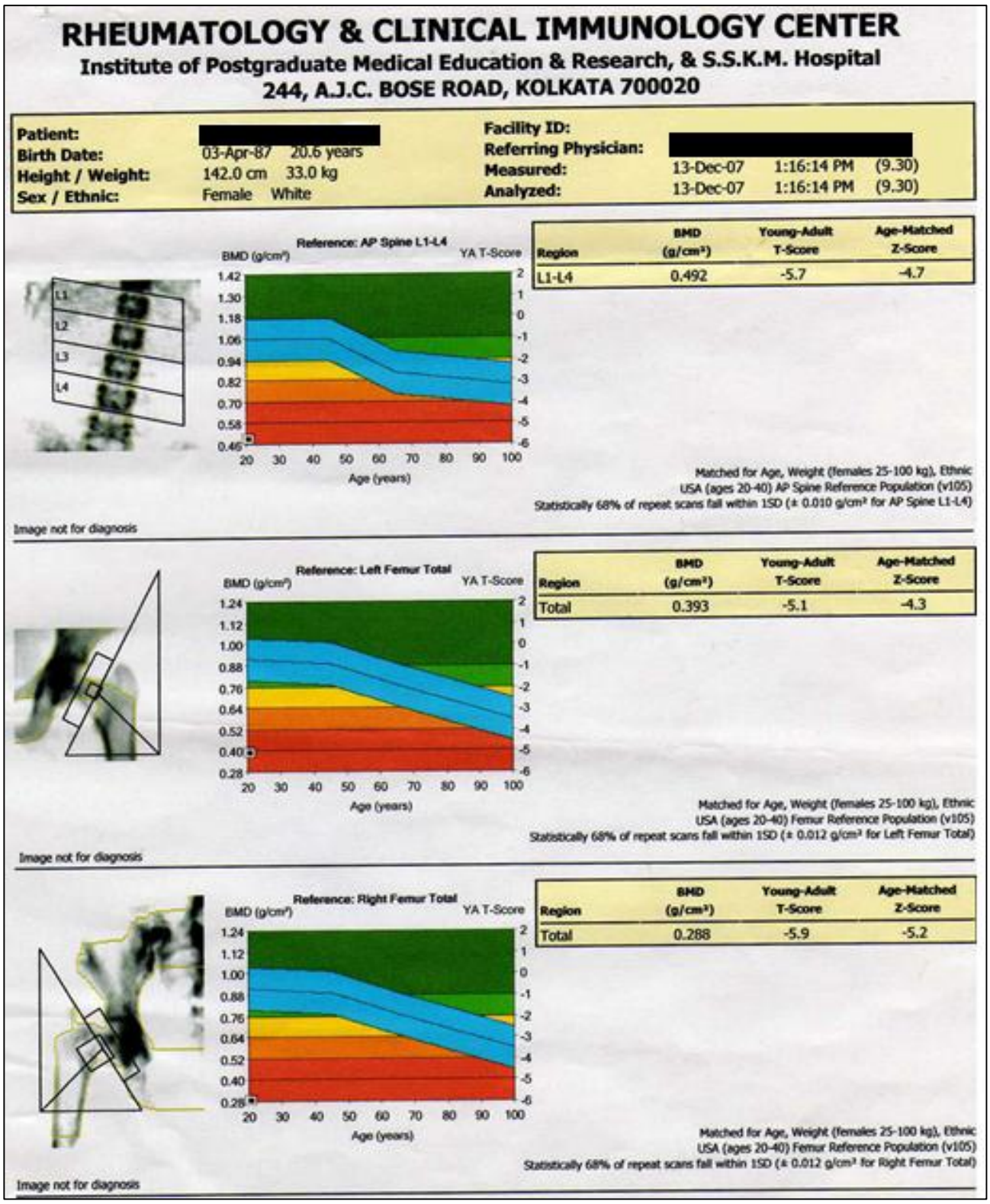

Figure 1a. DXA Scan in a 20-Year-Old Female (CKD Stage V) Reveals Osteoporosis at Lumbosacral Spine (T Score-5.7) and Both Femurs (T Score Right Femur-5.9, T Score Left Femur-5.1)

