METHODOLOGY OF TIME-DEVELOPMENT ANALYSIS OF VERTEBRAL TUMORS IN CT DATA

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Abstract: This paper presents the methodology of time-development analysis of vertebral tumors in CT data. It including an overview of suitable features which can relevantly characterize the shape of tumor tissue. We proposed two different analysis methodologies: for compact tumors and the whole vertebral body. The test database of five lytic compact tumors containing five follow ups was created. The initial result of time-development for statistical features for compact tumors on created database and whole body vertebra were shown.

Keywords: time-development, CT, lesion, spine

1 INTRODUCTION

Bones are the third most commonplace of metastasis right after lungs and liver. Seventy percent of skeletal metastases cases originate from breast and prostate cancer. These metastases are the main cause of morbidity characterized by strong pain, worsened mobility, pathological fractures, hypercalcemia, and compression of the spinal cord. There are two types of skeletal metastases: osteolytic and osteoblastic (see Fig. 1). [1]

Time-development analysis generally means monitoring given features over time. In oncology, the analysis of the development of treated lesions using this method is still at the beginning of the research process. However, in clinical practice, it might be beneficial for evaluating how lesions respond to a particular treatment. If relevant features characteristic for the development of lesion over time were found, it would be possible to assess the effectiveness of that treatment earlier.

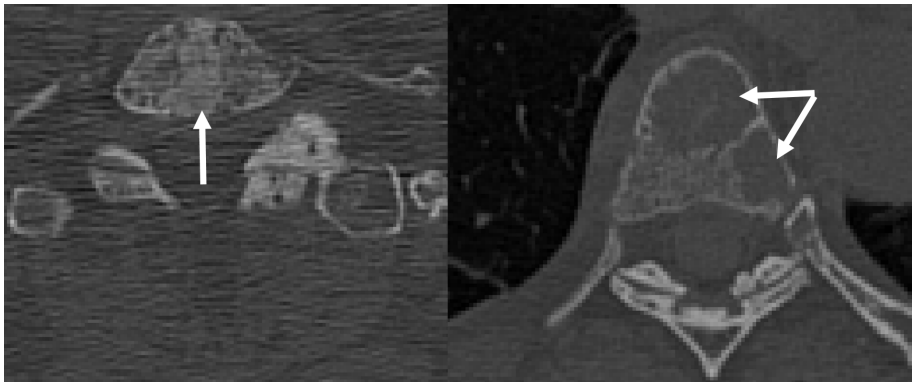

Figure 1: An axial image example of osteoblastic lesion (left) and osteolytic lesions (right) in spinal CT data.

2 DESIGN OF EVALUATION APPROACH

2.1 SHAPE CHARACTERIZATION OF TISSUE

Tumor analysis is a very difficult task because it is first necessary to segment the tumors themselves. It can be segmented manually, which is very challenging or samiautomatically with using some method like region growing. Obtaining the annotation of the compact tumor might be a challenging task as tumors might grow and change their shape and characteristics over time (see Fig. 2). Often there is more than one tumor in one vertebra, separated tumors from the first scan might connect during the following scans, or one tumor might separate into many smaller ones (see the second row of Fig. 2). Due to this fact, the analysis of these tumors might be unrealistic and another method has to be used. Tumors (metastases) according to their shape we suggested dividing into compact tumors and complex tumors which affect the whole body of the vertebra. Thus, it is necessary to divide the realization of time-development of spinal tumors according to the size of the damage on the vertebra into the analysis of compact tumors and the analysis of the characteristics of the whole body of the vertebra.

