

Medical Image Analysis to Determine the Effectiveness of Osteoporosis Treatment

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Abstract. This paper proposes a method for determining the effectiveness of osteoporosis treatment by analyzing medical images. Osteoporosis is a bone disease that leads to an increased risk of fracture. This method analyses bone density changes over a time period, by extracting cortical and trabecular bones from medical images and comparing their density on a medical image taken at the beginning of treatment and after the time period.

Keywords: osteoporosis, medical images, cortical bone, trabecular bone.

I. INTRODUCTION

Osteoporosis is a bone disease that leads to an increased risk of fracture. In osteoporosis the bone mineral density is reduced and bone microarchitecture deteriorates. The effect that osteoporosis has on a bone is displayed in Fig. 1. The areas of the bone architecture that are most affected by osteoporosis are the trabecular (spongy) bone and the cortical (compact) bone, where the trabecular bone is the sponge-like bone in the ends of long bones and vertebrae, and the cortical bone is the hard outer shell of bones. Osteoporosis causes the thinning of the cortical bone and deterioration of trabecular bone structure.

The diagnosis of osteoporosis can be made using conventional radiography and by measuring the bone mineral

density (BMD). The most popular method of measuring BMD is dual energy x-ray absorptiometry (DXA or DEXA) [1]. In addition, the diagnosis of osteoporosis requires investigations into potentially modifiable underlying causes; this may be done with blood tests.

An important part of treating osteoporosis is lifestyle changes (aerobics, weight bearing and other exercises), and there are several medications used to treat osteoporosis, depending on gender. Now finding out whether treatment is effective is another issue, because it has been shown that just knowing bone mineral density is not enough to determine the risk of a fracture [2]. Thus, to determine the effectiveness of treatment it is also necessary to analyse the changes in bone structure during treatment. Although there are methods that perform this analysis, they use sophisticated imaging equipment like high-resolution peripheral quantitative computed tomography (HR-pQCT) or high-resolution magnetic resonance imaging (MRI) [3], but so far these machines are very rare.

This paper proposes a method to determine the effectiveness of osteoporosis treatment by analyzing medical images acquired using conventional computed tomography machines, which can be found in most hospitals.

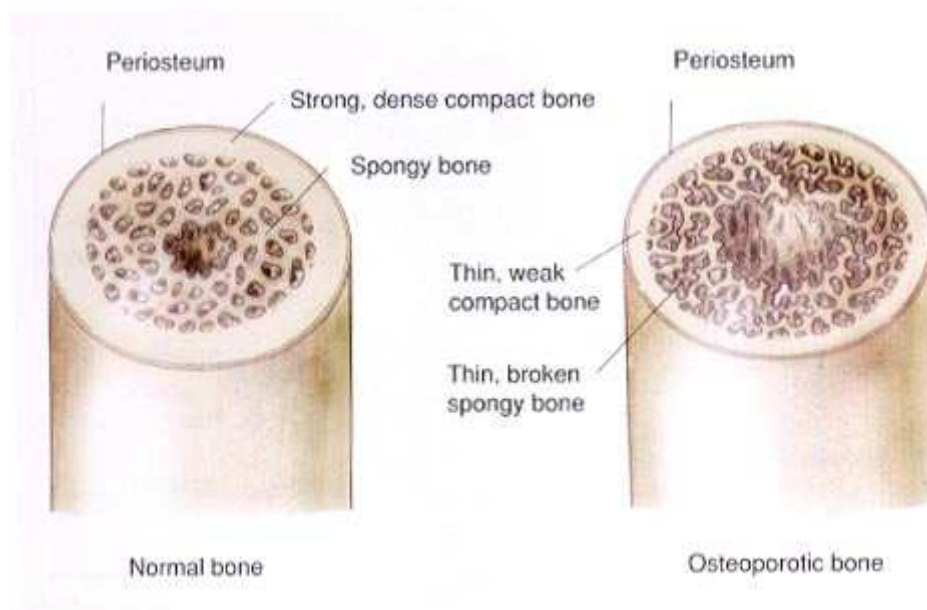


Fig. 1. Bone structure deterioration caused by osteoporosis

II. THE PROPOSED METHOD

The proposed method analyses the medical images acquired by computed tomography and saved in DICOM format, which stores additional information about the patient and the radiodensity of all the pixels.

