PItcHPERFECT: Primary Intracerebral Hemorrhage Prediction Employing Regression and Features Extracted from CT

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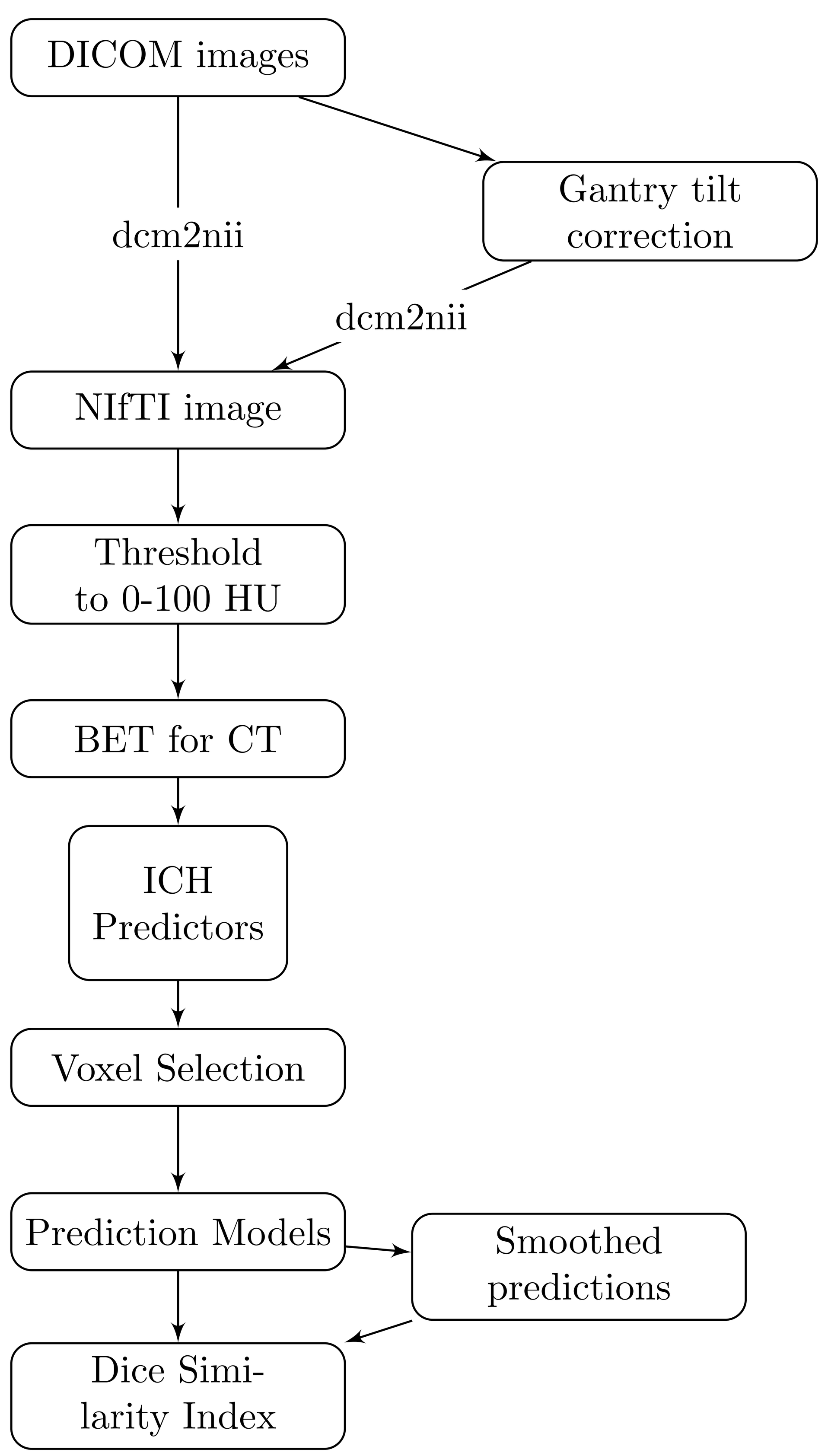
Goals and Methods

Compare gold standard, manual segmentation of intracerebral hemorrhage (ICH) in head CT images to an automated method using:

