Low Cost Bone Mineral Density Measurement

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Abstract*: Osteoporosis is a disease of the bones that leads to increased risk of fracture in pelvic girdle, femur, vertebrae and carpal bones. This disease is most common in women after menopause and it is called post menopausal osteoporosis. Osteoporosis can be diagnosed by reduced bone mineral density, disrupted bone micro architecture and alteration in the amount and variety of proteins in bones. Even though there are many methods for the diagnosis of osteoporosis condition, this paper explains a new method developed for the measurement of the bone mineral density (BMD). It is a low cost method for measuring BMD of the clavicle bone from a chest x-ray. The paper explains the segmentation of the clavicle bone by a simplified manner and the measurement of periosteal width (D) and endosteal width (d). In this method, some images of chest radiographs of both pre and post menopausal women were examined. The cortical thickness (endosteal and periosteal) of the right clavicle is computed with the help of mat lab. The result shows that the BMD decreases as age increases and used for the diagnosis of osteoporosis.*

INTRODUCTION

Osteoporosis is defined as a progressive systemic skeletal disorder characterized by low bone mineral density, deterioration of the micro-architecture of bone tissue and susceptibility to fracture[5]. Osteoporosis is age-related and characterized by low bone mass due to the loss of bone in the aging process. Such bones are easier to break even during falls at low heights, or during the course of simple daily activities. Patients with osteoporosis have high risk of fracture hence Bone Mineral Density measurement is very important for them[2].

Approximately 50% of women at 50 years of age will have an osteoporotic fracture in their lifetime. Osteoporosis-related fractures are associated with significant morbidity and mortality, frequently resulting in chronic pain, disability, and death[3]. Common methods like conventional radiography, quantitative CT (QCT), single-photon absorptiometry (SPA), dual-photon absorptiometry (DPA), quantitative ultrasonography (QUS) and Dual-energy X-ray absorptiometry (DEXA) are used for the measurement of BMD to diagnose osteoporosis. Nowadays DEXA is most widely used method and is the gold standard but expensive. So this paper describes a cost effective method to compute BMD.

The general stages of the osteoporosis are shown in the Table 1. The measuring parameter used here is the Standard Deviation (SD). The normal stage has the standard deviation within the value < 1.0 and osteoporosis stage has the standard deviation of > 2.5. In between the two stages include the osteopenia which has the standard deviation of 1.0 to 2.5[6].

MATERIALS & METHOD

For the diagnosis of the osteoporosis, the clavicle bone segmentation method was used. Then from the segmented bone BMD was measured and interpreted (Table 1). 125 Women whose age ranged from 17 to 85 years were studied. Of the 125 subjects, 20 had previous fractures; subjects with secondary bone diseases were excluded. The women selected for this study belonged to the middle class socio-economic strata; women aged about 50 years or less were active both in domestic and professional work whereas women greater than 50 years were sedentary in their life style. These patients were classified into five age groups.

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Table 1

S.No	Category	Standard Deviation
1	Normal	<1.0
2	Osteopenia	1.0 to 2.5
3	Osteoporosis	>2.5

Group I comprised of 25 patients whose age ranges from 15-40. Group II comprised of 25 whose age ranges from 41-50. Group III comprised of 25 whose age ranges from 51-60. Group IV comprised of 25 whose age ranges from 61-70. Group V comprised of 25 whose age ranges from 71-85.

BMD of the right proximal femur was measured by DXA using a Hologic QDR-1000 Densitometer. All the subjects underwent were underwent an x-ray chest PA view, in addition, biochemical serum parameters were measured in all cases. From the radiograph, radiogrammetry measurements were made on the clavicle (Table 2). Data analysis was done with the SPSS/PC statistical software package. Mean ± S.D. values of the various measurements were calculated in each group. Association between variables was investigated by correlation and multiple linear regression analysis. Student – T test was used to compare the Mean ± S.D. values of each variable between groups. A paired – T-test was used to test the significance of any difference between observed and predicted values.

The chest X ray image is stored in the system as an input image. First the edges are detected using the canny edge detector. For Canny algorithm, the object finds edges by looking for the local maxima of the gradient of the input image. It calculates the gradient using the derivative of a Gaussian filter. This algorithm is more robust to noise and more likely to detect true weak edges. The canny operation is performed using Mat lab.

