Improved Accuracy in Volume Measurement of Acoustic Neuroma Using Bayesian Classifiers

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Introduction: The accuracy of tumor volume and growth rate measurements affects both acoustic neuroma research and clinical care decisions. Segmentation and volume estimation from MR images are complicated by partial volume averaging effects that have the potential to introduce errors proportionately greatest in small tumors. We have developed a fast technique of volume measurement incorporating partial volume effects and requiring a single imaging sequence. The precision of this technique is compared to conventional methods of tumor size measurement currently available to the clinical community at large.

Methods: Post-contrast T1 weighted FFE volume MR scans were acquired from 48 acoustic neuroma (AN) patients, and a computer phantom was designed to mimic AN partial volume and noise characteristics. The phantom is a digital image that contains intensity profiles similar to average acoustic neuroma, brain, and csf tissue. The edges between tissues linearly shift from one tissue intensity distribution to another within error.

An algorithm was developed for automated estimation of tumor size using partial volume classification. A sample volume is placed around the tumor and a pixel intensity histogram extracted (fig 1). This histogram is fitted to a pixel intensity distribution model incorporating partial volume effects. Bayesian statistics allows for extraction of a partial volume corrected estimate of tumor volume. The whole process takes approximately 2 minutes for a full tumor volume and requires no expert supervision.

This technique is compared to a "gold standard" measurement of tumor volume derived by manual segmentation of the tumor from magnified image slices. Maximal tumor diameter, perimeter length, estimated elliptical area, and directly measured cross-sectional area were determined for the image slice demonstrating the largest tumor area. Automatic volume measurements using thresholded intensity seeding were also taken for comparison.

Results: The correlation, $R^2$, with gold standard volume measures was greatest for the partial volume algorithm (95% confidence interval is 0.923 to 0.937), area (0.645 to 0.872), elliptical area (0.755 to 0.916), diameter (0.491 to 0.803), and perimeter (0.436 to 0.774). Phantom studies on partial volume regions ranging from 12-80 pixels show the algorithm to converge to within 1-2 pixels of the true pixel volume on the entire range of phantoms. The accuracy of the volume measurements over this range of phantoms was 5% (cf. 13% for repeated manual area measurements). Initial studies on tumor growth indicate we can show stability and growth within the 5% accuracy of the single volume measurements. Figure 2 shows two probability maps taken from scans 11 months apart. The two shades of highlighted voxels show changes in the co-registered images of over ±25% voxel volume, while the overall volume remains the same within accuracy. The voxelated probability difference is therefore due to a sub-voxel shift in the image, not growth.

Conclusions: A Bayesian statistical classifier based on signal intensity can rapidly provide measures of tumor volume which are reproducible and offer better accuracy than current time consuming gold standard techniques. This method should also increase the accuracy of growth rate measurements for intra-canicular acoustic neuromas, in addition to other pathologies and anatomies. An extension to the algorithm is being developed to accommodate inhomogeneous tumors with features such as necrosis and cysts. Voxels enclosed within a tumor boundary are identified as tumor, and therefore contribute to tumor volume measurement in the algorithm. The basic Bayesian tissue classification algorithm is also presently being used for segmentation of brain tissue and volume measurement of the inner ear. It is available in the open source image analysis development package, TINA.

References: