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Correlate of Radiological Indexes for Osteoporosis with Histological Status of Osteoid of Bone

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Abstract: *This paper focuses the correlation of radiological index for osteoporosis with histological status of bone. This study was conducted in orthopaedics department in December 2012 to September 2014. A total 25 patients were recruited for the study of age group between 35-80 years and suffering from low energy trauma was considered. The detailed history and socio-demographic profile of each patient were recorded to rule out polytrauma. After recording clinical details the digital x-ray pelvis with both hip with proximal femur in* 30^o *internal rotation- anteroposterior view (the trabeculae pattern of proximal femur of uninjured side is studied), digital x- ray right hand- anteroposterior view, digital x-ray foot- lateral view and digital x-ray chest-posteroanterior view were conducted. The measurements from radiograph were taken by the help of software dicom cd viewver. For histological grading iliac crest samples were taken. Singh's index, jhamaria's index, frost index and nordin's metacarpal index were compared with nordin's histological grade. According to nordin's histological grade, out of 25 patients, 19 had osteoporosis; this was taken as gold standard in this study. According to singh's index, jhamaria's index, frost index and nordin's metacarpal index 14, 11, 9 and 13 patients were classified as osteoporosis respectively .it concluded that, singh's index had the highest sensitivity of 68.42% whereas frost's index had the lowest sensitivity of 47.36%. In terms of accuracy, singh's index with 72% was maximum and minimum in case of frost's index with 60%.*

Keywords: *Osteoporosis, Singh's Index, Radiological Index*

I. Introduction

Osteoporosis is defined as a "disease characterized by low bone mass and microarchitectural deterioration of bone tissue, leading to enhanced bone fragility and a consequent increase in fracture risk"[1]. It is characterized by generalized reduction in bone mass due to subnormal osteiod production, excessive rate of deossification and subnormal osteoid mineralization. Osteoporosis is a silent disease, reflected only in a low bone density, till a fracture occurs. Much in a manner that asymptomatic condition such as hypertension and dyslipidemia predispose to stroke and myocardial infarction, respectively, a low bone density (reflection poor bone health) predisposes to osteoporotic fractures[6]. With increasing longevity of Indian population, it is now being realized that, as in the West, osteoporotic fractures are a major cause of morbidity and mortality in the elderly[6]. The seriousness of the problem can be judged by the facts that osteoprotic fractures are four times more common than strokes[2]. 50 years old women have equal chance of dying from of complication of osteoporosis as from breast cancer[2]. The lifetime risk of experiencing an osteoporotic fracture in men over the age of 50 years is 30% (similar to prostrate cancer) or the combined lifetime risk for hip, forearm and vertebral fractures coming to clinical attention is around 40%, equivalent to the risk for cardiovascular disease[3]. The overall mortality is about 20% in the first year after hip fracture (higher in men than women) [3]. Based on 2011 census, approximately 12.5% i.e. nearly 150 million Indians are above the age of 55 years[8] ; this number is expected to increase to 230 million by 2015[6]. Even conservative estimate suggest that of these, 20% of women and about 10-15% of men would be osteoporotic[6]. The total affected population would be around 25 million[6]. If the lower bone density is shown to confer a greater risk of fracture, as is expected, the figure can increase to 50 million[6]. Complications related to osteoporosis can create social and economic burdens. For these reasons, the early diagnosis of osteoporosis is crucial. Conventional radiography allows qualitative and semi quantitative evaluation of osteoporosis, whereas other imaging techniques allow quantification of bone loss (eg, dual-energy x-ray absorptiometry and quantitative computed tomography [CT]), assessment for the presence of fractures (morphometry), and the study of bone properties (ultrasonography). In recent years, new imaging modalities such as micro-CT and high-resolution magnetic resonance imaging have been developed in an attempt to help diagnose osteoporosis in its early stages, thereby reducing social and economic costs and preventing patient suffering. The correct diagnosis of osteoporosis results in better management in terms of prevention and adequate pharmacologic or surgical treatment. The gold standard for diagnosis of osteoporosis is dual-energy x-ray absorptiometry[7]; also newer methods like quantitative computed tomography [CT], micro-CT and high-resolution magnetic resonance imaging provide early diagnosis of osteoporosis; but logistics needed for them are expensive and are not widely available; which makes their widespread utilization in developing nation difficult.

This study aims at evaluating four radiological index viz; Singh's index, Jhamaria's index, Frost's parabolic index of sixth rib and Nordin's second metacarpal index; all of which can be calculated by plain radiography, in diagnosis of osteoporosis.

II. Aims and objectives

1. To study various radiological index for osteoporosis.
2. To study correlation of radiological index for osteoporosis with histological status of osteoid of bone.
3. To find which radiological index can be used in clinical practice to diagnose osteoporosis.

III. Material and methods

The study was conducted on patient reporting in Emergency, Outdoor and patients admitted in Orthopaedics department with reference to age and sex for the period from December 2012 to September 2014.
The entire patient reporting to the institute the adult patient of age group between 35 years to 80 years suffering from low energy trauma were considered and 25 cases of these were selected for the study.

Patient inclusion criteria

1. Age group between 35 to 80 years.
2. Low energy trauma.
3. Patient willing to participate in the study.

Patient exclusion criteria

1. Age below 35 years and above 80 years.
2. High energy trauma
3. Polytrauma patient.
4. Patient involving trauma to bilateral hips, hand, foot and ribs.
5. Known cases of diseases causing secondary osteoporosis. e.g. Hypogonadism, Cushings syndrome, malabsorption syndrome, osteogenesis imperfecta, etc

These 25 cases have been recorded on exhaustive perfoma which contain detail account of the patient regarding; name, age, sex, place of residence with full correspondence address.
The detailed history of each case was recorded to rule out any cases of secondary causes of osteoporosis and thorough clinical examination was done to rule out polytrauma.
Soon after recording clinical details the following radiographs were obtained,

1. Digital x-ray Pelvis with both hip with proximal femur- anteroposterior view.
2. Digital x- ray Right hand- anteroposterior view.
3. Digital x-ray foot- lateral view.
4. Digital x-ray chest- posteroanterior view.

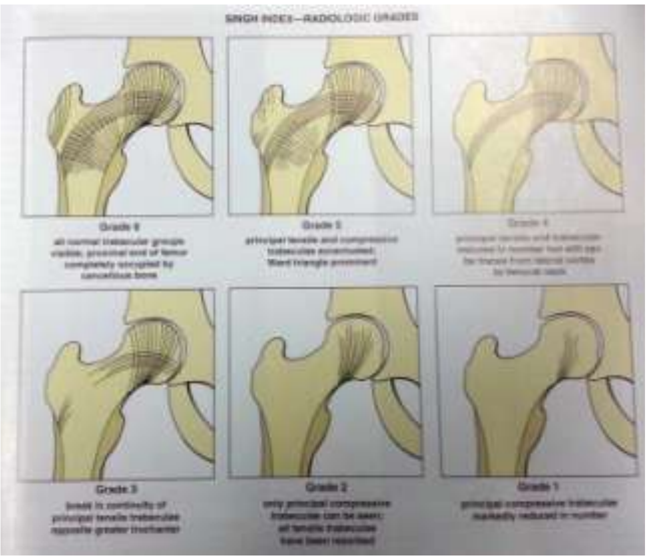
The measurements from radiograph were taken by the help of software DICOM CD VIEWVER.
These are following indices were used in this study.

(1) Singh's index

For grading of proximal femur X-ray of Pelvis-anteroposterior view with both hip with proximal femur in 30^o internal rotation is taken and the trabeculae pattern of proximal femur of uninjured side is studied. Normal trabeculae pattern in proximal femur.

Grading of Singh's index

Grade 6- All normal groups of trabeculae are visible in the x-ray of upper end of femur
Grade 5- The secondary compression trabeculae are not clearly demarcated.
Grade 4- Secondary tensile trabeculae are not clear.
Grade 3- The principal tensile trabeculae seen in only upper part not visible in the lower part. This indicates osteoporosis.
Grade 2- Principal tensile trabeculae are not even seen in the upper part. This indicates fairly advanced osteoporosis.
Grade 1- even the principal trabeculae are not clearly seen. This shows severe degree of osteoporosis.