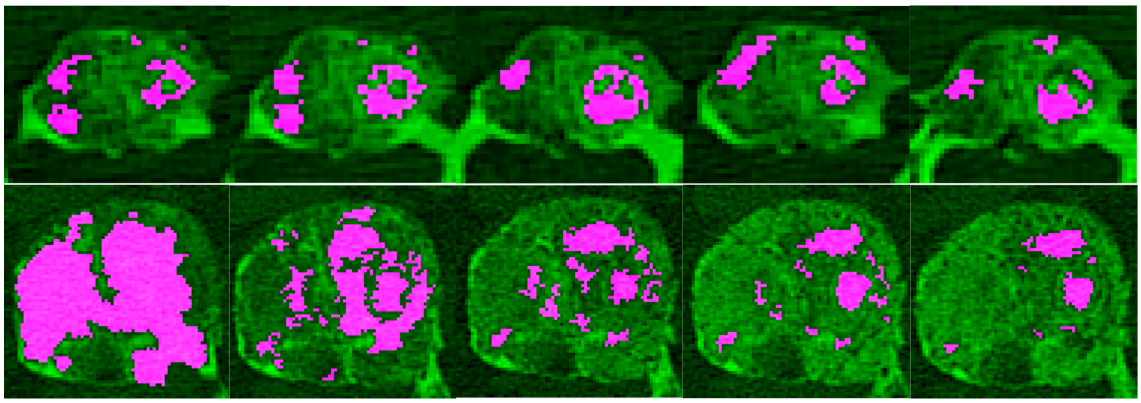

Figure 2: Example of time-development treated lytic lesions from the third cervical vertebra (up) and fifth lumbar vertebra (down). It fused images of original data and created annotation, where the green color is non-lytic tissue and the pink color is lytic tissue. There was a gap of three months between the first three CT scans, a fourth scan was after the next five months, and a fifth after another four months.

2.2 THE ANALYSIS OF COMPACT LESIONS

This approach requires segmentation of the lesions which is a very challenging task because segmentation must be accurate and it is very time-consuming. If we manage to segment a compact tumor, various relevant features can be obtained from it. These features include statistical local features and features based on shape analysis. Statistical local features that are suitable for evaluating the time course of tumors include the mean value and the variance or standard deviation of the lesion intensity. Determining the relative values of these features, which are related to healthy trabecular tissue, also allows us to better assess how the density of tumor tissue changes.

Another group of features that can be evaluated for a given tumor is based on shape analysis. Since spinal tumors are 3D objects, it is convenient to choose descriptors for 3D image data. The most simple descriptor is the volume of the tumor. This might show changes in size over time, which may indicate a response to the treatment. However, normalization is required for this feature because the volume increases to the third power, and without some normalization, evaluation of the results would be difficult. Another suitable 3D descriptor is the roundness, which can, over time, show whether

the tumor is compact or whether it changes its shape and grows into the surrounding tissue. Other possible features include the surface, the center of gravity, the length of the main and the secondary axis, etc.

2.3 THE ANALYSIS OF THE WHOLE VERTEBRAL BODY

This approach requires segmentation of vertebra or localization of the center of body vertebra for next analysis. It could be less time-consuming because such accuracy is not required there and is suitable for very damaged vertebrae. Some vertebrae can be so extremely damaged by tumor tissue, that it makes shape analysis very problematic. In that case, another method of analysis might be more appropriate. One possible approach might be to calculate features from the whole vertebral body. Features that may be appropriate to extract from the entire vertebra include the mean and especially the variance of intensity. Assuming a severely affected vertebra with a lytic tumor (Fig. 2 below), if the tumor is being treated, which means that calcium is deposited to the destination of the tumor, the overall variance of intensity in the vertebra should increase. This parameter might indicate the time-development of tumors even for very severely affected vertebrae, in which compact tumors can't be segmented. [1]

Another possible approach might be the usage of texture analysis. This analysis could detect unique primitives that could be characteristic for the tissue which is going through a remodelation with calcium storage. This would detect the response of the lesion to the treatment in the time-development analysis.

3 REALIZATION AND DISCUSSION OF METHODOLOGY

3.1 DATA

In this work, an anonymized database of an oncologically ill patient examined by CT scan was used. The data were obtained through Philips Healthcare Brilliance iCT 256-slice scanner with experimental CT protocol from IRST Meldola, Italy. The database of this patient contains five scans which allow us to observe the time-development of lesions. A more detailed study of the data showed that this patient suffers from very extensive tumor damage of almost the whole spine, however, it consists of compact tumors as well. The annotation of compact tumors was created with a significant final cleaning refinement by the author of this paper and it was very time consuming.

3.2 IMPLEMENTATION TOOLS

The implementation was performed in the MathWorks MATLAB 2020a programming environment. The Image processing toolbox for visualization of data was used and the Statistics toolbox was used for statistical analysis. For segmentation of lesions and their refinement, the region growing method realized via Image Segmenter has been used which is included in the Image Processing toolbox.