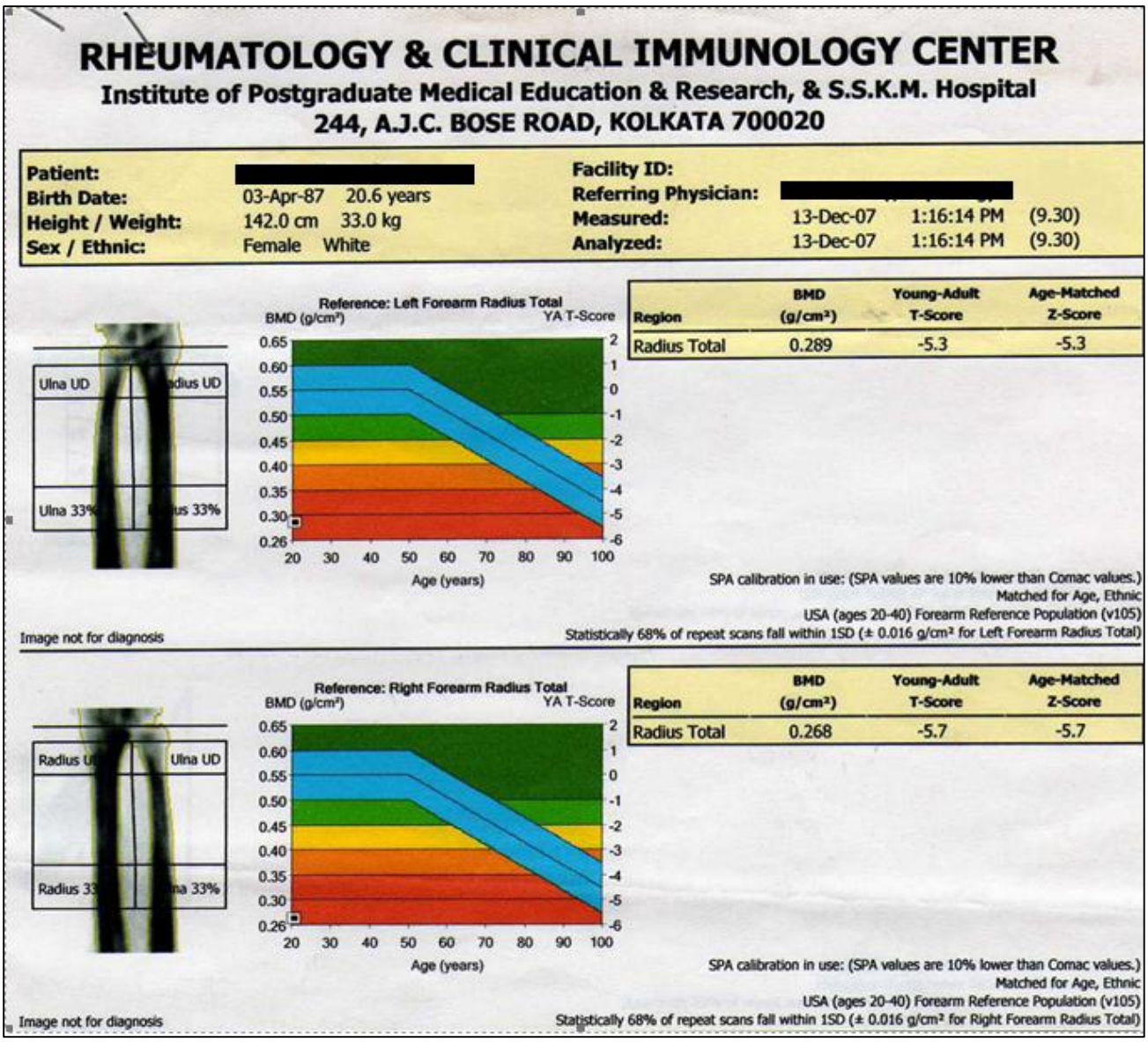

Figure 1b. DXA Scan of a 20-Year-Old Female (CKD Stage V) Reveals Osteoporosis at the Radius of Both Hands (Right Radius T Score-5.7, Left Radius T Score-5.3)