(2) Jhamaria's index

For grading according to Jhamaria's index X-ray of foot- lateral view is studied.

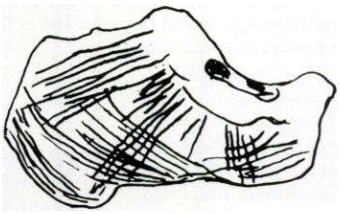
The normal trabecular pattern of the calcaneum has been described by Lockhart, Hamilton and Fyfe *(1959).* In a sagittal longitudinal section , the trabeculae are arranged in two groups corresponding to compression stresses and to tensile stresses.

Compression trabeculae are disposed in two sets. One originates at the subtalar articular surface and diverges downwards and backwards through the waist of the calcaneum ; the trabeculae become finer and more numerous as they pass backwards to fan out over the entire posterior surface and reach the inferior border slightly in front of the posterior tubercle. The second set of compression trabeculae pass anteriorly from the subtalar articular surface to the articulation with the cuboid.

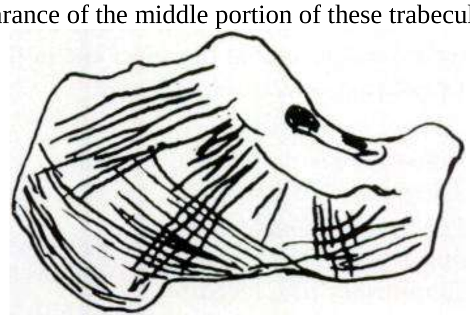
Tensile trabeculae start in front of the tuberosity of the calcaneum and sweep both backwards and forwards between the two compression struts. Another set of trajectory trabeculae is seen in the line of pull of the calcaneal tendon ; it is a thick compact group of parallel trabeculae along the subcutaneous part of the bone. Between the anterior and posterior groups of compression trabeculae is an area which contains only a few thin vertical trabeculae and is known as the foramen calcanei.

The Jhamaria's index is graded as described below:

Grade 5 (normal). Lateral view of the calcaneum and diagram showing the trabecular pattern. Compression and tensile trabeculae are uniformly distributed.



Grade 4 (normal). The posterior compression trabeculae are divided into two pillars separated by a radiolucent area due to recession and disappearance of the middle portion of these trabeculae.



Grade 3 (borderline). There is also recession and disappearance of the posterior tensile trabeculae which now cross only the anterior pillar of the posterior compression trabeculae.

Grade 2 (osteoporotic). The antenor tensile trabeculae have disappeared and the posterior tensile trabeculae have receded.

Grade 1 (severely osteoporotic). There is complete disappearance of both sets of tensile trabeculae : the compression trabeculae are reduced in number.

(3) Frost index

Harold Frost had developed a simple method of calculation of the parabolic index that he defined as Anabolic Index- Catabolic Index. The sixth rib in the mid axillary line on a chest x-ray was taken.

On X-ray chest- posteroanterior view, Midpoint of the right clavicle is located. A tangent is drawn to the right chest wall at the level of sixth rib. Another line parallel to the above line is drawn at the midpoint of clavicle up to sixth rib. At this point a perpendicular is drawn across the sixth rib and the diameter and the cortical thickness are measured at level of the midaxillary line.

Diameter of rib cross-section = D
Cortical thickness = C
Radius of rib cross-section = D/2
Radius of marrow cross - section = (D/2) – C
Total area = $\pi(D/2)^2$
Marrow area = $\pi[(D/2)-C]^2$
Cortical area = $\pi(D/2)^2-\pi[(D/2)-C]^2$

$$PI = \frac{Cortical\ area}{total\ area} \text{ X } \frac{marrow\ area}{total\ area}$$

$$= \frac{\pi(\frac{D}{2})^2 - \pi[(\frac{D}{2}) - C]2}{\pi(\frac{D}{2})^2} \text{ X } \frac{\pi[(\frac{D}{2}) - C\}2}{\pi(D/2)2}$$

$$= \frac{(\frac{D}{2})2 - [(\frac{D}{2}) - C]2}{(\frac{D}{2})2} \text{ X } \frac{[(\frac{D}{2}) - C]2}{(\frac{D}{2})2}$$

Dividing the expression by (D/2) we get

$= \frac{1-(1-2C)^2}{D} X \frac{(1-2C)^2}{D}$

The rib index value of 0.2208 +0.0388 has been chosen as the lower mean limit of normalcy. A lower value of 0.145 will be obtained when two S.Ds are subtracted from the mean value.
A rib parabolic index of 0.145 can be more sensitive in diagnosing this condition.
Any value below 0.145 is considered to be as osteoporosis.

