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Analysis of interstitial cells of Cajal networks and functions in the gastrointestinal tract

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Background

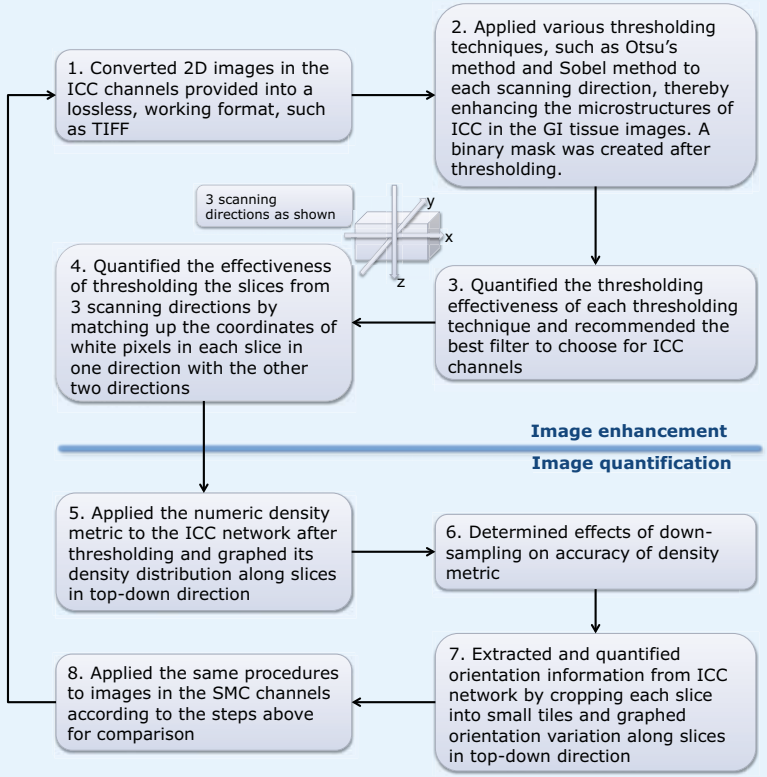
Gastrointestinal (GI) electrical activity is one of the vital factors that underpin digestive functions. Normal GI motility results from coordinated contractions of smooth muscle cells, which are regulated by an electrical activity – slow waves. In particular, the interstitial cells of Cajal (ICC) which act as pacemaker cells in the GI tract, evoke slow waves in much of the GI tract, including the surrounding smooth muscle cells (SMC). Therefore, understanding the variations in the structures of ICC would help our analysis of the functions of the GI tract.

Aim

The main aim of the project was to enhance and quantitatively extract micro-structural information of GI tissue. The micro-structural information of ICC and SMC were quantified by numerical metrics, such as density and orientation information. These quantitative information could then be adapted to compare with the diseased tissues and to predict the functional significance of ICC depletion in patients suffering from GI motility diseases.

Method

The project started with images with 2PE/multiphoton (Ex950), z-stack 300 microns obtained via immunofluorescence microscopy which contains 2 channels, i.e. ICC and SMC structures. The results were obtained using MATLAB and ImageJ and the process of the project could be referred to the flowchart below.



Results

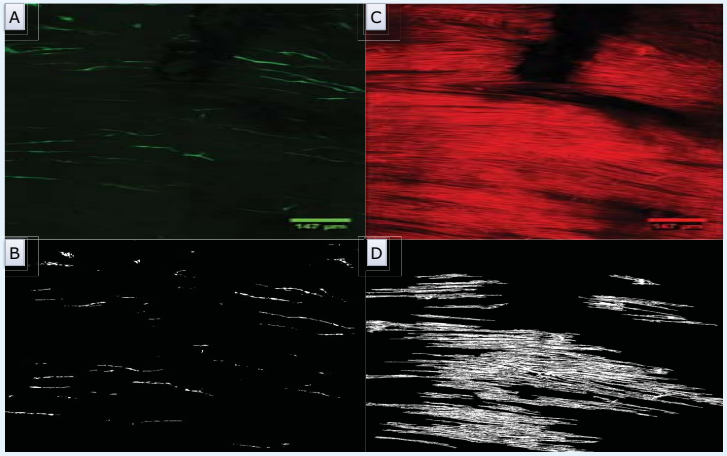


Fig.1.Original and processed ICC network (A) Original ICC image slice from top-down direction; (B) Binary ICC image after thresholding by filters using Sobel method, where thresholding effectiveness was 0.032±0.012; (C) Original SMC image slice from top-down direction; (D) Binary SMC image after thresholding by filters using Otsu's method, where thresholding effectiveness was 0.669±0.022.

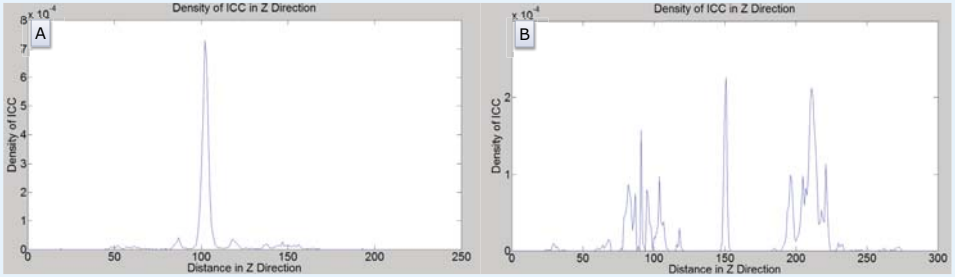


Fig.2.Density distribution of ICC channels along slices in top-down direction (A) Density metric applied on images with 2PE/multiphoton (Ex950), z-stack 300 microns; (B) Density metric applied on images with 1PE (Ex488), z-stack 200 microns.

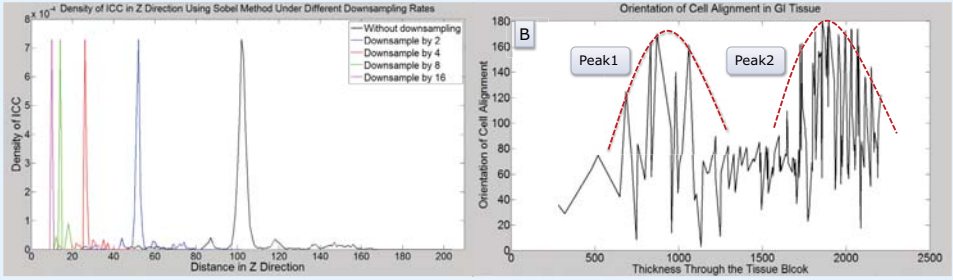


Fig.3. (A) Density of ICC channels along slices in top-down direction under different downsampling rate; (B) Orientation of ICC alignment on slice #45 from images with 2PE/multiphoton (Ex950), z-stack 300 microns.

Conclusions

- Significant peaks in the density graph of ICC channels indicated an intense distribution of ICC in the middle of the GI tissue provided.
- The bi-peak appearance of orientation graph indicated a shift in the orientation of ICC network through the thickness of the GI wall.
- Microstructures of GI tissue images obtained by immunofluorescence microscopy were enhanced and extracted quantitatively via developed image processing techniques in this project. Future improvements of masking techniques are required for better precision of quantitative comparisons of microstructures between healthy and damaged GI tissues.

Acknowledgement

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