Automatic medical image analysis for measuring cortical bone porosity

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Introduction. Cortical bone porosity is caused by osteoporosis, which causes bones to become weak and brittle and more likely to break. Osteoporosis causes the bone mineral density to decrease and the micro architecture of the bone is also disrupted.

At present osteoporosis is mostly diagnosed by measuring the bone mineral density (BMD), which is usually obtained using dual-energy x-ray absorptiometry (DXA). DXA is a two-dimensional, projection-based radiographic technique that measures integral BMD of both cortical and trabecular bone. BMD only explains about 70% to 75% of the variance in bone strength [1], while the remaining variance is due to the cumulative and synergistic effect of other factors such as bone architecture, tissue composition and micro damage. One of the important factors that contribute to bone fragility are the thinning of the cortical bone and increased cortical bone porosity [2].

In recent years there have been increased interests in developing techniques to analyze medical image to evaluate bone microstructure [3]. Most of these techniques use medical images that were acquired by high resolution computed tomography and magnetic resonance imaging tools that are fairly expensive and not available in most clinics. It is also possible to analyze bone structure, by using axial quantitative ultrasound (QUS) [4], which is an alternative to the radiological methods, but it is only used to analyze the cortical bone structure.
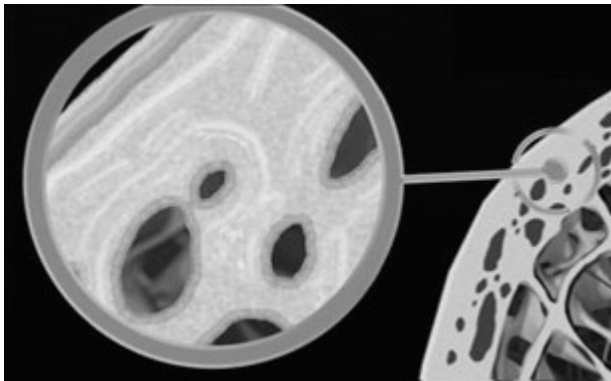

Fig. 1. Cortical bone porosity

In this paper a method of automatic measurement of cortical bone porosity is proposed. This method uses medical images that were acquired using conventional computed tomography. It automatically finds and defines the cortical bone region of interest and measures the porosity inside this region, it also calculates the average cortical thickness.

Proposed method. Before it is possible to measure the cortical bone porosity, it is first necessary to perform the medical image segmentation, where the soft tissue is removed from the medical image. The medical image segmentation is done based on the radiodensity of each pixel in an image. The Hounsfield scale is used to define a radiodensity threshold of a cortical bone and all the pixels, whose radiodensity falls outside the defined threshold are blackened, which leaves only the cortical bone on the medical image (Fig. 2).

Then it is necessary to classify the bones, so that the program could distinguish between the left leg and the right leg and between the tibia and the fibula bones and remove any parts of the image that are not cortical bones, but have the same radio density. The bones are classified based on their volume, position and aspect ratio [5].

After the segmentation of the medical image it is necessary to find the inside contour of the cortical bone. This is done by first finding the center point of the cortical bone, which is done by calculating the average position between all of the pixels that belong to the cortical bone. Then a collection of points in a shape of a circle are placed at the starting point and they expand in all directions, and adjust to the shape of the cortical bone (Fig. 3 a), thus creating the contour of the inside edge of the cortical bone.

This inside contour of the cortical bone is then used to find the outside contour of the cortical bone. At each point of the inside contour, a new point is placed and then it moves in the direction, which is normal to the inside contour (Fig. 3 b), until it reaches the outer edge of the cortical bone (Fig. 3 c). The distances between the points on the inside contour and the outside contour are then used to calculate the average thickness of the cortical bone.
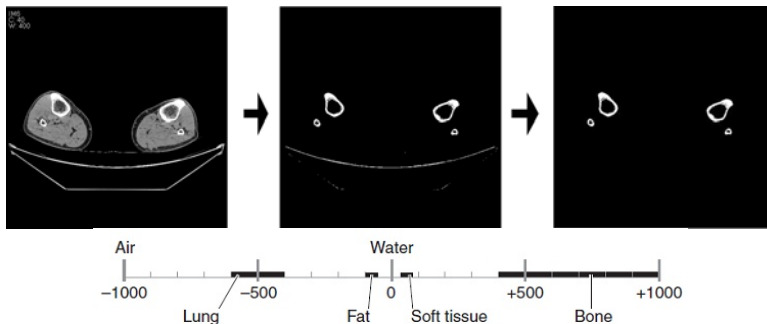

Fig. 2. Medical image segmentation showing the initial medical image on the left, the image with the applied radio density threshold, the medical image after segmentation on the right and the Hounsfield scale

To better describe the shape of the cortical bone, new points are created and placed between the existing points on the outside contour (Fig. 3 d), then they move in direction that is normal to the outside contour, until they reach the edge of the cortical bone, thus creating the final contour of the outside edge of the cortical bone (Fig. 3 e).

