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Supplemental material

Quantification of tumor response of cystic vestibular schwannoma to Gamma Knife radiosurgery by using artificial intelligence

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Supplemental Methods: **Process of fuzzy C-means clustering**

The function of fuzzy clustering is defined as follows:

$$\sum_{j=1}^{N} u_{ij} = 1, \quad i = 1, 2, \ldots, D$$

where N is the number of clusters, which equals to 2 in our study (cystic and solid components); D is the total number of voxels in the tumor ROI; u_{ij} is the membership grade of the ith voxel in the tumor ROI in the jth cluster.

The objective function is defined as follows:

$$J_m = \sum_{i=1}^{D} \sum_{j=1}^{N} u_{ij}^{m} \left\| x_i - c_j \right\|^2$$

where J_m is the objective function; m is the fuzzy partition matrix exponent that controls the degree of fuzzy overlap and was set at 2 in our study (default setting); u_{ij} is the degree of membership of data point x_i in the jth cluster; x_i is the ith voxel in the tumor ROI; c_j is the center of the jth cluster and was calculated as follows:

$$c_j = \frac{\sum_{i=1}^{D} u_{ij}^{m} x_i}{\sum_{i=1}^{D} u_{ij}^{m}}$$

Fuzzy clustering was performed as follows:

Step (1) u_{ij} was randomly initialized

Step (2) c_j was calculated as described above.

Step (3) u_{ij} was renewed according to the following formula:

$$u_{ij} = \frac{1}{\sum_{k=1}^{N} \left(\frac{\left\| x_i - c_j \right\|}{\left\| x_i - c_k \right\|} \right)^{\frac{2}{m-1}}}$$

Step (4) The objective function J_m was calculated as described above.

Step (5) Steps (2) to (4) were repeated iteratively until self-improvement J_m was smaller than a specified threshold or until a specific number of iterations has been performed. In our study, the minimum improvement was set at $1e^{-5}$ and the maximum number of iterations was set at 100 (both were default settings).

Step (6) Each voxel in tumor ROI was classified as cystic or solid component based on the final u_{ij}.