- Voxel selection methods
- Logistic regression modeling
- Smoothing

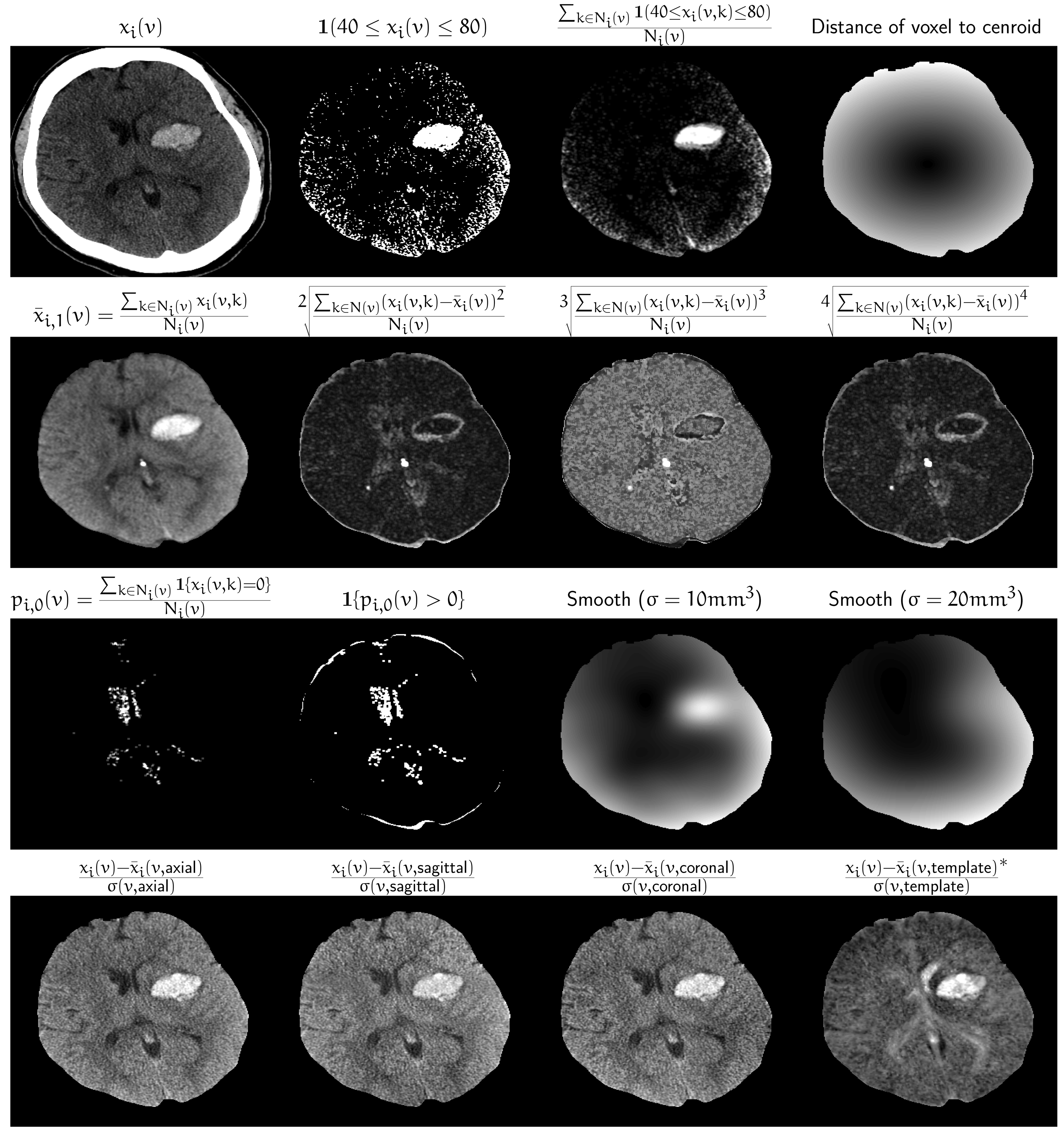
Data were from 112 patients with intracranial hemorrhage from 26 MISTIE [3] stroke trial centers. Mean (SD) age: 60.7 (11.2) years old, 68.8% male.