The block diagram 1 explains the process of capturing the X ray image in the digital camera. The block diagram 2 illustrates the steps involved in the measurement of BMD after loading the image.

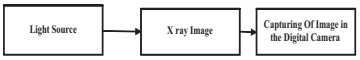

Diagram 1: *Measurment Setup*

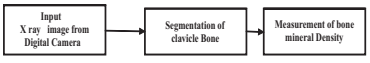

Diagram 2: *Block diagram for BMD measurement*

Table 2: *Measurement of BMD Between Age Groups*

Age Group 17-40	CCT	BMD	Age Group 41-50	CCT	BMD	Age Group 51-60	CCT	BMD	Age Group 61-70	CCT	BMD	Age Group 71-85	CCT	BMD
27	0.46	0.8177	45	0.36	0.8177	50	0.25	0.8177	65	0.43	0.6543	71	0.35	0.7244
35	0.45	0.8408	45	0.23	0.8408	57	0.46	0.8408	64	0.35	1.2495	84	0.34	0.7178
34	0.44	0.8372	44	0.35	0.8372	52	0.24	0.8372	68	0.4	0.7281	72	0.31	0.6838
23	0.35	0.7539	44	0.4	0.7539	56	0.37	0.7539	64	0.19	0.7352	77	0.45	0.7802
18	0.38	0.799	47	0.35	0.799	56	0.35	0.799	68	0.31	0.5796	80	0.11	0.5225
39	0.3	0.6996	50	0.28	0.6996	52	0.24	0.6996	64	0.23	0.6722	71	0.48	0.8128
31	0.49	0.8313	47	0.59	0.8313	60	0.3	0.8313	65	0.35	0.6378	71	0.41	0.7656
23	0.23	0.6495	44	0.14	0.6495	54	0.46	0.6495	63	0.21	0.6948	78	0.62	0.8794
30	0.5	0.833	50	0.48	0.833	52	0.28	0.833	68	0.19	0.6135	75	0.15	0.5602
33	0.27	0.6789	50	0.23	0.6789	60	0.29	0.6789	70	0.06	0.6193	75	0.29	0.6797
24	0.39	0.8383	49	0.33	0.8383	53	0.32	0.8383	65	0.31	0.4933	73	0.24	0.6682
30	0.22	0.6493	47	0.45	0.6493	53	0.52	0.6493	67	0.26	0.6937	78	0.33	0.6921
29	0.41	0.7997	47	0.37	0.7997	59	0.24	0.7997	62	0.07	0.6341	83	0.15	0.5554
23	0.41	0.7941	48	0.52	0.7941	53	0.16	0.7941	61	0.48	0.4966	84	0.19	0.5889
35	0.83	0.6177	42	0.21	0.6177	54	0.24	0.6177	65	0.2	0.8036	75	0.06	0.4955
36	0.48	0.8429	46	0.47	0.8429	57	0.52	0.8429	70	0.32	0.5804	79	0.12	0.5293
30	0.55	0.9505	41	0.18	0.9505	52	0.08	0.9505	70	0.29	0.6979	79	0.14	0.5875
30	0.45	0.8288	42	0.44	0.8288	52	0.45	0.8288	64	0.37	0.6534	75	0.26	0.6528
28	0.96	0.107	42	0.25	1.107	53	0.43	1.107	65	0.31	0.1838	72	0.24	0.6161
39	0.45	0.8323	45	0.31	0.8323	56	0.35	0.8323	68	0.32	0.6772	73	0.19	0.5872
17	0.45	0.8316	48	0.4	0.8316	52	0.53	0.8316	65	0.23	0.6979	75	0.34	0.6859
30	0.38	0.7792	46	0.46	0.7792	56	0.53	0.7792	64	0.35	0.6372	75	0.36	0.7161
31	0.56	0.9252	43	0.32	0.9252	51	0.18	0.9252	63	0.31	0.7282	73	0.52	0.6078
23	0.65	1.0479	45	0.35	1.0479	56	0.31	1.0479	67	0.19	0.6772	77	0.45	0.7802
29	0.31	0.7508	50	0.25	0.7508	54	0.24	0.7508	65	0.07	0.6193	75	0.29	0.6797

Then the regions are segmented by masking method. An ROI is created by creating a *binary mask*, which is a binary image that is the same size as the image and to process with pixels that define the ROI set to 1 and all other pixels set to 0.