(4) Nordin's metacarpal index

Nordin and McCormick described a technique of measurement of the metacarpal bone index. This was calculated on a simple AP x-ray of the right hand done under normal magnification. The length of the metacarpus divides the thickness of the cortex of the second metacarpal in the middle of the metacarpus and this gives the metacarpal bone index. Cortical area less than 44% is considered as osteoporosis. i.e., index of 0.44 and below is considered of osteoporosis.

IV. Nordin's histological grade

For histological evaluation sample was collected from Iliac crest which was obtained during surgical treatment of the patient after taking proper informed consent.

Iliac crest obtained was cut with knife to obtain block of size 1cm X 1cm to facilitate decalcification, then bones were immersed in hydrochloric acid (10 %) for de-calcification, the acid being changed at intervals of 2-3 days till the bones became soft, taking approximately 7-10 days for complete de-calcification. The bones were then immersed in Acetone solution 1, 2 and 3 for 15 minutes in each of the solution. Next they are immersed in Benzene solution 1, 2 and 3 for 15 minutes in each of the solutions. Then the bones were immersed in paraffin baths 1, 2 and 3 (maintained at temperature of 58'C to 60'C) for two hours in each of the baths. Next the bones were removed and sections of the block were cut with the help of microtome. The cut sections were mounted on glass slide and made free of paraffin wax by immersing in xylene solution 1 and 2 for five minutes in each of the solution. Next they were kept in alcohol solutions in descending concentrations of absolute alcohol. 90 %, 70 % and 50 % for one minute in each and then finally immersed in distilled water for one minute.

A few drops of Haematoxyline solution was poured over the cut section and retained for 30 seconds. The slides were then immersed in distilled water for six minutes. Next Eosin (2 %) solution was then poured over it and retained for 2 minutes and finally washed by immersing in distilled water.

The sections were dehydrated by immersing them in ascending concentrations of alcohol, 50 %, 70 % and 90 % and absolute alcohol for one minute in each of the solutions. The sections were then made alcohol free by immersing in Xylene solutions 1 and 2 for 5 minutes each. Then the cut sections were dried in air and over it a drop or two of PDX mount was placed and a cover glass slip applied, taking care not to allow any air bubble to enter into it. The slides were then ready for microscopic examination and microphotography.

Decalcified bone samples were prepared and then photomicrographs were taken with 15 times magnification. Areas of bone tissue were measured with the help of transparent graph paper from photomicrographs. These samples were graded on a 9-point scale according to the amount of bone present per unit area.

Beck and Nordin's histological parameters of bone in iliac crest biopsies
Score 1 = 6% of bone present/unit area
Score 2 = 9% of bone present/unit area
Score 3 = 12% of bone present/unit area
Score 4 = 14% of bone present/unit area
Score 5 = 16% of bone present/unit area
Score 6 = 18% of bone present/unit area
Score 7 = 21% of bone present/unit area
Score 8 = 24% of bone present/unit area
Score 9 = 27% of bone present/unit area

A score of less than 5 on this scale was observed in old people and osteoporosis. A score of more than 5 was found in normal healthy individuals.

In this study, Nordin's histological grading is taken as standard and other four radiological index are compared in terms of Sensitivity, Specificity, Positive predictive value, Negative predictive value and Accuracy.