Image Processing Pipeline



Imaging Predictors

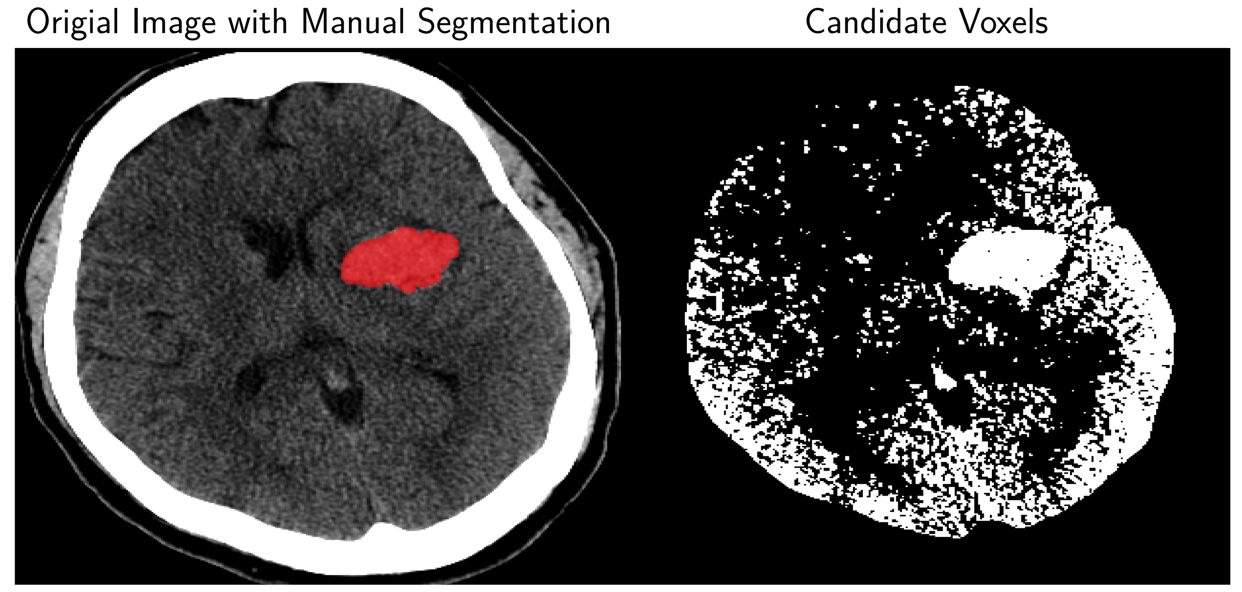
Notation: Let i denote subject/scan, v: voxel, $\mathbf{1}$: indicator function, $N(v)$: neighborhood for voxel v, and $x(v)$: intensity for voxel v in Hounsfield Units (HU).



*This image is similar to those created in Gillebert, Humphreys, and Mantini [2].

Voxel Selection

Origial Image with Manual Segmentation | Candidate Voxels



We estimated the 0.5% and 99.5% quantiles for the distributions of the voxel intensity, and standardized voxel score along the axial and sagittal planes. Only voxels within all of these values were categorized as candidate voxels. All other voxels are set to $Y_i(v) = 0$.

Estimating Voxel-wise ICH Probability

$Y_i(v)$ is the indicator manual segmentation classified a voxel as ICH. We fit the following model using 10 scans and derived a cutoff for $\hat{P}(Y_i(v) = 1)$:

$$\text{logit}(P(Y_i(v) = 1)) = \alpha_0 + X(v)\beta$$

Measuring Model Performance

We validated the model on 51 validation scans: for each scan, we calculated a 2×2 table compared to the manual segmentaion:

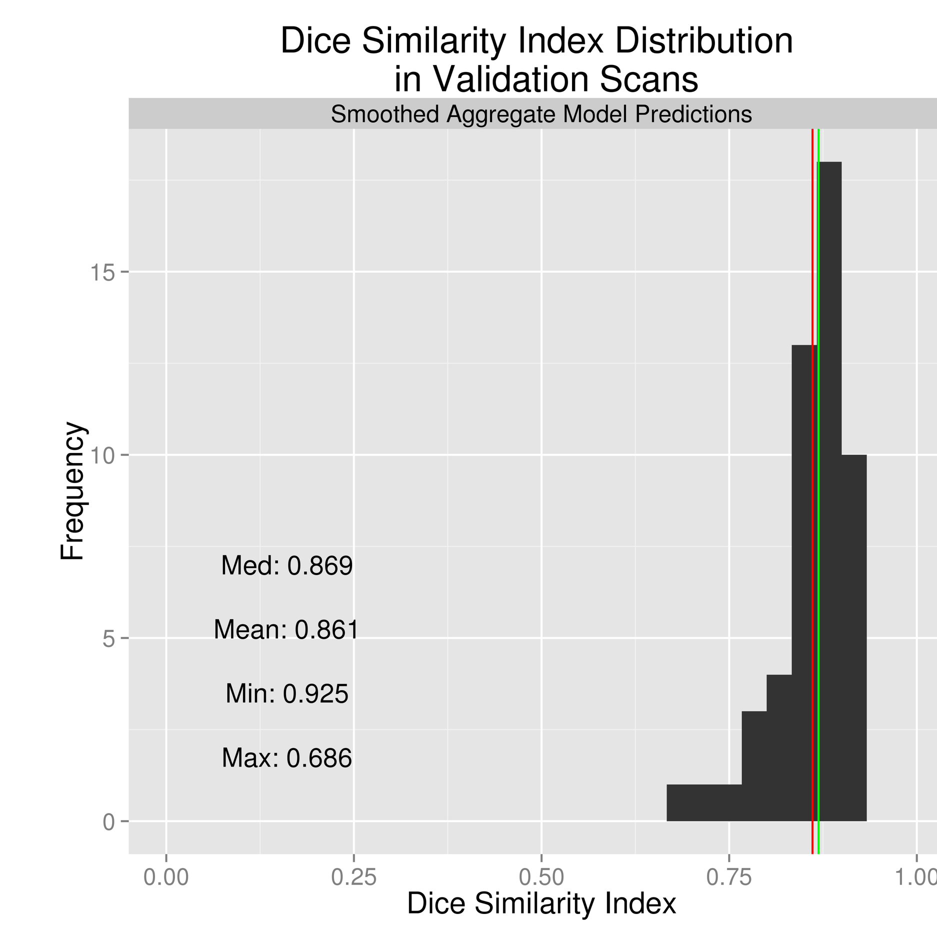
		Manual segmentation	
		0	1
Model Prediction	0	TN	FN
	1	FP	TP