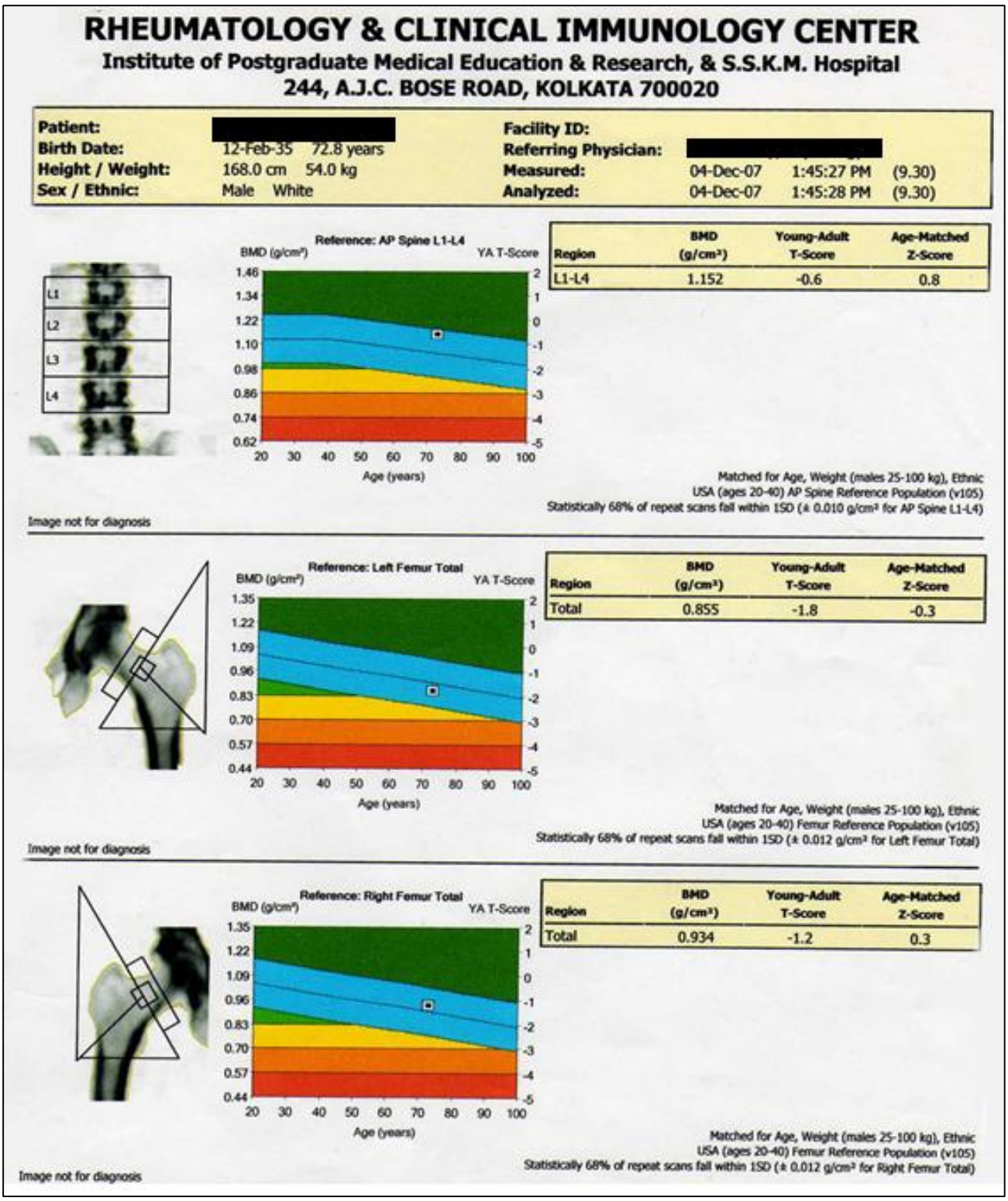

Figure 2a. DXA Scan of a 72-Year-Old Male (CKD Stage IV) Reveals Normal Lumbosacral Spine (T Score-0.6) and Osteopenia at Both Femurs (Right Femur T Score-1.2, Left Femur T Score-1.8)