The input image is first taken and the clavicle bone is segmented using edge detection and masking operation. Then the midpoint in the clavicle bone which is the junction of 1/3rd lateral and 2/3rd medial point is located. Then the endosteal width and periosteal width is measured (Figure 1). After segmenting out the regions, the width is calculated in the area where BMD is needed to measure. As that the edges are clear it is easier to measure the width.

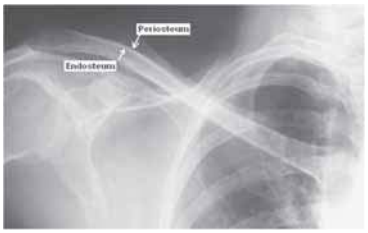

Figure 1 : *X-ray of the clavicle bone showing periosteal and endostial thickness*

From the segmented region, right clavicle length l, periosteal width D, endosteal width d and the cortical bone indices combined cortical thickness (CCT) and Percentage combined cortical thickness(% CCT) of the clavicle bone are measured. The obtained CCT values are used as per the kjh-Anburajan formula, below to find the bone mineral density [1].

$Y=0.47+0.003938 *X1+0.420914*X2-5.05139*X3*10^{-4}$ gm/cm^2

Where X1= % CCT; X2 = CCT; X3 = Age

Measurement of CCT and % CCT:

The CCT of the clavicle bone and % CCT is given as

CCT = (D-d)cm % CCT =100*((D-d)/D)

The endosteal width and periosteal width calculated for a sample image is shown in the figure 2, 3 & 4

D =1.2 cm d = 0.62 cm

Figure 2 : *The original image taken for analysis.*

Figure 3: *Shows the canny edge detected image. For the detection of boundary and edges canny operator is used and the edge segmented image is shown.*

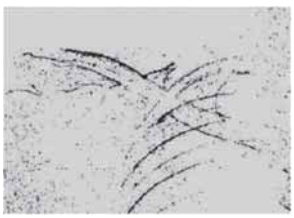

Figure 4: *The final binary mask for the required output is taken and applied in the edge detected image and the corresponding output is shown.*

RESULTS

There was a significant difference found between the mean peak value of total hip BMD, the CCT and the age of the patients. This significance was achieved in all the age groups classified. In this study it was found

that 58.6% of the post – menopausal women was diagnosed as having osteoporosis.It was significant that as the age increases, the CCT and BMD value decreases. This decrease in the BMD and CCT values are influenced by the hormonal changes. A comparison was made between CCT values obtained digitally and the BMD values obtained from DEXA.

For comparison between various age groups, T-test was applied and p value was calculated. The resulting P – value showed significance between CCT and BMD ($p<0.05$). It was evident that the BMD decreases as age increases. The resulting BMD values by using the software were compared with the conventional values for accuracy rate. Within various age groups the mean BMD values are found highest in young adults and lowest in 70-85 age group patients. It was also observed that there was a slight increase in BMD values in certain age groups due to hormonal changes.

Table 3

S.No	Images	Periosteal D	Endosteal d	BMD	Condition
1	**Sample Image1**	1.67	0.65	0.64	Normal
2	**Sample Image2**	1.31	0.56	0.72	Normal
3	**Sample Image3**	1.62	0.62	0.64	Normal
4	**Sample Image4**	2.87	0.15	1.95	Osteopenia
5	**Sample Image5**	4.6	0.01	2.56	Osteoporosis
6	**Sample Image6**	1.58	0.61	1.22	Osteopenia
7	**Sample Image7**	2.56	0.79	1.12	Osteopenia
8	**Sample Image8**	1.58	0.61	1.22	Osteopenia

DISCUSSION

Osteoporosis is characterized by low bone mass with micro architectural deterioration of bone tissue leading to enhance bone fragility, thus increasing the susceptibility to fracture. Although exact numbers are not available, based on available data and clinical experience, on estimated 25 million Indians may be affected. Osteoporotic fractures in India occur commonly in both sexes, and may occur at a younger age than in the West. Recently published data have clearly demonstrated widespread vitamin D deficiency across India, at all ages and in both sexes, particularly in the urban areas. Poor sunlight exposure, skin pigmentation and a vitamin D-deficient diet are some obvious causes for this finding. Indians have low BMD as compared to the western Caucasians. This could be attributed to differences in skeletal size; however, the high prevalence of vitamin D deficiency is a major factor in the low BMD and poor bone health of Indians[4]. For the sample image shown the CCT and % CCT are 0.58 and 48.33. Then the BMD is measured from the above said formula. The sample image is taken for the patient of age 55. From the results, it shows that the BMD is 0.88SD. Then the condition is Normal. The results are tabulated in table 3.