We used the Dice Similarity Index (DSI) [1] to estimate performance:

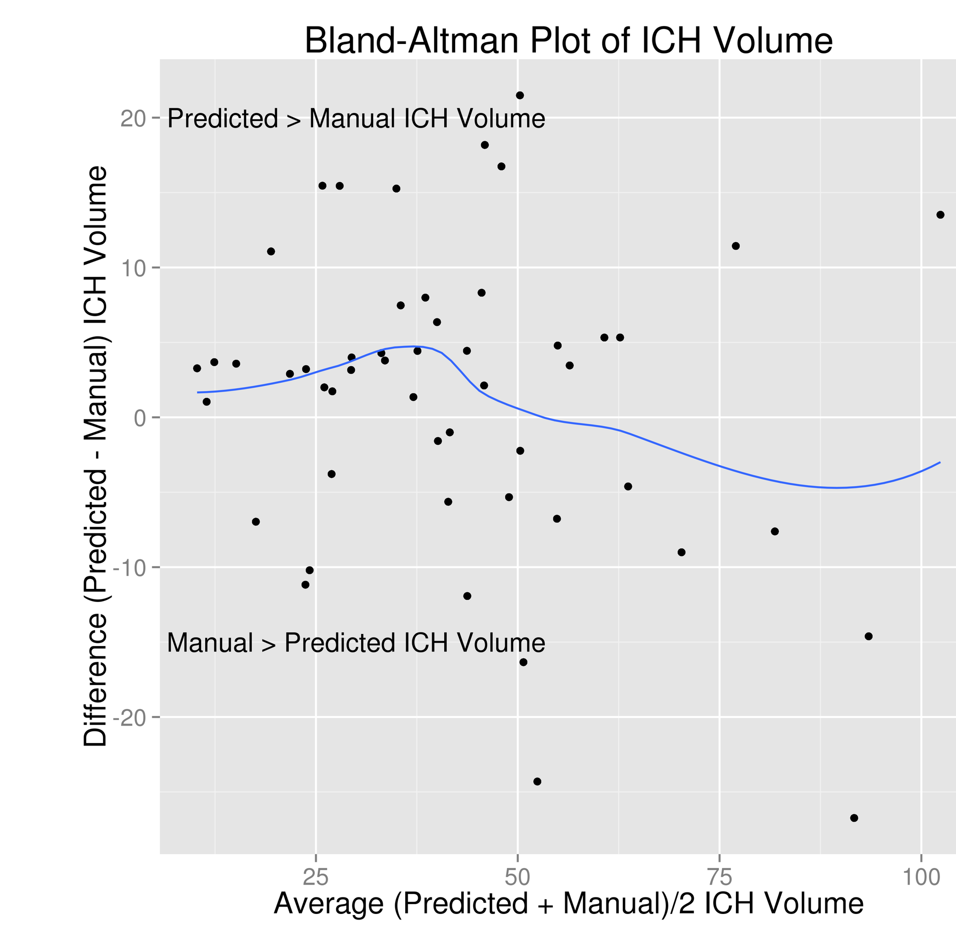
$$\text{DSI} = \frac{2 \times \text{TP}}{2 \times \text{TP} + \text{FN} + \text{FP}}$$

where TN/TP refer to true negative/positive voxels, and FN/FP: false negative/positive voxels.

