Development of computer system to aid of diagnosis osteoporosis in human hip joint region

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1. Introduction

Human bone system is subject to frequent demages and diseases. One of them is osteoporosis. This is a disease of bone which causes progressive decreasing of bone mass and the changes in bone structure. In the course of time loss of bone mass is so serious that it can cause the disorders of functioning of bone in organism. In a consequence bones become weak and more subject on fracture. At people suffering from this disease more often occurred the fractures e.g. femoral neck and vertebral of spine. Very important factor is early diagnosis. This is a serious problem because osteoporosis progresses without symptoms. The first symptoms – difficulties during move and appearing pains in the spine and in the hip joint appear when the big loss of bone mass exists and it is the large risk of fractures. Unfortunately it is a serious phase and the fractures are common – after fracture one should stabilization of places of fracture [2]. There is a several prophylactic method which are realized to diagnose the osteoporosis: Radiology Absorptiometry (RA), Roentgen Absorptiometry (two method: Single X-ray Absorptiometry – SXA and Dual-energy X-ray Absorptiometry – DEXA), Quantitative Ultrasonography (QUS), Quantitative Computed Tomography (QCT). In our work the QCT method was used. This is radiology examination in which the images from CT are used to analyze the mineral density of bone. Throught using the composition of projection images from different directions one can to get cross-sectional and solid images in all researched structures. Tomograms consist of individual voxels. Each voxel is characterized by coordinates x, y, z and color in gray scale. On the base of an experimental research the formulas between amount of radiation and bone density is possible determining a value of density for each voxels. During QCT the bone system as well as density phantom is X-rayed. The phantom is composed of regions representing specimens of bone density (in Hounsfield Units). This procedure one may to estimate bone density (in g/cm³) in all analyzed object, with accuracy to one voxel. So this method makes possible not only distinction of bone structures, but even the differences of thickness in the same tissue [1, 3].

2. Methods

After radiological examination we obtain images of researched structure. The next step is to converse these data to receive information about analyzed bones. The general course of transforming data is following:

1. Performing of tomography researches. During examinations the bone system and density phantom is X-rayed. In a result the images (sections in different places) of analyzed object is received.
2. Analyzing the X-ray photographs by use specialist software (the dependence between quantity of the absorbed radiation and the radiological density in bone tissue is used).
3. Standardizing obtained density to Hounsfield scale – HU:

\[
1HU = K \frac{\mu_p - \mu_u}{\mu_u}
\]  

\( K \) – amplification factor of images,
\( \mu_p \) – absorption factor,
\( \mu_u \) – absorption factor of reference object,
4. On the base of HU density determining the density of bone tissue [2].

Fig. 1. Images from QCT: a) original images, b) images after removal useless information, c) density phantom.
\[ \rho = 1.122 \cdot HU + 47 \]  
(2)

5. Delimitation the material properties of bone tissue, especially elastic modulus (on the basis of experimental research the dependences between bone density and material properties were developed) [2].

\[ E = 1.92\rho - 170 \]  
(3)

3. Results

After QCT examinations the tomograms of researches structure are obtained. By using relationship between density of bone tissue and material properties it is possible to calculate material properties of bone tissue in each voxel. From the other hand, on the base of QCT data it is possible to create the geometry of numerical model. When the model is prepared the material properties are inserted and the strength calculations (according to FEM) are performed. On the ground of obtained results (distributions of stresses, strains and displacements) one can get to know about effort in researched bone [3].

In preparing is the computer program which will be aid doctor’s work in diagnosing of osteoporosis in human pelvic bone. The general principle is as follow: after radiology examination it takes place searching to finding the most similar images (searching CT photo from data base). When these images are found the whole model with strength parameters is assigned. Next the results (from strength calculations) are analyzed. As a consequence, particular images from QCT are subordinated effort of bone. In case of need it is possible to return to searching of base and analyzing the larger number of data. The simplified block diagram of the program is presented in Fig. 2.

4. Discussion

- Applied procedure facilitates interpretation of data from QCT and it helps diagnosis what enable earlier detection of osteoporosis and enlarges chance of the treatment.
- Information from QCT can be helpful for researching progress of osteoporosis in individual clinical cases (because easier one can find the differences between earlier and later images).
- Subordinating individual images from QCT of effort state provides information about bone system.
- Creation of numerical model on the base of radiological data (especially material properties) increasing it conformance to real conditions.
- Presented procedure enables noticing changes in bones more precisely than standard methods (this is important when the difficulties with clear diagnosis appear).

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References

