Automatic Segmentation of Femur Bone Features and Analysis of Osteoporosis

P. Santhoshini, R. Tamilselvi, and R. Sivakumar, Member, IACSIT

Abstract—This paper mainly focuses on diagnosing the osteoporosis using X-Ray images. Osteoporosis is a metabolic bone disease which is characterized by compromised bone strength predisposing a person in to an increased risk of fracture. It is most common in women after menopause where it is called post menopausal osteoporosis. The condition of Osteoporosis are decrease in the bone density, decrease in the bone strength resulting in fragile bones and susceptibility to fracture. In clinical practice, dual energy X-ray absorptiometry (DEXA) scanning is the most common way of diagnosing and monitoring the osteoporosis. In DEXA scanning, the method of comparing individual BMD measurements to the normal is called the ‘T-score’ system. This project work presents an efficient method to diagnose the osteoporosis by measuring the bone mineral density (BMD) of segmented femur bone parts with the help of X-Rays images and also compare the bone mineral density obtained from the DEXA scan with the density obtained from the conventional X-rays.

Index Terms—Bone mineral density (BMD), dual-energy X-ray absorptiometry (DEXA), t-score, osteoporosis.

I. INTRODUCTION

Bone is a living material which helps to form the skeleton, thereby enabling the locomotion and giving protection to the organism [1]. Human body has increasing complex levels of organization progressing from cells to tissues to organs to organ systems and finally to the organism. The principal functions of the skeletal bone are giving mechanical support and maintain the calcium homeostasis and haematopoiesis in the bone marrow of an organism.

This can be disturbed by various skeletal disorders. Osteoporosis is one of the systemic skeletal disorders, Characterized by low bone density and micro architectural deterioration of bone tissue with a Consequent increase in bone fragility [2]. It is three times more common in women than in men because women have a lower peak femur bone mass and the hormonal changes that occur at the menopause stage [3].Femur or thigh bone is the largest, longest and strongest bone in the human body. The upper end of femur bone is a part of the hip joint (the largest joint in the body) and the lower end of femur bone is a part of the knee joint. It is almost perfectly cylindrical in the greater part. In the erect posture, it is not look like a vertical cylinder. it is being separated above from its fellow by a considerable interval, which corresponds to the breadth of the pelvis but inclining gradually downwards and medial wards, so its fellow is approach towards its lower part for the purpose of bringing the knee-joint near the line of gravity of the body. The degree of this inclination varies from different persons and is greater in the female than in the male because women having pelvis of greater breadth. The femur bone is divisible into a body, upper and lower extremities like other long bones. The upper extremity consists of a head, a neck, a greater and a lesser trochanter.

The Head: The head, which is globular in shape. Its surface is coated with smooth cartilage in the fresh state except the fovea captious femoris, which is situated a little below and behind the center of the head .the head region is partially embedded in pelvis region. In this project, Hough filter is used to segment the head region in the femur bone by detecting the spherical shape .The bone mineral density of head part in normal femur bone must have 0.846994.

The Neck: The neck is a flattened pyramidal shape which connects the head with the body and forms a wide angle in the medial ward. The angle becomes lessened during puberty. So it forms a gentle curve from the axis of the bone body. In the adult stage, the neck forms an angle of about 125° with the body. It is inversely proportion to the development of the pelvis region. For female, the femur

(DXA) scans are one of the bone measuring techniques which are used to diagnose the osteoporosis but it requires high radiation dose to the patients. It is the current ‘gold standard’ for the diagnosis of osteoporosis [4] . In this project work, normal x-ray image of femur bone is taken. Four main parts in that femur bone image are automatically segmented and measure the bone mineral content of each part which helps to diagnose the Osteoporosis. The term “bone mineral content” describes the amount of mineral in the specific bone site is scanned, from which a value for BMD can be derived by dividing the bone mineral content by the area or volume. BMD values are expressed in relation to the young adult mean called T-score or age-matched controls called Z-score. Finally, compare the normal X-ray image bone mineral density and DEXA image bone mineral density for their accuracy.

II. FEMUR BONE FEATURES

The femur or thigh bone is the largest, longest and strongest bone in the human body. The upper end of femur bone is a part of the hip joint (the largest joint in the body) and the lower end of femur bone is a part of the knee joint. It is almost perfectly cylindrical in the greater part. In the erect posture, it is not look like a vertical cylinder. it is being separated above from its fellow by a considerable interval, which corresponds to the breadth of the pelvis but inclining gradually downwards and medial wards, so its fellow is approach towards its lower part for the purpose of bringing the knee-joint near the line of gravity of the body. The degree of this inclination varies from different persons and is greater in the female than in the male because women having pelvis of greater breadth. The femur bone is divisible into a body, upper and lower extremities like other long bones. The upper extremity consists of a head, a neck, a greater and a lesser trochanter.

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neck forms more nearly a right angle with the body. The angle decreases during the period of growth but after full growth has been attained, it does not undergo any change, even in old age. It varies in different persons who having same age. In addition, the femur neck is also projecting 12° to 14° upward and medial ward from the body. The bone mineral density of neck part in normal femur bone must have 0.59259.

**The Trochanter:** The greater Trochanter is a large, irregular, quadrilateral eminence, situated at the junction of the neck with the upper part of the body. It is directed a little lateral ward and Backward. It has two surfaces and four borders. The lesser Trochanter is a conical eminence which varies in size. It projects from the lower and back part of the base of the neck. The bone mineral density of trochanter part in normal femur bone must have 0.7975.

