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Theme: Clinical Gastroenterology

Automated Multiparametric Pancreatic Magnetic Resonance Images Segmentation and Fat Quantification Using TransUNet

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Background:

Pancreatic steatosis is crucial in developing pancreatic diseases, especially Pancreatic Ductal Adenocarcinoma (PDAC). Understanding its progression is key to early PDAC diagnosis. Traditional methods for measuring pancreatic fat distribution are labour-intensive and often inaccurate due to natural variability. This study proposes using the TransUNet architecture for automated 3D MRI pancreas segmentation and PDFF quantification to study pancreatic steatosis evolution in diseases like PDAC.

Methods:

The study involved 140 adults who underwent chemical shift encoded MRI to diagnose steatotic liver disease after fatty liver was diagnosed on ultrasound. Patients were divided into a training cohort (n=120) and a testing cohort (n=20), with one-fifth of the training group used for validation. Five TransUNet models using single and multi-contrast inputs, as well as the nnUNet and UNet models, were trained. Segmentation performance was evaluated using the Dice Similarity Coefficient (DSC). Figure 1 shows the overall workflow pipeline. The best model was applied to the testing cohort to generate 3D pancreatic segmentations and compute the proton density fat fraction (PDFF) using water and fat images in each voxel within the predicted masks by the formula shown in figure 1c. The automatically computed PDFF was compared to the manually calculated PDFF from the entire pancreatic tissue across all slices.

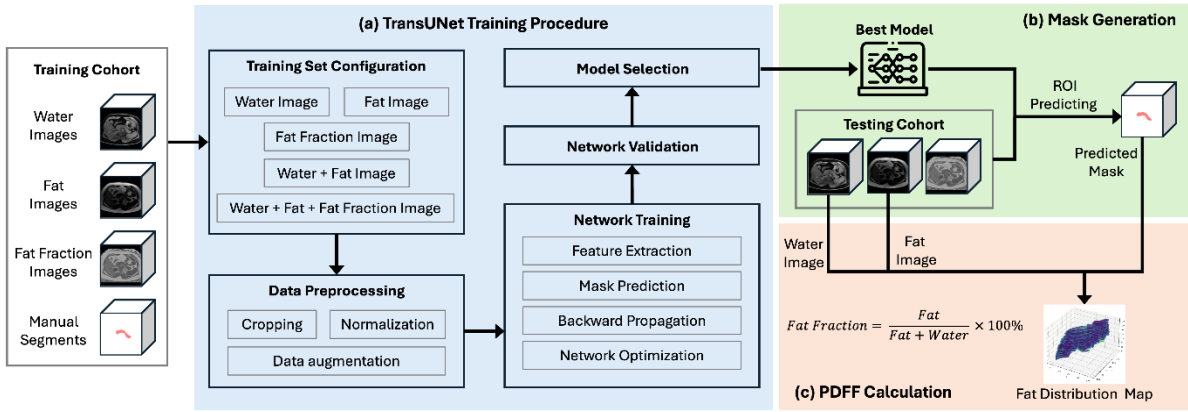

Figure 1. The pipeline of our work: model training, model validation, 3D mask prediction, and PDFF calculation

Results:

TransUNet model using water and fat input achieved the highest average DSC of 83.83% as presented in figure 2. This DSC was higher than that of nnUNet and UNet models by 1.2% and 12.6%, respectively. Figure 3 shows results from the three models. The automatically computed 3D PDFF from each voxel correlated strongly with the manually calculated PDFF from the entire pancreas (r=0.877, 95% CI: 0.695-0.954, p<0.001) and showed no proportional bias (p=0.977), providing a visual spatial distribution of fat deposition as shown in figure 4.

