

Masatoshi Abe Self-Supervised Learning for Feature Extraction from Glomerular Images and Disease Classification with Minimal Annotations

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link: https://journals.lww.com/jasn/abstract/2025/03000/self_supervised_learning_for_feature_extraction.17.aspx

github: <https://github.com/abebe9849/kidneyDINO>

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Deep learning is known to be effective for the analysis of renal biopsy pathology images. However, the need for large amounts of labeled data to adequately train deep learning models, and the scarcity of such data, hinders the widespread application of deep learning in analyzing renal biopsy images.

We applied DINO (self-distillation with no labels), a self-supervised learning method, to 10,423 glomerulus images derived from PAS-stained slides of 384 patients who underwent renal biopsy at the Department of Nephrology, Osaka University Hospital. Visualization of feature maps generated by the DINO pre-trained model using Principal Component Analysis (PCA) revealed distinct clusters corresponding to different glomerular components, confirming that different tissues strongly expressed distinct principal component elements (Fig. 1).

Subsequently, we trained models for classification tasks using features extracted from either the DINO pre-trained model or a conventional ImageNet pre-trained model, and evaluated their performance using metrics including the Area Under the Receiver Operating Characteristic curve (ROC-AUC). The classification tasks included: 1) a 4-class disease classification (Minimal Change Disease, Mesangial Proliferative Glomerulonephritis, Membranous Nephropathy, and Diabetic Nephropathy), and 2) classification of clinical parameters such as hypertension, proteinuria, and hematuria.

In the disease classification task, the DINO pre-trained model (ROC-AUC=0.934) outperformed the ImageNet pre-trained model (ROC-AUC=0.892). When labeled data was limited, the ROC-AUC of the ImageNet pre-trained model decreased to 0.763 [95% Confidence Interval: 0.724-0.802], whereas the DINO pre-trained model maintained superior performance (ROC-AUC=0.882 [95% CI: 0.862-0.903]). The DINO pre-trained model also achieved higher ROC-AUC values for the classification of several clinical parameters.

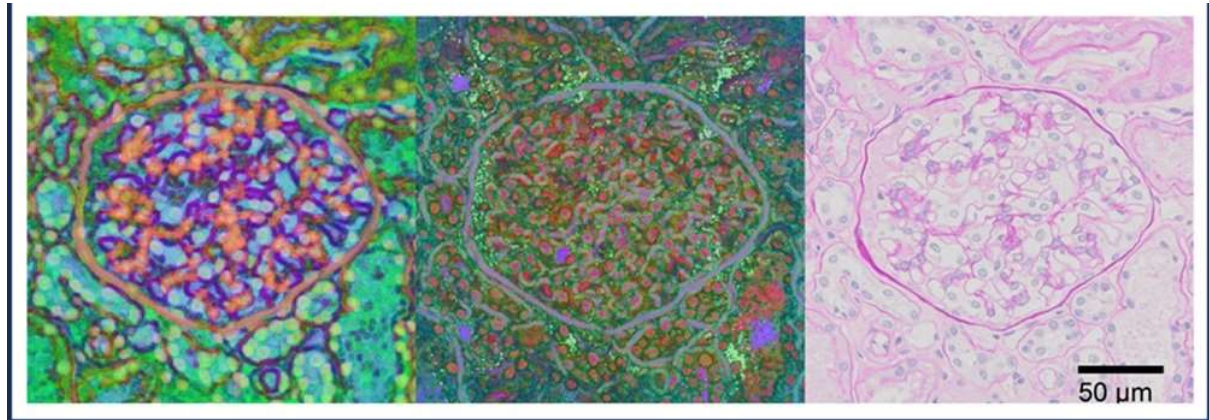


Figure1: Extracting histological features without human supervision using self-supervised learning. Color visualization of the principal components of image features extracted using self-supervised learning and conventional methods. With self-supervised learning, distinct colors correspond to different components of the renal glomerulus.