The areas of the bone that are most affected by osteoporosis and are visible on the medical images are the trabecular and cortical bones, so that the proposed method focuses on these areas. The analysis of the medical image consists of several stages: the cortical and trabecular bone extraction and bone density comparison.

A. Cortical Bone Extraction

The first step in extracting the cortical bone from the medical image is the segmentation of the medical image to find which parts belong to the cortical bone. This is done by analyzing the radiodensity of pixels in the image. The radiodensity of a cortical bone is usually more than 400Hu on a Hounsfield scale, but an operator can also define their own radiodensity threshold. Using these values we segment the image to find which pixels belong to the cortical bone and blacken all other pixels, so that only the cortical bone is visible. Fig. 2 shows the segmented medical image; as it is seen on the segmented medical image (b), the segmentation process also leaves some of the pixels that do not belong to the cortical bone, this happens because the radiodensity of these pixels is similar to the radiodensity of the bone.

To remove all of these pixels that do not belong to the cortical bone, all of the pixels in the image are joined into

separate clusters by using a region growing algorithm, which joins all the adjacent pixels into clusters. Then it is necessary to find which clusters contain the cortical bone. As it is seen in the medical image (Fig. 2.), most of the pixels that do not belong to the cortical bone are located on the bottom of the image and belong to the motorized platform, on which the patient lies, and the cortical bones are located on the top. As a result, the proposed method picks the four topmost clusters (two tibia bones and two fibula bones), that contain no less than 50 pixels, and these clusters are considered to contain the cortical bone and they are saved so that they can later be used in the trabecular bone extraction and bone density comparison.

B. Trabecular Bone Extraction

The first step in extracting the trabecular bone from the medical image is the selection of all the pixels that are located inside the cortical bone. That is done by using the cortical bone clusters found during the cortical bone extraction. All the pixels that are located inside the cortical bone clusters are selected using the region growing algorithm: starting at the centers of the cortical bone cluster, all of the pixels that do not belong to the cortical bone and do not go outside the cortical bone are selected.

All that is left is to remove the pixels that do not belong to the trabecular bone from the selection. This is done by defining a radiodensity threshold of the trabecular bone and removing all of the pixels from the selection that fall outside this threshold. Fig. 3 illustrates the trabecular bone extraction process.