V. Observations and results

In this study, we found that patient's sex ratio is 3: 2. Out of 25 patients the youngest patient was 36 years and oldest patient was 80 yrs with the mean age of 62.3 years with standard deviation 10.01years. Out of 25 patients, 18(72%) had fractutre neck of femur, 5(20%) had trochanteric fracture, 1 had fracture shaft of femur and 1 had fracture of tibia and fibula. According to Nordin's histological grading out of 25 patients, 19 patient had osteoporosis (i.e., grade 5 and below) and other 6 were classified as normal (i.e., above grade 5). According to Singh's index, 14 patients were classified as osteoporosis (i.e., Grade 3 & below) and 11 were classified as normal (i.e., above grade 3). According to Jhamaria's index, 11 patients were classified as osteoporosis (i.e., Grade 3 & below) and 14 were classified as normal (i.e., above grade 3). According to Frost Parabolic index, 9 patients were classified as osteoporosis (i.e., below 0.145) and 16 were classified as normal (i.e., above 0.145). According to Nordin's Metacarpal index, 13 patients were classified as osteoporosis (i.e., below 0.145) and 12 were classified as normal (i.e., above 0.145)

In the study, Singh's index had the highest sensitivity of 68.42% whereas Frost's index had the lowest sensitivity of 47.36%.

Jhamaria's index and Frost's index had highest specificity of 100% and Nordin's metacarpal index had lowest specificity of 66.67%.

Positive predictive value was highest with 100% in case of Jhamaria's index and Frost's index and it was lowest in case of Nordin's metacarpal index with 85.71%

Negative predictive value was highest in case of Singh's index with 45% and lowest with 36.36% in case of Nordin's metacarpal index.

Accuracy of Singh's index with 72% was maximum and minimum in case of Frost's index with 60%.