Model Results

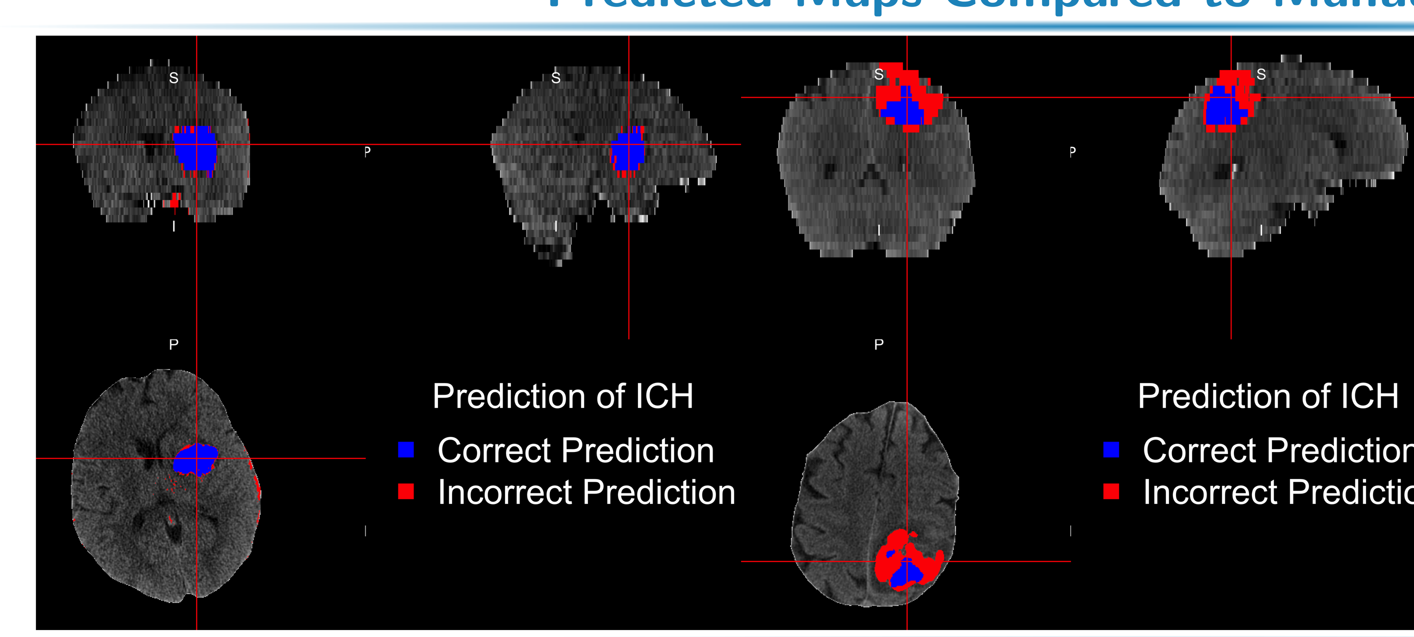


Distribution of Dice Similarity Index (DSI) for 51 validation scans. The group had a mean (red line) DSI of 0.861 (SD = 0.052), median 0.869 (green), and 0.686 minimum DSI.



Bland-Altman plot of predicted ICH volume vs. manual ICH volume for validation scans. Although we see some mis-estimation of volume, it does not appear strongly related to true ICH volume.

Predicted Maps Compared to Manual Segmentation



Example of High DSI (left, DSI = 0.90) and Lower DSI (right, DSI = 0.686). In the left panel, the predicted ICH mask has a high overlap between the manual segmentation, with some incorrect predictions towards the surface of the cortex. This panel represents case of predictors shown. The right panel, however, depicts a large area of incorrect prediction, largely towards the surface of the brain. This indicates some predictors (such as distance from the centroid) may negatively affect prediction in validation scans unlike the training data.

Conclusions

These results indicate that the approach described can achieve accurate segmentation of ICH in a population of patients from a variety of imaging centers. Improvements can be made on the method, as deleting the distance to centroid would likely increase the accuracy of the case with low DSI. This method extends to using other covariates to predict ICH.

References

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[2] Céline R. Gillebert, Glyn W. Humphreys, and Dante Mantini. "Automated delineation of stroke lesions using brain CT images". In: *NeuroImage: Clinical* 4 (2014), pp. 540–548.
[3] T. Morgan et al. "Preliminary findings of the minimally-invasive surgery plus rtPA for intracerebral hemorrhage evacuation (MISTIE) clinical trial". In: *Cerebral Hemorrhage*. Springer, 2008, pp. 147–151.

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