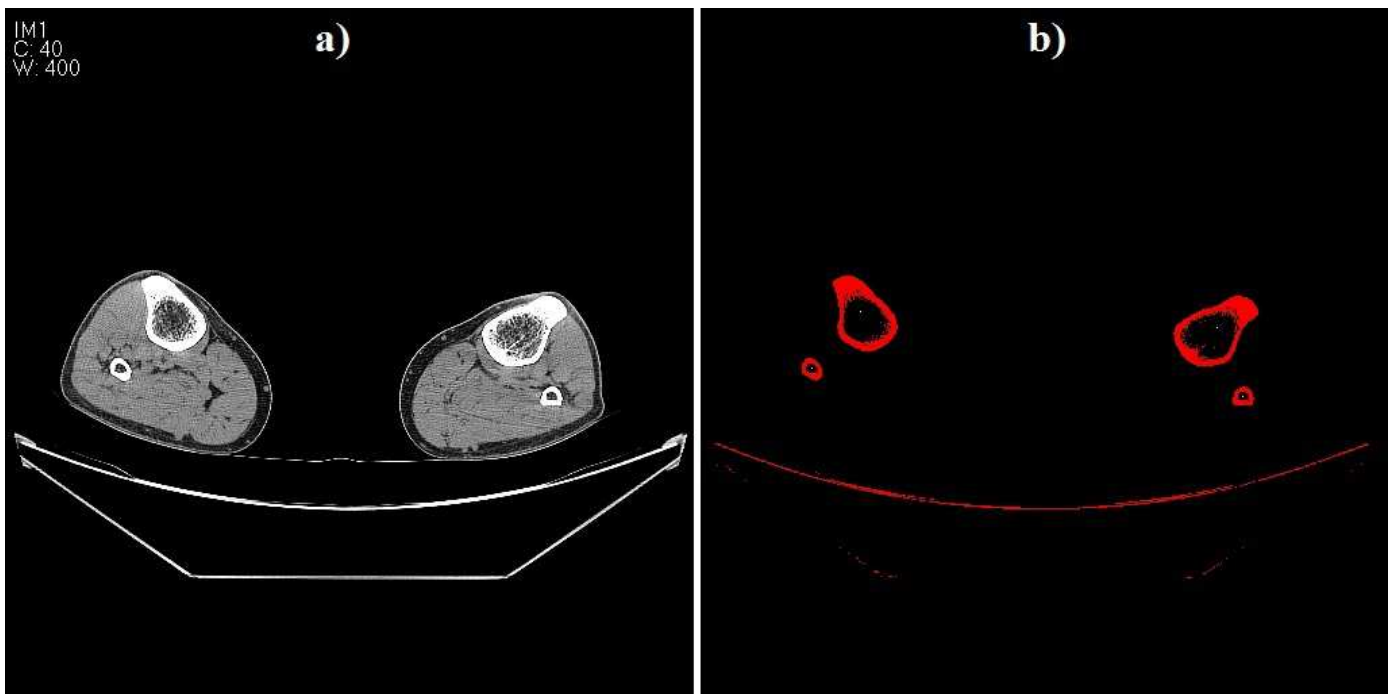


Fig. 2. Cortical bone extraction, a) initial medical image, b) segmented medical image

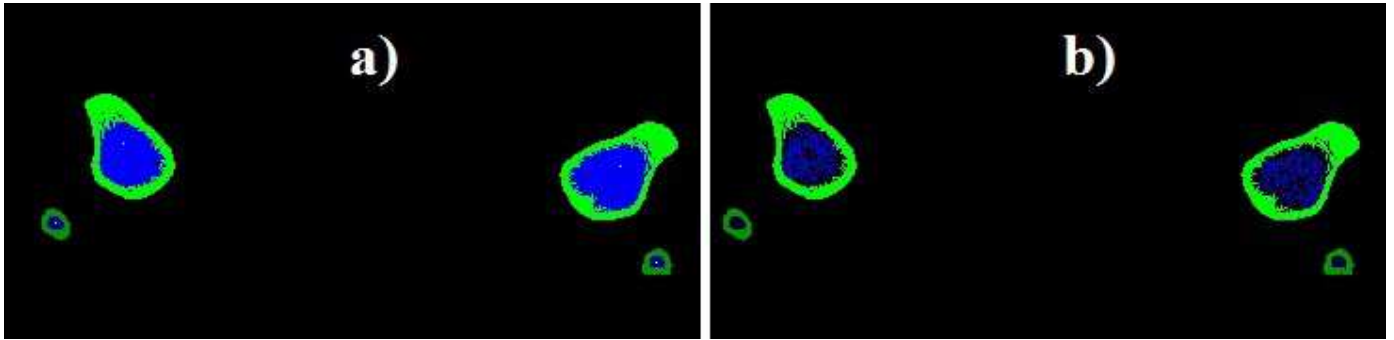


Fig. 3. Trabecular bone extraction, a) all of the pixels inside the cortical bone are selected, b) the pixels that do not belong to the trabecular bone are removed from the selection

C. Bone Density Comparison

To determine the effectiveness of osteoporosis treatment, it is necessary to compare the cortical and trabecular bone densities on medical images taken at the beginning of treatment and after a certain time period (three or six months).

To measure the bone density, we need to count the number of pixels that belong to the cortical and trabecular bones that were extracted from medical images. Then we simply compare the number of pixels on the medical images taken at the beginning of treatment with the number of pixels on the medical images taken after a certain time period.

If within a certain time period the number of pixels has increased, it means that the bone density has increased and the bone has become stronger, in which case we can conclude that treatment has been effective. However, if within a certain time period the number of pixels has decreased, it means that the bone density has decreased and the risk of fracture has

increased, in which case the treatment has not been effective, and the doctors should adjust their treatment plan or work out a different plan.