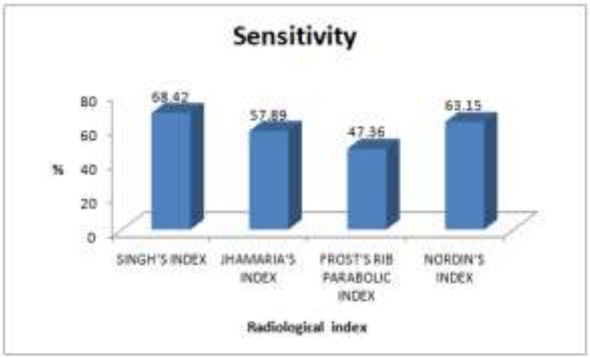


Fig.1: Bar graph showing the sensitivity of different radiological index

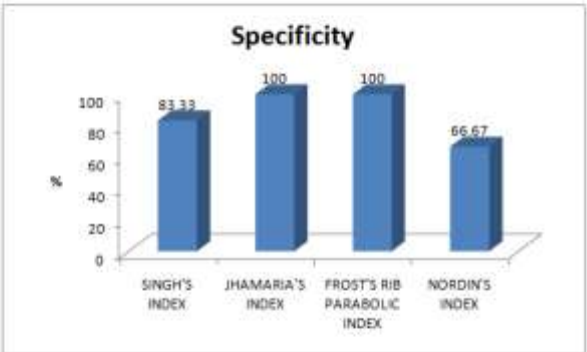


Fig.2: Bar graph showing the specificity of different radiological index

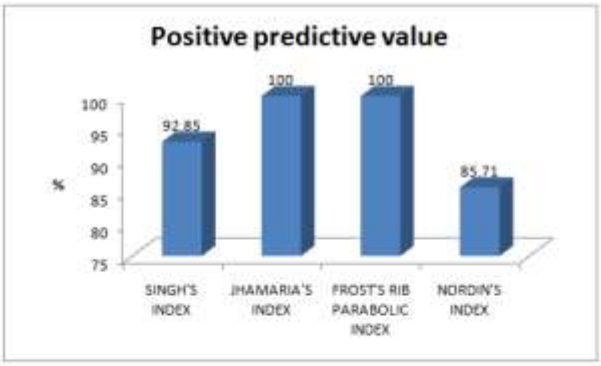


Fig.3: Bar graph showing the PPV of radiological index

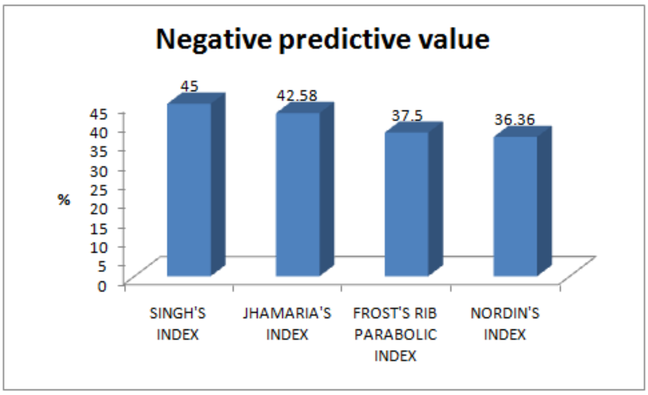


Fig.4: Bar graph showing the NPV of radiological index

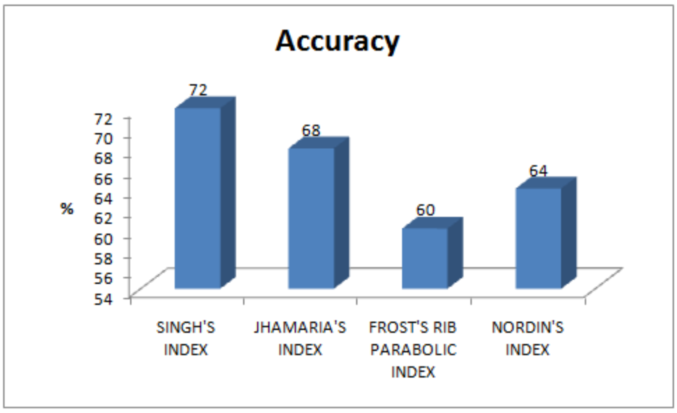


Fig.5: Bar graph showing the Accuracy of radiological index

VI. Discussion

As the life expectancy has risen significantly in recent decades, the geriatric population has increased several folds and thus there is increase in prevalence of diseases of geriatric age group of which osteoporosis is one of the most important. Being a silent disease, osteoporosis often leads to a fracture as the first symptom which results in high morbidity and mortality and thus increases significant financial burden on the health care system. Thus early diagnosis and treatment of osteoporosis is essential to improve the quality of life of people and curb the financial burden on the health care system. The gold standard for the diagnosis of osteoporosis is DEXA-SCAN, the logistics of which is expensive and not readily available especially in developing country like India. So there is a dire need for an inexpensive screening tool for diagnosis of osteoporosis. This study was aimed to evaluate the efficiency of four such inexpensive radiological indices viz Singh’s index, Jhamaria’s index, Nordin’s second metacarpal index and Frost’s rib parabolic index, all of which can be calculated from plain radiograph.

In this study Singh’s index had the highest sensitivity of 68.42 % and specificity with the value of 83.33 % was low compared to other indices. The specificity of Jhamaria’s index and Frost’s rib parabolic index was 100% which may be due to small sample size of the study but the observation of high specificity was consistent with the observation made by Aggarwal[5] (1966) and La Fianza et al[4] (1994) for Jhamaria’s index and Balu Sankaran[7] (2000) for Frost’s index. The sensitivity of Frost’s rib parabolic index was lowest among the four indices. This observation was different from the observation made by Balu sankaran[7] (2000). These two studies differed in term of sample size which may have given rise to the discrepancy in the observation. The Nordin’s second metacarpal index had sensitivity, specificity and accuracy of 63.15 %, 66.67 % and 64 % respectively. This observation was consistent with observation of Balu Sankaran[5] (2000) which predicted the accuracy of 66 % for the Nordin’s index. Among the four indices the accuracy of Singh’s index with the value of 72 % was highest and thus it is the best tool among the four mentioned indices in this study. The drawback of Singh’s index was its low specificity and negative predictive value. Thus giving rise to a high false positive percentage. To overcome this problem, it can be combining with Jhamaria’s index and Frost’s rib parabolic index to improve accuracy in diagnosis of osteoporosis.

VII. Conclusion

This study concludes that Singh's index is found to be more accurate, cheap and simple method for diagnosis of osteoporosis.

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Annexure 1

Histological and Radiological picture of some cases

Case no 3

Case no-18


Foot
Lateral
L
RIMS, RANCHI


Hand
L