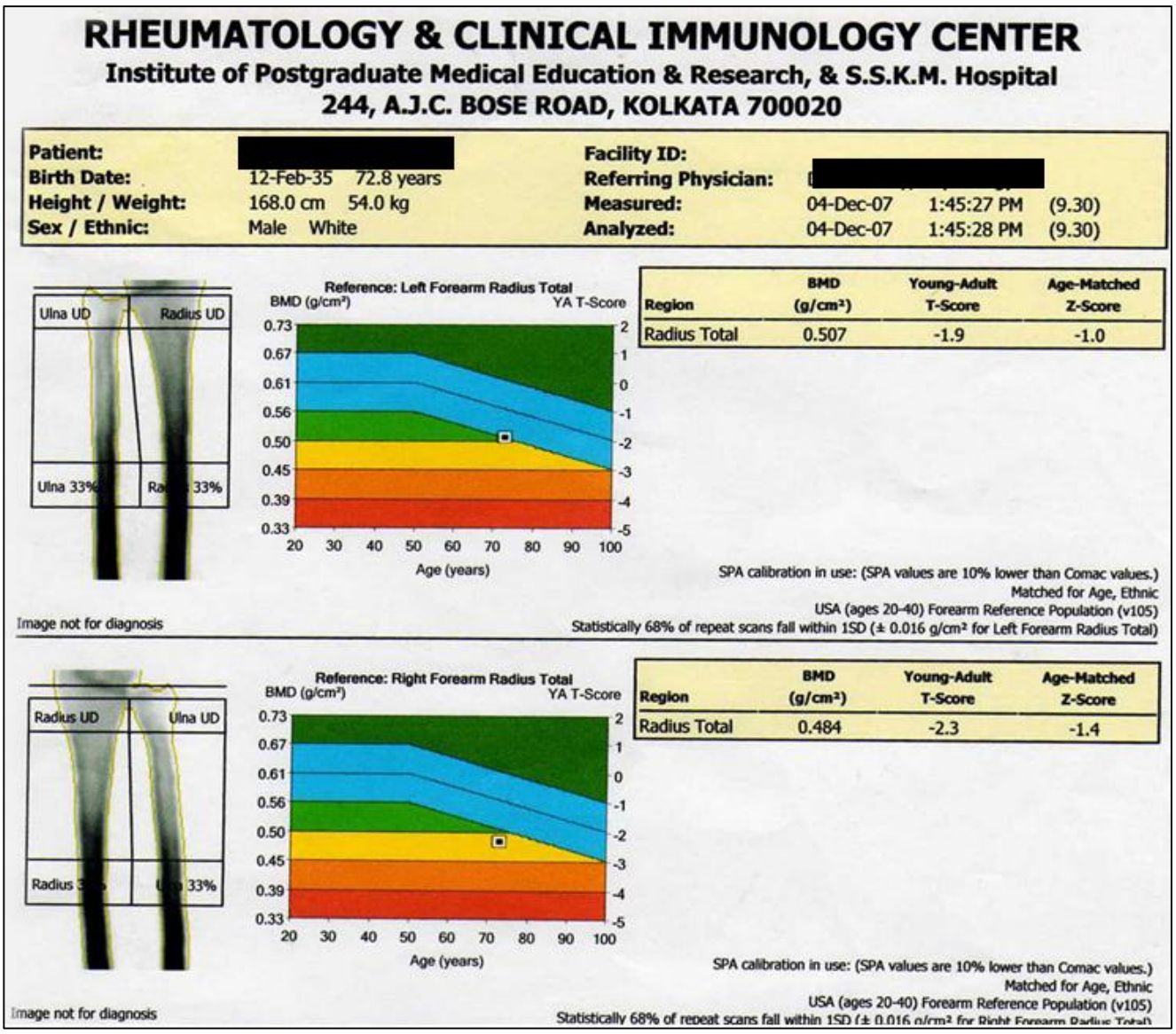

Figure 2b. DXA Scan of a 72-Year-Old Male (CKD Stage IV) Reveals Osteopenia at Radius of Both Forearms (Right Radius T Score-2.3, Left Radius T Score-1.9)

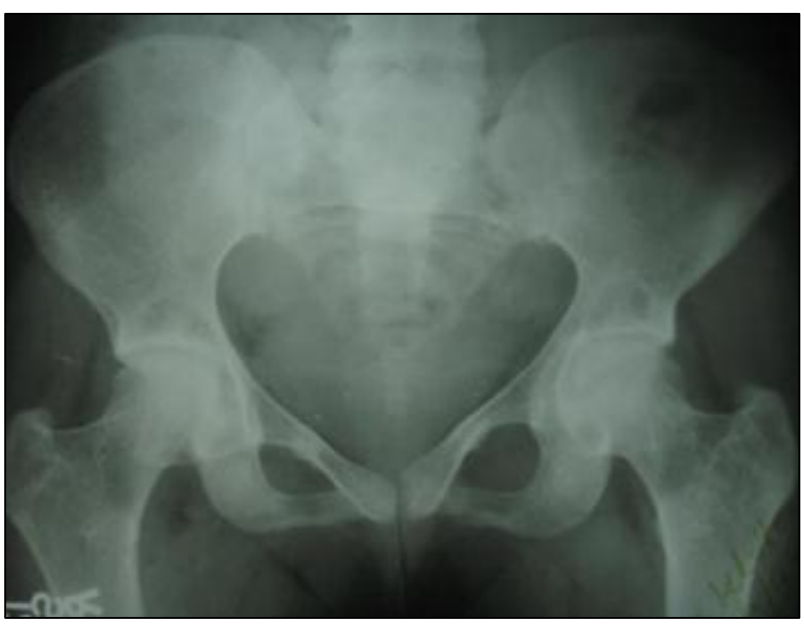

Figure 3. X-Ray Pelvis AP View in a 32-Year-Old Female (CKD V) Showing Looser Zone in Superior Pubic Rami