III. EXPERIMENTS

The proposed method has been tested using a set of 300 medical images acquired with conventional computed tomography. The medical images contain the lower extremities of a human being, and the experiment has been focused on the tibia and fibula bones.

The proposed method has enabled us to successfully extract the cortical and trabecular bones from the medical images and to measure the bone density by counting the number of pixels that belong to the extracted bones. Fig. 4 demonstrates the results of extracting the cortical and trabecular bones from six different medical images.

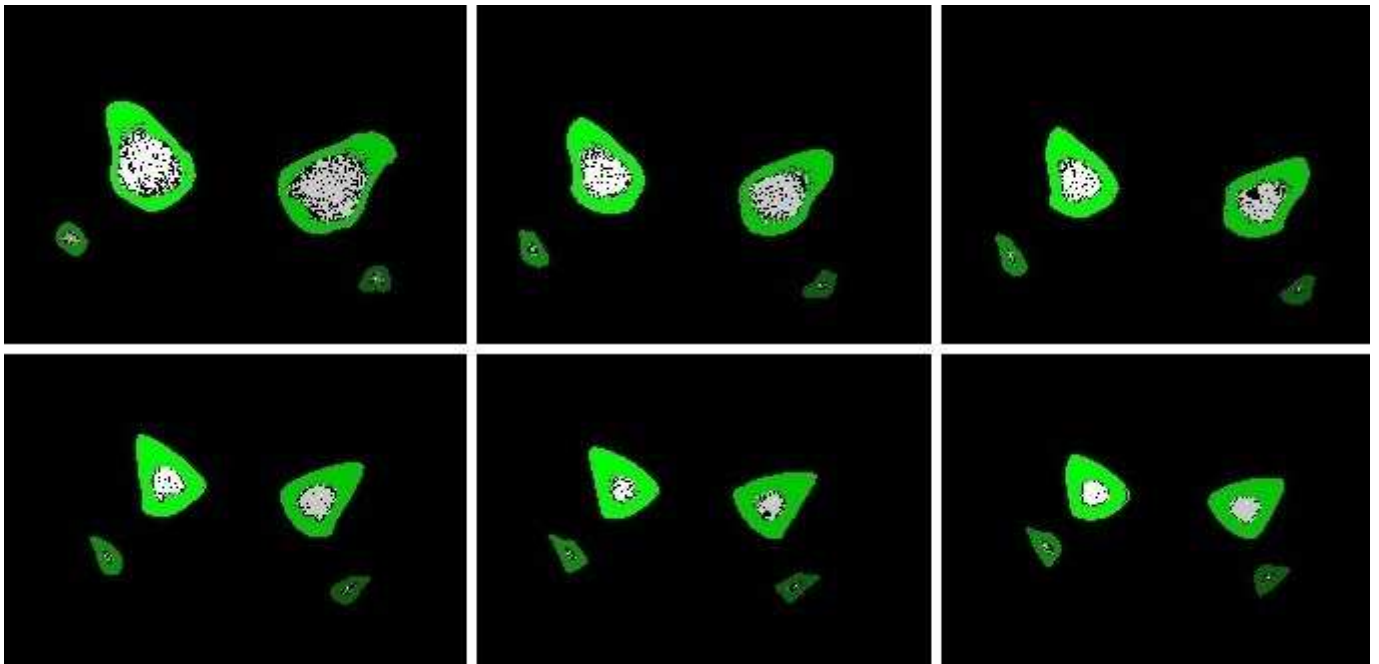


Fig. 4. Cortical and trabecular bone extraction results

IV. CONCLUSIONS

The method proposed in this paper should help doctors treating osteoporosis to determine whether their treatment plan is effective so that they could adjust it and choose a better treatment plan.

The advantage of this method is that it does not require sophisticated imaging equipment and can be implemented using conventional computed tomography, which can be found in most hospitals.