**The Body or Shaft:** The body, almost cylindrical in shape which is little broader than in the center. It is slightly arched, the shaft part is convex in front and concave behind. The shaft and the lower extremity is separated from one another by a smooth shallow depression called the patellar surface. The bone mineral density of shaft part in normal femur bone must have 1.12771. The block diagram in Fig. 1, clearly explains the various stages for measuring bone mineral densities in femur bone.

<table>
<thead>
<tr>
<th>STAGE 1</th>
<th>AUTOMATIC SEGMENTATION OF FEMUR BONE PARTS</th>
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<td>STAGE 2</td>
<td>BMD MEASUREMENT FROM NORMAL X-RAY</td>
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<td>STAGE 4</td>
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Fig. 1. Block diagram.

In this work, Normal X-Ray image of pelvis femur bone is taken. By using canny Edge-based image segmentation, femur bone parts are automatically segmented and then measure the T-score value of BMD of each femur bone parts which is used to diagnose the Osteoporosis. Finally, compare the accuracy between normal X-ray and DEXA scan.

### III. SEGMENTATION

Normal X-ray image of femur bone of a 75 aged women is collected from CETIR centre medic, Barcelona, Spain through E-mail. The Fig. 2 shows the X-Ray image of left and right of the femur bone which is along with pelvis region.

Before segmentation of femur bone x-ray image, the threshold of each region is to be calculated. It is done by thin plate spline Transformation (TPS).it has been widely used for non-rigid Transformation model such as image alignment and shape matching. The interpolation gets smoothened with derivatives of any order for its energy function [5]. Thin spline interpolation is done after the initial estimation. It helps to calculate the area of each femur bone parts. The area of each parts is not constant . It is varied image to image. The rectangle box (red color) in Fig. 3 indicates the area of region wish to measure which is selected by the user. After thresholding the selected region, the image of femur bone becomes interpolated which is shown.

Fig. 2. X-Ray image of femur bone.

Fig. 3. Thin plate spline interpolation.

Fig. 4. Canny edge detection.

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Segmenting the femur bone parts such as neck, ward, trochanter and shaft regions. Initially measure the pixel value inside the blue box for each part in the femur bone x-ray image. The neck and ward region segmentation is shown in Fig. 5. The Trochanter and shaft region segmentation is shown in Fig. 6. It helps to make segmentation easier. After
segmenting out the regions, calculated the areas of each femur bone part which is actually needed to measure the BMD. As the edges are clear it is easier to measure the area. The area obtained was in pixels, so we used pixel conversion calculator to attain the area in centimeter square. In x-ray images of femur bone, the areas defined for the neck region is a rectangle, for the ward region it is a square and for the shaft and the trochanter it is a triangle. This geometrical shape makes comparison more flexible.

The area of region is obtained from the pixel conversion calculation. The bone mineral content values of the normal femur and the osteoporotic femur is collected from hospitals. BMD is a measure of degree and heterogeneity of mineralization in bone tissue [6], which is calculated by bone mineral content divided by area of each femur part.

IV. T-SCORE MEASUREMENT

The T-score is the number of standard deviations below the average for a young adult at peak bone density [7]. The prevalence of low bone density in the general population can be assessed by means of the WHO diagnostic criteria. According to these criteria, persons with bone density levels of t-score more than 2.5 standard deviations and below the young adult reference mean are considered to have osteoporosis. Persons with bone density below this threshold who also sustains a fracture meet the definition of “established or severe osteoporosis” [8].

Then we have placed the pushbutton named ‘Measure BMD’. First a particular femur image is selected, and then clicking on the ‘Measure BMD’ button gives the BMD value of the particular femur. The Fig. 9 shows the GUI layout page displaying the area, the BMC and the measured BMD values of the osteoporotic femur. Fig. 10 shows the GUI layout page displaying the area, the BMC and the measured BMD values of the normal femur.

The head region is still manually removed by setting the threshold value. But, in this work, it represents a method which is potentially removed automatically by incorporating a Hough filter for detecting spherical objects in head region which is articulates in pelvis area [5]. Fig. 11 highlights the head region of femur from pelvis which is done by matlab using Hough filter.
is a major risk factor for fragility fracture and other risk factors may act via their effect on bone mineral density. The BMD values measured from X-ray image is very close to the BMD values measured from DEXA image. The BMD Measurement from X-ray image is very much simpler compared to the DEXA method. This makes the method much easier as well as efficient. The Table I compares the BMD values.

<table>
<thead>
<tr>
<th>REGIONS</th>
<th>NORMAL FEMUR</th>
<th>OSTEOPOROTIC FEMUR</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>DEXA IMAGE</td>
<td>X-RAY IMAGE</td>
</tr>
<tr>
<td>Neck</td>
<td>0.847</td>
<td>0.8469</td>
</tr>
<tr>
<td>Ward</td>
<td>0.593</td>
<td>0.5925</td>
</tr>
<tr>
<td>Trochanter</td>
<td>0.797</td>
<td>0.7975</td>
</tr>
<tr>
<td>Shaft</td>
<td>1.128</td>
<td>1.1277</td>
</tr>
</tbody>
</table>

The Fig. 12 shows the BMD values obtained from X ray and DEXA images in chart, showing small variations for all the regions namely, the neck, the ward, the trochanter and the shaft of the osteoporotic femur. From the chart it can conclude that, the BMD measured from X-ray image by this method does not vary to a great extent for the osteoporotic femur.

V. CONCLUSION

Then comparing the BMD values obtained from X ray image and DEXA image. This is done for both normal femur image and an osteoporotic femur image and estimates their accuracy. The BMD values measured from X-ray image is very close to the BMD values measured from DEXA image. The BMD Measurement from X-ray image is very much simpler compared to the DEXA method. This makes the method much easier as well as efficient. The Table I compares the BMD values.

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