# Pancreatic Islets Volume Estimation from Single Images

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**Abstract**

Pancreatic islets (PI) grafts volume is routinely estimated using 2D light microscopy images assuming spherical shapes of the islets. Our goal is to improve bias and precision of estimator of PI volume by incorporating the shape of the segmented PI images. We calibrated the estimator using 3D images of PI from lightsheet microscope and simulated 2D images of PI in stable positions on the horizontal plane with the probabilities of the projections.

We processed 3D images of PI by minimization of the total variation functional with $\mathbf{L}^1$ data term before thresholding. Such filtering outperforms mathematical morphology opening by preserving small salient details. The volume of the binary image was measured and second moments tensor was used for shape analysis. Parameter of regularity was calculated as ratio of the volume to the volume of the equivalent ellipsoid. Highly irregular islets (regularity less than 0.75, cca 3 percent of islets) were excluded from further analysis. Compactness and oblateness were calculated from ratios of the ellipsoid semiaxes lengths. The shape parameters of the real islets were obviously different from the parameters of sphere or spheroids.

Stable positions of the islet were calculated using the radial support function of 3D set $A$

$$s\left(v\right) = \max_{x \in A} v \cdot \left(x - c\right)$$

where $c$ is centre of mass and $v$ a unit vector. Stable positions of the islet on horizontal plane correspond to the local minima of the support function. The support function was evaluated on grid obtained by dense triangulation of the sphere. 2D images were obtained by projection of the set in directions of the local minima of discrete support function. We assumed that the probability of a given stable position is proportional to the area of the zone of attraction of corresponding local minimum. The zones of attraction were calculated by watershed transform of the support function.

The 2D contour of the islet projection was extruded into 3D by union of balls which equatorial circles are inside the contour $C$. The height of the extrusion $h$ as the function of 2D point $x$ in $A$ is

$$h\left(x\right) = \max_{s} \sqrt{d\left(s, C^c\right)^2 - d\left(x, s\right)^2}$$

where $d$ is Euclidean distance, $C^c$ is the exterior of the contour and $s$ is the centre of the equatorial circle. The extrusion was implemented efficiently as opening of indicator function of the contour by quadratic structuring function (QSF). The height of spherical extrusion model was adjusted using function

$$f_{\beta,\delta}\left(y\right) = \beta\,\delta\,\ln\left(\frac{y}{\delta} + 1\right)$$

with parameters $\beta$ and $\delta$ that were fitted by nonlinear regression of real volumes. Volume of the model is

$$V_{mod}^{\beta,\delta}\left(C\right) = 2 \int_C f_{\beta,\delta}\left(h\left(x\right)\right) dx$$

and the parameters were calculated by minimizing the sum of squared relative residuals weighted by the projection probabilities:

$$\beta, \delta = \arg\min_{\alpha,\gamma} \sum_{ij} p_{ij} \left( \frac{V_{mod}^{\alpha,\gamma}\left(C_{i,j}\right) - V\left(A_i\right)}{V\left(A_i\right)} \right)^2$$

The training set of 9434 simulated projections $C_{i,j}$ from 869 islets $A_i$ yielded the parameters $\beta = 1.035$ and $\delta = 188.65$ micrometers. The model was applied on test set of 9392 projections from the remaining 863 islets and relative bias -0.005 and mean relative squared error 0.12 were obtained.

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