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Mihails Kovalovs, Aleksandrs Glazs. Medicīnisko attēlu analīze, lai noteiktu osteoporozes ārstēšanas procesa efektivitāti

Pētījums apraksta metodi, ar kuras palīdzību var noteikt osteoporozes ārstēšanas procesa efektivitāti, analizējot medicīniskos attēlus. Osteoporoze ir smaga kaulu slimība, kas nemanāmi attīstās daudz gadu laikā. Osteoporozes rezultātā kauli kļūst poraini un dubumaini, ievērojami samazinās kaulu masa, tie kļūst trausli un viegli lūst.

Piedāvātā metode veic cilvēka kājas kaulu medicīnisko attēlu analīzi, lai aprēķinātu kortikālo (blīvīve kaulaudi) un trabekulāro (irdenie kaulaudi) kaulu blīvumu. Lai atrastu kaulu blīvumu, vispirms ir nepieciešams segmentēt medicīnisko attēlu pēc rentgencauskatāmības, balstoties uz Haunsfilda skalu. Tāda veidā attēlā tiek atrasti pikseli, kuri pieder kaulam, bet pēc segmentācijas uz attēla parasti vēl paliek daži pikseli, kuri nepieder kaulam, tāpēc ka viņu rentgencauskatāmība ir līdzīga kaulam. Tāpēc visi pikseli uz attēla, kas paliek pēc segmentācijas, tiek apvienoti klāsteros, un tālāk tiek atrasti tie klāsteri, kuri satur tikai kaulu pikselus. Tālāk, lai noteiktu kaulu blīvumu, jāaskaita, cik daudz pikseļu ir šajos klāsteros. Lai noteiktu osteoporozes ārstēšanas procesa efektivitāti, atliek tikai salīdzināt kaulu blīvumu uz medicīniskajiem attēliem, kas bija izveidoti ārstēšanas procesa sākumā un pēc kāda laika (3 vai 6 mēnešiem). Ja kaulu blīvums pēc kāda laikabūsi palielinājies, tad ārstēšanas metode ir bijusi efektīva, pretējā gadījumā, - ja kaulu blīvums samazinājies, - ārstēšanas process nav bijis efektīvs un ārstiem ir jāmaina ārstēšanas metode.

Piedāvātā metode tika pārbaudīta uz 300 medicīniskajiem attēliem, un tā spēja sekmīgi segmentēt medicīniskos attēlus un noteikt kaulu blīvumu. Šīs metodes galvenā priekšrocība ir tāda, ka tai nav vajadzīga sarežģīta tomogrāfijas aparatūra un var strādāt ar parasto datortomogrāfiju.

Михаил Ковалёв, Александр Глаз. Анализ медицинских изображений для оценки эффективности лечения остеопороза

Данная работа описывает метод определения эффективности лечения остеопороза с помощью анализа медицинских изображений. Остеопороз является заболеванием, которое связано с повреждением (истончением) костной ткани и приводящее к переломам и деформации костей. В результате остеопороза кости истончаются, становятся менее прочными и упругими.

Предложенный метод использовался для анализа медицинских изображений костей ног, для того чтобы определить объем кортикальной пластины и trabecularного (губчатого) вещества. Для этого сначала необходимо сегментировать медицинские изображения по рентгенопрозрачности в соответствии со шкалой Хаунсфилда. Таким образом, на изображениях находятся пиксели, которые отображают кости, но после сегментации на изображениях часто остаются лишние пиксели, потому что их рентгенопрозрачность совпадает с рентгенопрозрачностью костей. Поэтому все пиксели, найденные в ходе сегментации, объединяются в кластеры и далее находятся кластеры, которые содержат только пиксели костей. Далее для того чтобы найти объем костей, надо сосчитать, сколько пикселей находятся в этих кластерах. Для определения эффективности лечения остеопороза остается только сравнить объемы костей на медицинских изображениях, сделанных в начале лечения и после определенного промежутка времени (3 или 6 месяцев), тогда если после промежутка времени объем кости увеличился, то лечение эффективно, в противном случае, если объем кости уменьшился, значит лечение неэффективно, и врачам следует изменить метод лечения.

Предложенный метод был проверен на 300 медицинских изображениях, и он успешно смог отсегментировать медицинские изображения и рассчитать объем костей. Главное преимущество предложенного метода заключается в том, что он не требует сложной томографии и способен работать с обычной компьютерной томографией.