Urethra Identification in CT Images Based on 3-D Model Construction

Objective: Prostate IMRT treatment planning requires dose constraints on urethra to minimize acute urinary morbidity under dose escalation or followed by seed implant brachytherapy. However, it is difficult to identify it in CT image since its density is very close to those of the surrounding tissues. Here, we present a novel 3-D model of urethra in voxel space based on anatomy data and mechanical consideration.

Materials and Methods: A urethra model is constructed with a 512x512x50 grid. The first part is embedded in prostate gland and the second part is described as a free suspended string. Since CT images are acquired with the patient lying prone, prostate gland will descend anteriorly due to gravity, resulting in the first part of the urethra model being slightly convex. Assuming that the tissues outside the prostate are uniform, the second part of the urethra will suspend like a string with two ends fixed. From mechanics, the string follows equation

$$C_1 + C_2 \cosh(C_3 + C_4 x)$$

where C_1, C_2, C_3, and C_4 are constants determined by the known anatomy data, like prostate size and urethra length, in this voxel space. Considering the statistical uncertainty for each individual patient and this model's simplification, we set a 10 pixel tolerance as the urethra diameter.

Results: This model urethra intercepts each slice of CT images with an area that varies in size and location. These intercepted areas will be used as the urethra contours for treatment planning. The urethra volume segmented this way is more accurate than the current manual delineation by visual observation only.

Conclusions: The method developed here may be a feasible approach to those organs that human eyes can hardly distinguish from their background in CT images such as the rectum. Its utility in IMRT treatment planning needs to be further explored.