Thus BMD of clavicle bone is measured from X ray images. It is much simpler than the DEXA method. The measurement is cost effective. As measurement of BMD is possible with the conventional X ray image, hospitals need not replace their X ray machines with high cost DEXA equipment to diagnose osteoporosis, especially to measure BMD. This would be of great use in rural hospitals. Moreover special training to personnel to handle the DEXA equipment is also not needed.

CONCLUSION

Osteoporosis can be diagnosed by reduced bone mineral density, disrupted bone micro architecture and alteration in the amount and variety of proteins in bones. This paper explains a new low cost method developed for the measurement of the bone mineral density (BMD).

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LITERATURE REVIEW

SURVIVAL ANALYSIS OF PATIENTS ON MAINTENANCE HEMODIALYSIS

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Despite the continuous improvement of dialysis technology and pharmacological treatment, mortality rates for dialysis patients are still high. A 2-year prospective study was conducted at a tertiary care hospital to determine the factors influencing survival among patients on maintenance hemodialysis. 96 patients with end-stage renal disease surviving more than 3 months on hemodialysis (8-12 h/week) were studied. Follow-up was censored at the time of death or at the end of 2-year study period, whichever occurred first. Of the 96 patients studied (mean age 49.74 ± 14.55 years, 75% male and 44.7% diabetics), 19 died with an estimated mortality rate of 19.8%. On an age-adjusted multivariate analysis, female gender and hypokalemia independently predicted mortality. In Cox analyses, patient survival was associated with delivered dialysis dose (single pool Kt/V, hazard ratio [HR] =0.01, P = 0.016), frequency of hemodialysis (HR = 3.81, P = 0.05) and serum albumin (HR = 0.24, P = 0.005). There was no significant difference between diabetes and non-diabetes in relation to death (Relative Risk = 1.109; 95% CI = 0.49-2.48, P = 0.803). This study revealed that mortality among hemodialysis patients remained high, mostly due to sepsis and ischemic heart disease. Patient survival was better with higher dialysis dose, increased frequency of dialysis and adequate serum albumin level. Efforts at minimizing infectious complications, preventing cardiovascular events and improving nutrition should increase survival among hemodialysis patients.

LITERATURE REVIEW

A NATIONWIDE COHORT STUDY SUGGESTS THAT HEPATITIS C VIRUS INFECTION IS ASSOCIATED WITH INCREASED RISK OF CHRONIC KIDNEY DISEASE.

Chen YC, Lin HY, Li CY, Lee MS, Su YC. *Kidney Int. 2014 May;85(5):1200-7*

The association of hepatitis C virus (HCV) infection with chronic kidney disease (CKD) remains widely debated. Here we quantify this association by analysis of data from the Taiwan National Health Insurance Research Database and ICD-9 codes to identify 9430 adults with newly diagnosed HCV (years 1999-2006) and randomly selected 37,720 matched non-HCV control individuals. The incidence rate and risk of incident CKD were evaluated through the end of 2010. The frequency of CKD was 1.66-fold higher in the HCV than the non-HCV cohort (5.46 compared with 3.43 per 1000 person-years), and the adjusted hazard ratio remained significant at 1.28 (95% confidence interval, 1.12-1.46). A multivariate analysis was used to determine the influence of HCV on CKD risk with regard to age, gender, follow-up duration, and comorbidities. The risk for CKD in HCV-infected individuals was higher with diabetes, hyperlipidemia, and cirrhosis (8.44; 3.70-19.23), followed by men<50 years (2.32; 1.49-3.61), all individuals<50 years (1.90; 1.33-2.73), men overall (1.44; 1.22-1.71), and individuals followed for e”6 years (1.35; 1.06-1.71); all with considerable significance. Thus, HCV infection is associated with an increased risk of CKD. Hence, high-risk HCV-infected individuals should be aggressively monitored for development of CKD.