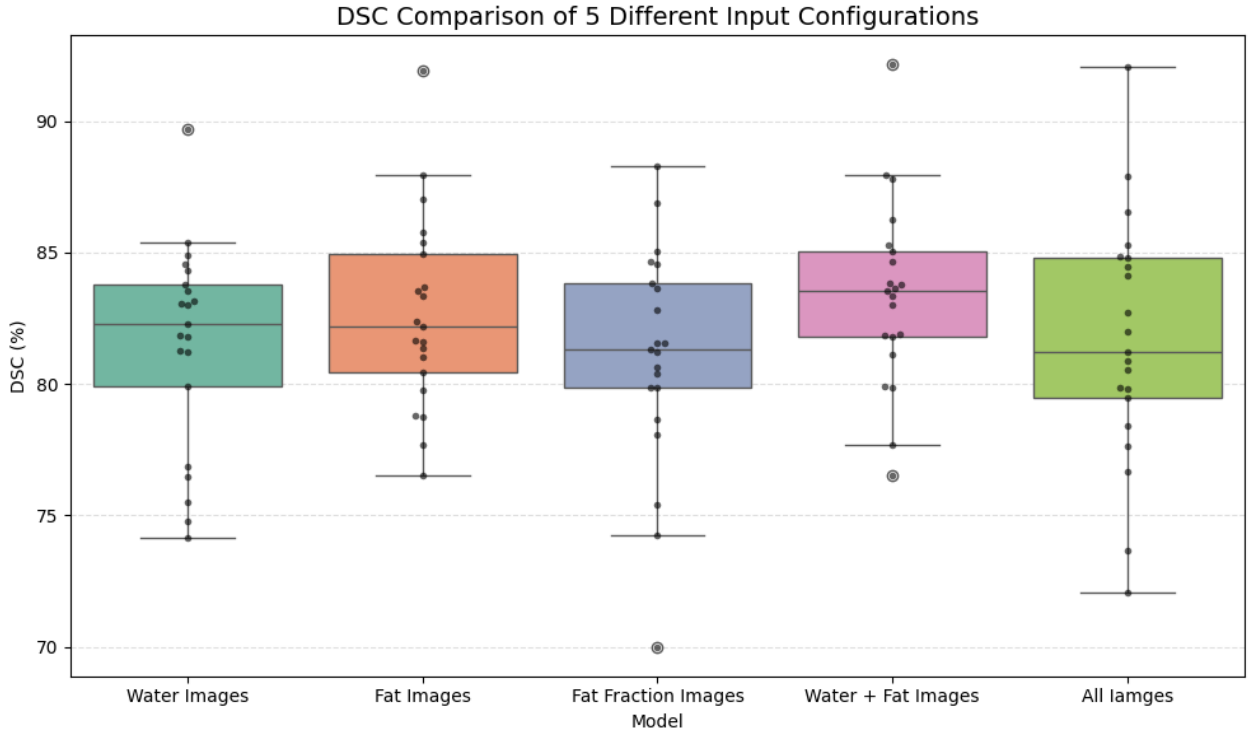

Figure 2. The Kruskal-Wallis H test segmentation results of five models

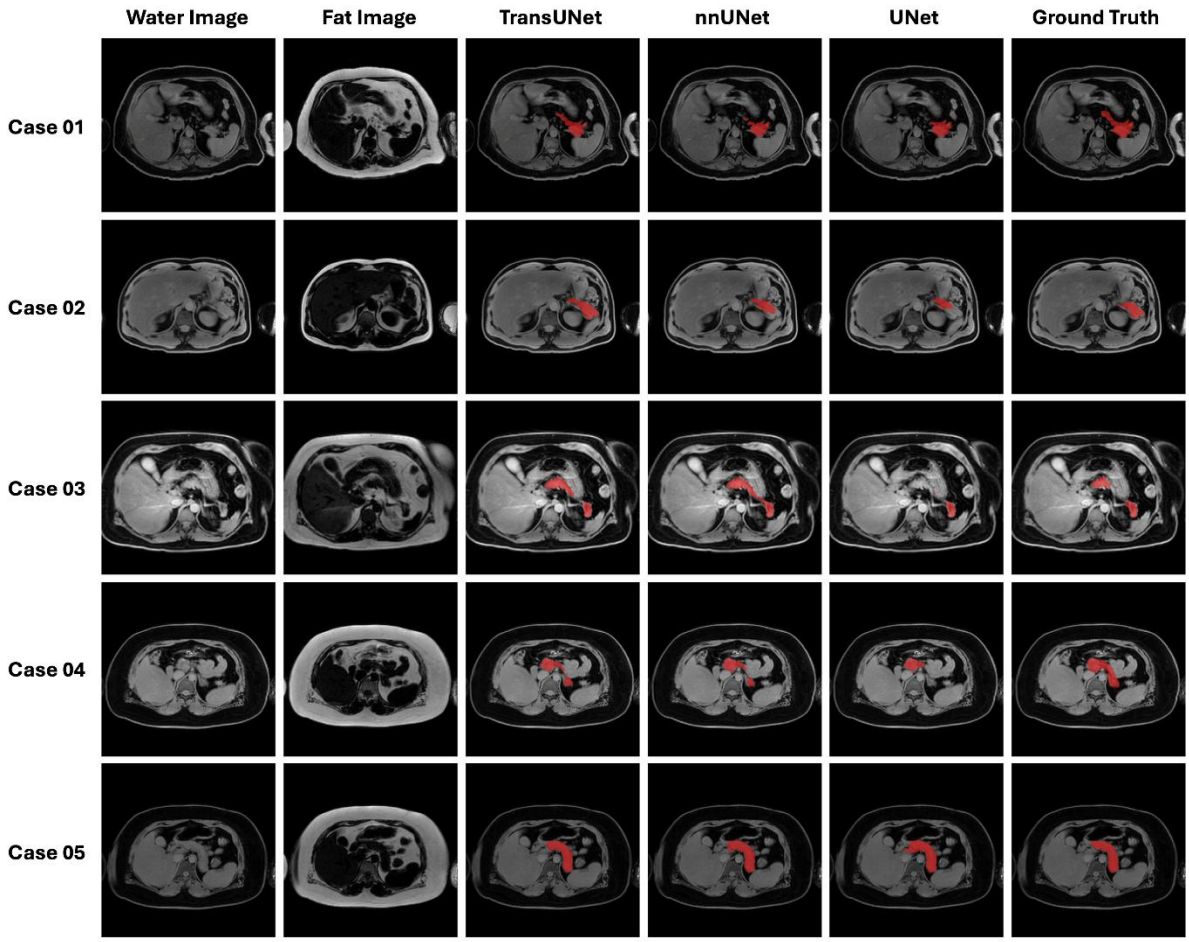

Figure 3. Shows representative TransUNet segmentation slices and a visual comparison with nnUNet and UNet, where nnUNet uses the same image input and UNet uses only water images