When both of the contours have been found, it is possible to measure the cortical bone porosity. The entire area that is located between both contours is analyzed, and the cortical bone porosity is measured as a difference between the pixels with a radiodensity that falls inside the cortical bone threshold and the pixels that fall outside this threshold. The result is given as a percentage, where if the number is bigger it means the cortical bone is more porous.

Conclusions. The proposed method was tested on a set of medical images, that were acquired using conventional computed tomography and the proposed method proved capable of extracting the cortical bone from a medical image and measuring the cortical bone porosity and the average cortical bone thickness.

The main advantage of the proposed method is that it is fully automatic, the operator only needs to define the cortical bone radiodensity threshold and after that the algorithm can automatically extract the cortical bone from the medical image and measure the cortical bone porosity and average cortical thickness.
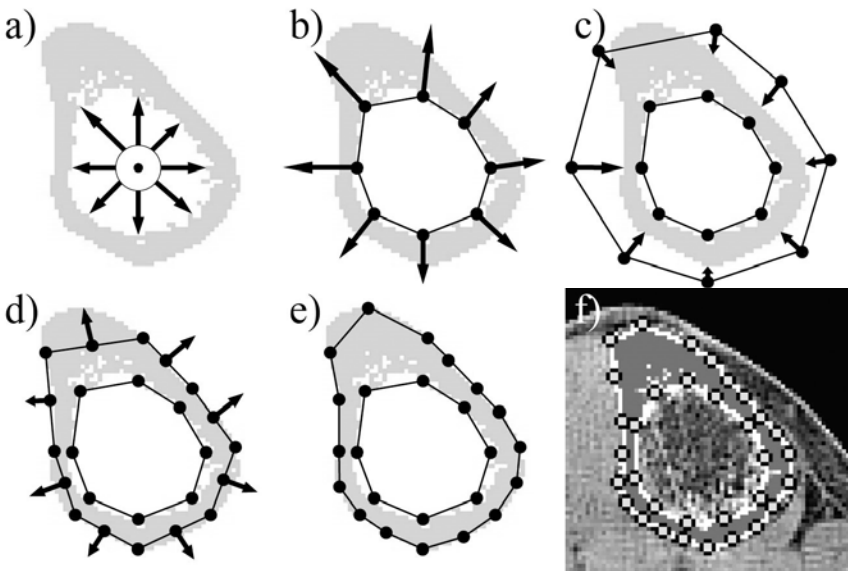
Fig. 3 a), b), c), d), e) Finding the inside and outer contour of the cortical bone, f) proposed method used on a medical image (Cortical bone porosity - 6.13%, average cortical thickness - 5.95 pixels)

This method should make it easier and faster to analyze the medical images for rehabilitation clinics doctors that are treating patients with osteoporosis.

References
1. Ammann P, Rizzoli R. Bone strength and its determinants // Osteoporosis International, Vol. 14, Issue 3 Supplement, 2003. – P. 13–18.

2. Bousson V, Peyrin F, Bergot C, et al. Cortical bone in the human femoral neck: three-dimensional appearance and porosity using synchrotron radiation // Journal of Bone and Mineral Research, Vol. 19, Issue 5, 2004. – P. 794–801.

3. Krug R., Burghardt A. J., Majumdar S., Link T. M. A High-Resolution Imaging Techniques for the Assessment of Osteoporosis // Radiologic Clinics of North America, Vol. 48, Issue 3, 2010. – P. 601–621.

4. Tatarinov A. M., Egorov V. P., Sarvazyan A. P. The Dual Frequency Method for Ultrasonic Assessment of Skeletal System // Acoustical Physics, Vol. 55, Issue 4–5, 2009. – P. 665–673.

5. M. Kovalovs, A. Glazs, The cortical and trabecular bone extraction from medical images to determine the effectiveness of treatment of osteoporosis // Conference Biomedical Engineering Proceedings. Kaunas, Lithuania, 2012. – P. 103–106.

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Cortical bone porosity is caused by osteoporosis, which causes bones to become weak and brittle and more likely to break. In this paper a method of automatic measurement of cortical bone porosity is proposed. This method uses medical images that were acquired using conventional computed tomography. The proposed method works by finding and defining the cortical bone region of interest on a medical image and measuring the cortical bone porosity inside this region, it also calculates the average cortical thickness.