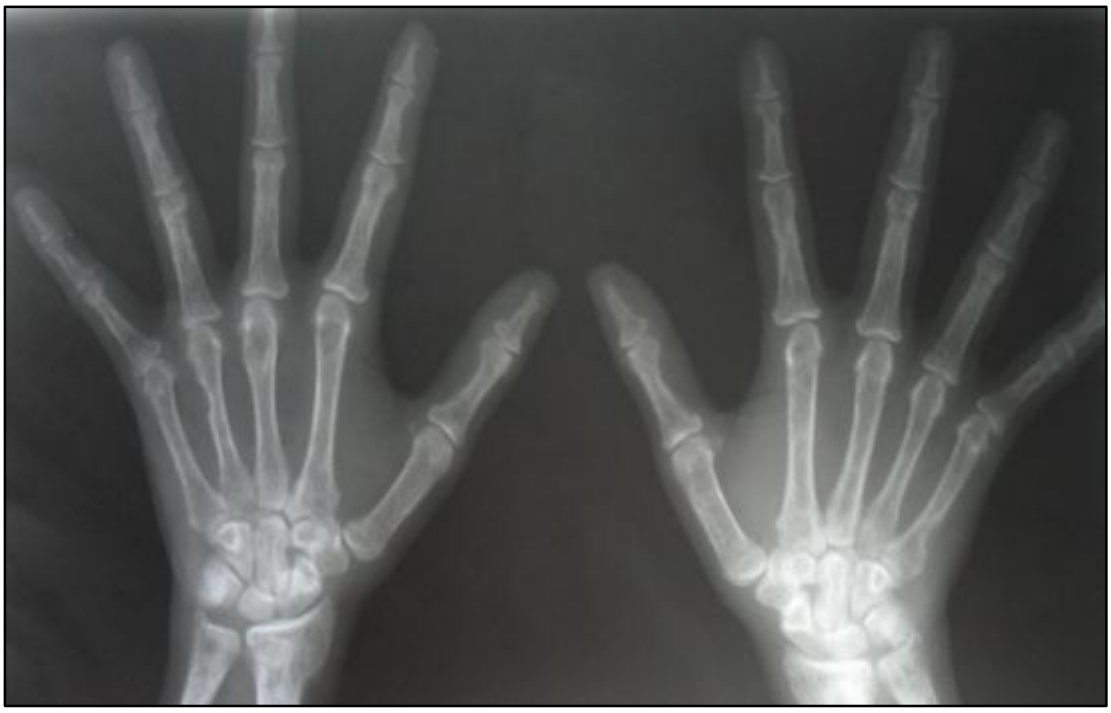

Figure 4. X-Ray Both Hands PA View in a 20-Year-Old Female (CKD Stage V) Showing Subperiosteal Resorption of the Metacarpals and Acroosteolysis at the Terminal Phalanges

DISCUSSION

Disturbances in mineral and bone metabolism are prevalent in Chronic Kidney Disease (CKD) and are important causes of morbidity, decreased quality of life and have been associated with increased cardiovascular mortality.

In our study, we had total 52 subjects of which 23% had stage III CKD, 33% had stage IV and 44% had stage V with diabetes mellitus (32%) and hypertension (27%) as the two most common associated medical illness. The mean age of our study population was 49.5±12.38 yrs. A study done on "assessment of renal bone mineral disorder in naive CKD patients- a single centre prospective study" by Sanjay K. Agarwal[5] at AIIMS, New Delhi, found 46.6% patients in CKD stage V, 30.1% in CKD stage IV and 17% in CKD stage III. The two basic diseases reported were diabetic nephropathy in 37.9% and hypertensive nephrosclerosis in 15.3%. The mean age was 46.89±13.4 yrs.

Thus, we see that in chronic kidney disease, most of the patients present at an advanced stage of their disease process and in Indian scenario CKD is clinically manifested in the fifth decade.

In our study, we subjected our study population to both conventional radiography and DXA and then compared the results to test the diagnostic utility of both imaging modalities.