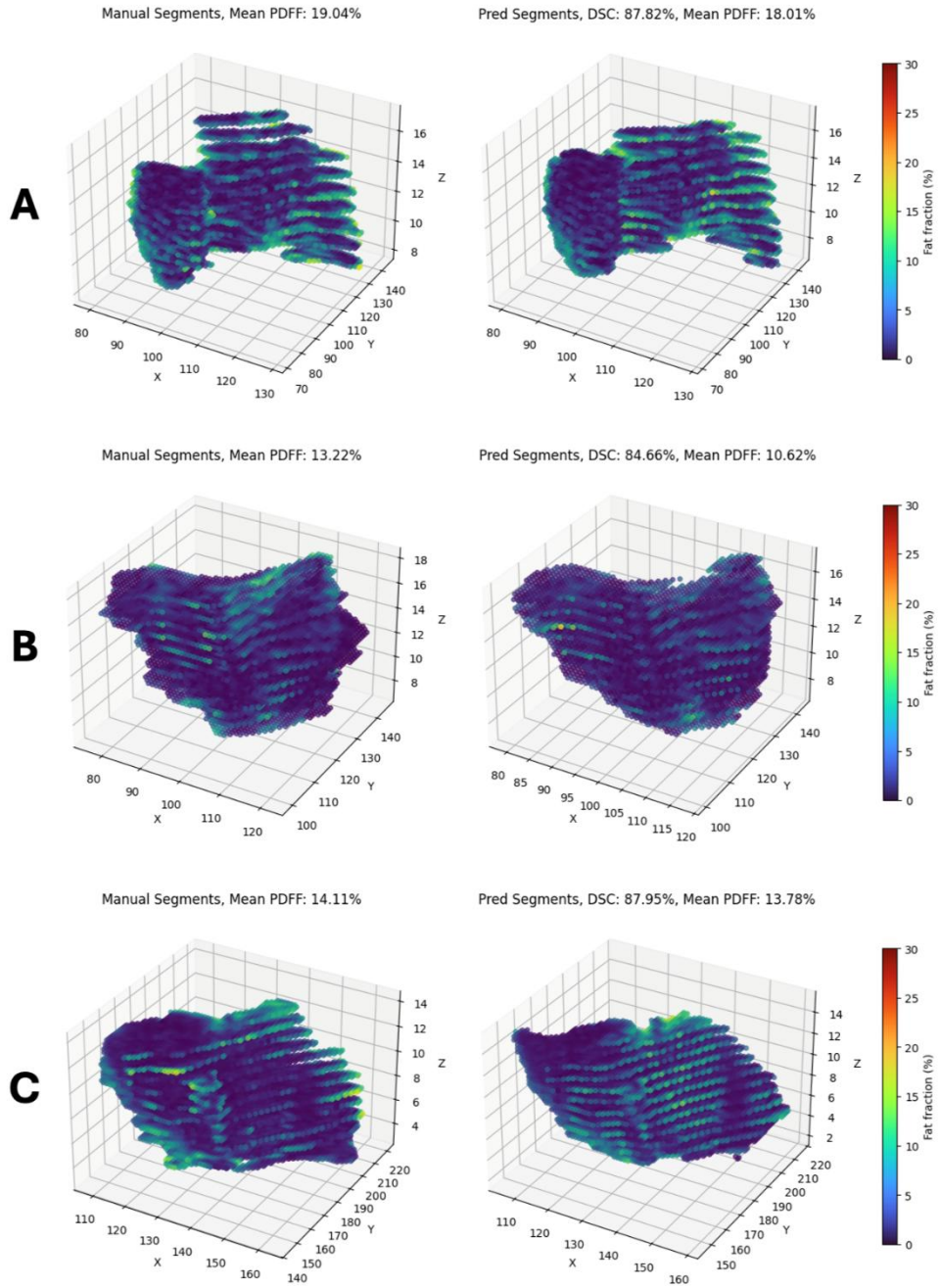

Figure 4

Shows the spatial distribution of fat deposition and compares PDFF calculated from predicted masks with manual segments

Conclusions:

The TransUNet architecture shows promise for pancreatic segmentation and automated 3D PDFF computation, enabling precise visualization of pancreatic fat distribution. This reliable and efficient method enhances the understanding and diagnosis of pancreatic steatosis, aiding in studying its progression, which could be crucial for early PDAC diagnosis.