3.3 EXPERIMENTS AND DISCUSSION

The data are from a patient who had a primary breast tumor with spinal metastases and was treated with bisphosphonates that inhibit bone de-mineralization. The patient suffers from severe damage to the tumor tissue, therefore it was very difficult to find a compact tumor in five consecutive scans. Lesions of different sizes and from different vertebrae were selected. The created database of five compact lytic lesions shows the time-development of the mean value of intensity (see Fig. 3 left) and volume from shape descriptors (see Fig. 3 right). In the mean intensity graph, we can see a slight decrease in mean intensity, which can characterize that the treatment does not work. In the graph of the volume we can see that two lesions are growing, two lesions are decreasing in size and one stays

the same. Next, a graph of the mean value and normalized variance from the whole body of the fifth lumbar vertebra is shown (see Fig. 2). An area of 40×45×40 voxels was selected and the features from this area were calculated. Their time-development was plotted (Fig. 4). It can be seen from the graph, that the mean intensity value and normalized variance increase over time. It could indicate a response to the treatment where calcium is deposited in the area of the lytic lesions.

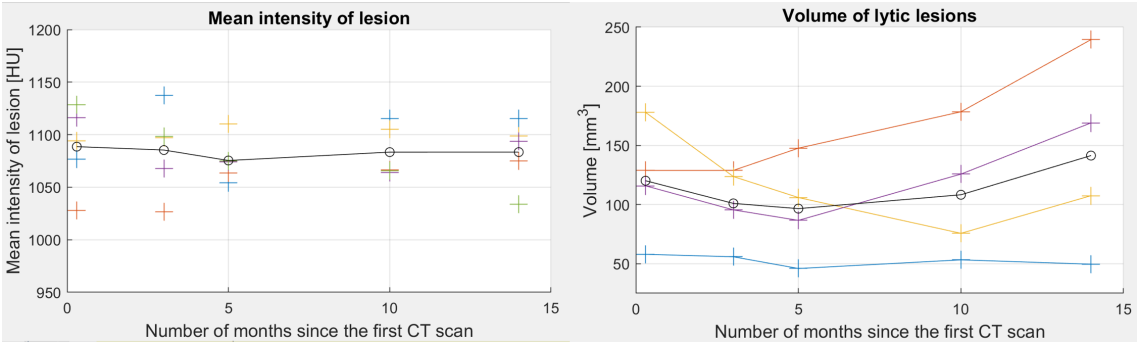

Figure 3: There are two graphs for the analysis of compact tumors. On the left is the mean intensity of lesions and on the right is the pseudo linear graph of shape descriptor. The volume was chosen for simplification. Each color of points and curves represents one lytic tumor and the black line shows the mean across all tumors for a given feature.

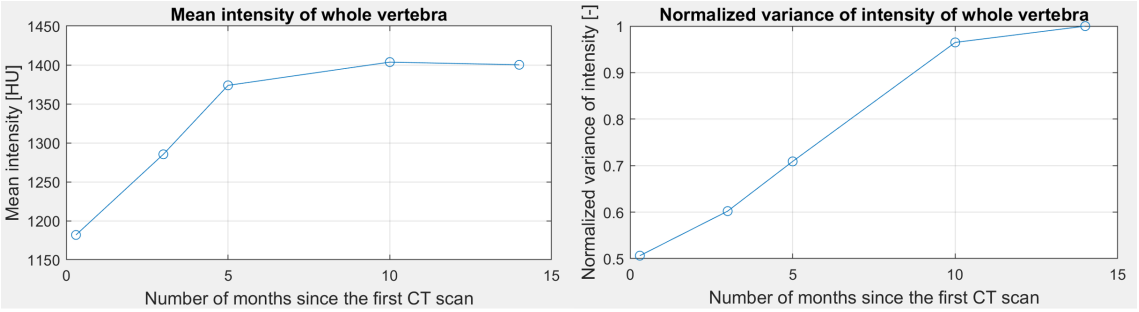

Figure 4: Pseudo linear graph of mean intensity from whole fifth vertebra body (left) and normalized variance of the intensity of this vertebra (right).

4 CONCLUSION

This contribution deals with the design of the methodology for the time-development analysis of vertebral tumors in CT data. The basic challenges for lesions analysis are described. In this paper has been designed a methodology of evaluation of time-development, which was divided into the analysis of compact tumors and the analysis of whole vertebral bodies. For each of both analysis methods, the potential relevant features have been suggested. A manually segmented annotation of lytic tumors was created and examples of statistical features were calculated and plotted by time-graphs.

REFERENCES

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