Estimation of Breast Anatomical Descriptors from Mastectomy CT Images

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ABSTRACT

Breast cancer is one of the most prevalent cancers in the world. It is the second leading cancer in terms of death rate. Early detection and diagnosis is the key for decreasing the mortality rate. Because of the advancements in breast imaging systems and screening, the mortality rate has been reduced. However, the breast imaging systems have not been completely successful in diagnosing cancer accurately. Development of efficient imaging systems is still an ongoing research and the improvement is being made continuously. The validation of novel imaging systems requires clinical trials on large number of human subjects, limited by the duration, cost, and risk of repeated use of ionizing radiation; in objectively assessing image quality and radiation dose. Virtual clinical trials (VCTs) have been introduced as alternative pre-clinical evaluation, based upon the modeling of breast anatomy (using software phantoms), image acquisition, image compression, and statistical analysis. The MEDIS Lab at Delaware State University and the X-Ray Physics Lab at the University of Pennsylvania have jointly been working on the development of VCT tools. Anthropomorphic breast phantoms

based on the simulation of breast anatomical structures, must be realistic enough in order to build an efficient VCT. Mathematical modeling of the phantoms provides tremendous flexibility where the user can control the simulation of structures such as adipose tissue compartments, fibroglandular tissues, Cooper's ligaments and skin. However, in order to approach the realism of clinical data, phantom parameters must be carefully selected.

For this work, we have analyzed anonymized CT images of a normal anatomy from a mastectomy specimen, previously acquired at the University of Pennsylvania. We estimated the anatomical descriptors in the breast from the CT image data. Through the segmentation of adipose compartments from the CT images, we determined the distribution of adipose compartment volumes. Fitting ellipsoids to the adipose compartment volumes, we characterized the phantoms by calculating the sizes, shapes, and orientations. In a separate process, we generated anthropomorphic breast phantoms using a previously developed octree based recursive partitioning algorithm. A set of simulation parameters was controlled by the user for defining voxel size, number of compartments, percentage of dense tissue, shape and orientation of the compartments, etc. After determining the adipose compartment volume distribution in a set of 1,440 software-generated phantoms, we measured the distances of phantom size distribution in CT and the phantoms. Using different distance measures, we determined the phantoms closest to the segmented CT images in size distributional sense. The distance measurement results were used in the multilevel multifactor analysis of variance (ANOVAN), to estimate the effect of simulation parameters on the distribution of compartment volumes.

The most useful contribution of this work is an efficient method for the selection of simulation parameters, for the realistic simulation of breast anatomical properties, namely the distribution of adipose compartment volumes. The method could be extended to the optimization of compartment orientation and shapes, and potentially to other properties of simulated breast anatomy. The proposed work can be utilized in a variety of future endeavors. *e.g.*, the realistic breast phantoms in VCTs can be used to accelerate specific task-based validation of new imaging systems. Eventually, the improved features of any validated imaging device can benefit breast cancer patients by improvement in the early detection and diagnosis.