Several studies have assessed bone mineral status in CKD patients, but most of them have been done in postdialysis patients. A study by Kosowicz J and Bolko P et al[6] on "results of bone scintigraphy, densitometry and radiography in secondary hyperparathyroidism in patients with chronic renal failure" was done on predialysis patients, but it was done in patients of secondary hyperparathyroidism.

In our study, 50% of patients revealed reduced bone density at the LS spine of which 40% had osteopenia and 10% had osteoporosis. At pelvis including both hip joints, 52% patients revealed reduced bone mineral density of which 42% had osteopenia and 10% had osteoporosis. At the hands and radius, our study showed reduced BMD in 62% of cases of which 45% had osteopenia and 17% had osteoporosis.

A study by Negri AL and Barone et al,[7] "bone mineral density- serum markers of bone turnover and their relationships in peritoneal dialysis" reported reduced BMD in 58.4% (44.6% osteopenia and 13.8% osteoporosis) at lumbosacral spine in CKD patients on dialysis and reported osteopenia in 56% and osteoporosis in 21.5% cases at femoral neck.

At the vertebral bodies, Kosowicz J and Bolko P et al[6] found osteopenia in 48% and osteoporosis in 33% of the cases of predialysis CKD patients with secondary hyperparathyroidism. At radius, the study reported osteoporosis in approx. 75% cases in predialysis patients of secondary hyperparathyroidism.

Z. Jabbar, P. K. Aggarwal et al[8] assessed the bone mineral density of radius in newly-diagnosed CKD and found reduced BMD in 70% cases out of which 47.5% showed osteopenia and 22.5% showed osteoporosis.

Thus, we see that reduced bone mineral density is prevalent in both pre and postdialysis patients and radius is found to be the most sensitive site for analysis by DXA.

In our study, conventional radiography revealed abnormality in 21% of the patients at lumbar spine of which only one patient was not detected on DXA. This patient showed osteosclerosis at end plates of vertebral bodies suggesting rugger jersey spine.

At pelvis and femur, conventional radiography showed positive findings in only 19% of which one patient showed features of pseudofracture and another showed evidence of insufficiency fracture at neck of femur along with cortical erosion at symphysis pubis in addition to reduced bone density.

At radius, conventional radiography detected abnormalities in 27% of patients, all of them showing abnormal DXA results with subperiosteal resorption and reduced bone density as most common findings. Few cases showed cortical erosions and tunnelling, one case showed osteitis fibrosa.

A study by Mitwalli A H[9] on "spectrum of renal osteodystrophy in dialysis patients at a tertiary hospital in Riyadh, Saudi Arabia" reported low BMD on DXA at femur and lumbosacral spine in all 57 patients of ESRD on dialysis. But, skeletal survey with conventional radiography showed positive findings in only 58% patients with osteoporosis in 12%, hyperparathyroid cystic changes in 12%, mixed picture of renal osteodystrophy in 21%, subperiosteal resorption in 3%, osteosclerosis in 3% and osteomalacia in 3%.

On conventional radiography, Kosowicz J and Bolko P et al[6] reported skeletal changes of acroosteolysis in 60%, showing subperiosteal resorption in 43% and cortical fibrosis in 35%.

Thus, we see that radius is found to be the most sensitive site for analysis by both DXA and conventional radiography studies. As shown in our studies by statistical evaluation, we see that radius is the most sensitive site for DXA in both early and late stage of chronic kidney disease.

We also see that DXA is more sensitive than conventional radiography in detecting bone density abnormalities. However, conventional radiography is found superior in disease pattern analysis when compared to DXA.

CONCLUSION

Our study focussed on comparing the DXA findings with conventional skeletal radiographs and concludes that;

a. Bone mineral density is markedly decreased in the radius and to a lesser extent in vertebral bodies and femurs and hence DXA studies of the radius are most appropriate site for evaluation of mineral bone density in predialysis CKD population.
b. For conventional radiography studies, the most sensitive site for radiographic abnormality is hand. The most common finding being a normal study. Reduced bone density is the commonest abnormal finding followed by subperiosteal resorptions, cortical erosions, osteitis fibrosa. Manifestations of osteomalacia and osteosclerosis are relatively uncommon.
c. Comparing DXA with conventional radiography, we can see that the overall sensitivity of DXA is higher than conventional radiography at all three sites, but the specific features of renal osteodystrophy is better done by conventional radiography.

We can see that dual x-ray absorptiometry can be used as a noninvasive tool for identifying reduced bone mineral density in predialysis CKD population. Conventional radiograph being cost-effective tool can be used for follow up and detecting various patterns of renal osteodystrophy.

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