AI-based glomerulosclerosis scoring method for rodents using deep learning

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Background & Aim

Accurate assessment of glomerulosclerosis is essential for diagnosis, prognosis, and treatment of kidney diseases. Here, we developed a deep learning–based scoring method for glomerulosclerosis in PAS-stained kidney tissue.
Additionally, we implemented an AI-based compartmental analysis to evaluate how distinct kidney regions contribute to disease progression and treatment response, enabling deeper insight into spatial disease patterns.

Methods

For the glomerulosclerosis pipeline, a pretrained Grounded-SAM model was used for tissue detection, followed by the development of a glomerular segmentation model using a U-Net model. Image tiles centered on each glomerulus were extracted and used together with expert-assigned scores to train an Inception model predicting disease severity (GS0–GS4).

The compartment analysis was performed in Visiopharm where expert annotations of cortex, outer medulla, inner medulla, and papilla, were used to train a DeepLabv3+ model for automated segmentation.

Conclusion

- The glomerulosclerosis scoring method provides a fast, consistent automated assessment that reduces variability and improves kidney disease assessment.
- The kidney compartment analysis enables independent evaluation of kidney compartments for more detailed analysis of structure and pathology.

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1 AI-based detection of kidney whole-section and glomeruli

2 AI-assisted scoring of glomerulosclerosis severity

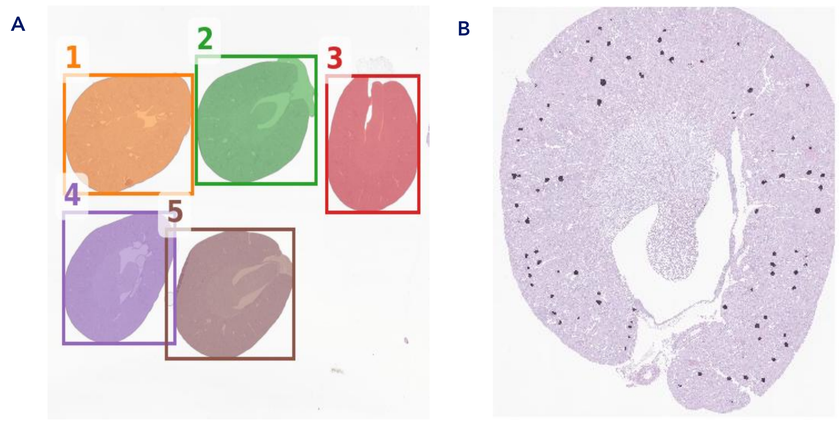

Figure 1. AI-assisted glomeruli detection in a CKD mouse model. (A) Example of the tissue detection output showing separated kidney sections and followed by **(B)** The detection of glomeruli done by the Unet model and used for further scoring analysis.

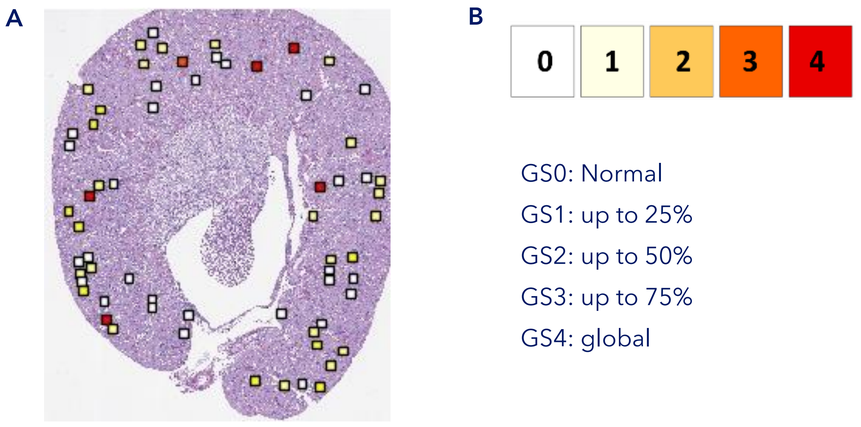

Figure 2. AI-assisted glomerulosclerosis scoring. (A) Example of the inception model detecting and scoring the glomeruli in the kidney. **(B)** Colored score system indicating the severity of glomerulosclerosis, with scoring ranging from 0 to 4.

3 Glomerulosclerosis severity in the AI-assessed scores

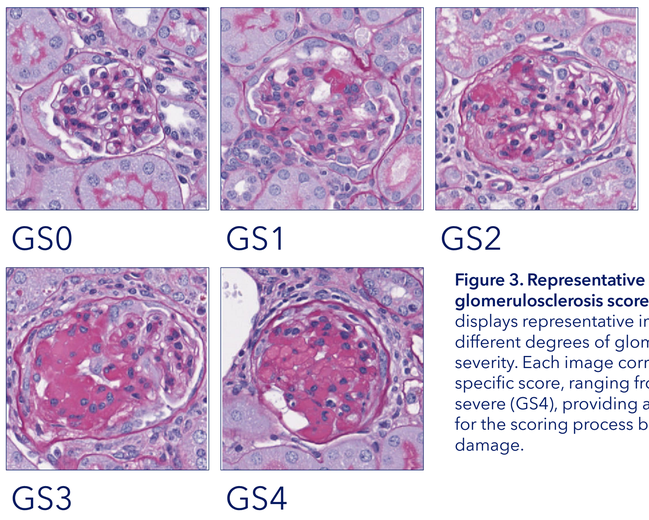

Figure 3. Representative images of glomerulosclerosis scores. This figure displays representative images illustrating different degrees of glomerulosclerosis severity. Each image corresponds to a specific score, ranging from mild (GS0) to severe (GS4), providing a visual reference for the scoring process based on glomerular damage.

4 AI-assisted glomerulosclerosis scoring in rodent CKD model

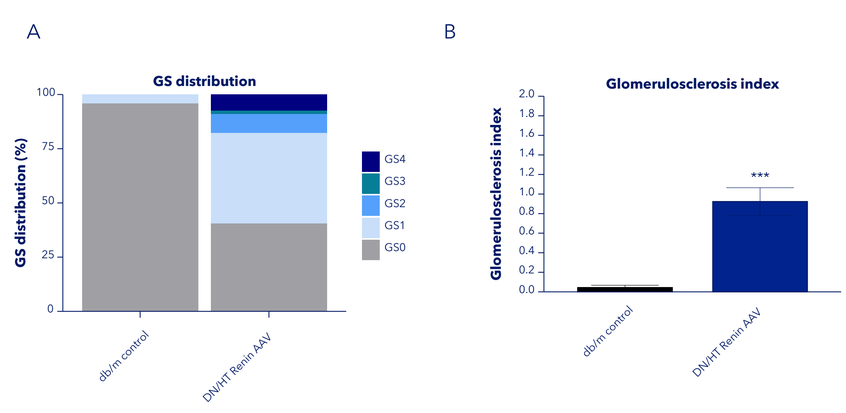

Figure 4. Comparative analysis of glomerulosclerosis for the ReninAAV Unx db/db model for CKD. (A) Distribution of glomerulosclerosis scores shows the distribution of glomerulosclerosis severity across the groups, categorized by scores from GS0 to GS4. **(B)** Glomerulosclerosis index represents the average burden of the disease across groups.

5 AI-assisted segmentation of kidney compartments

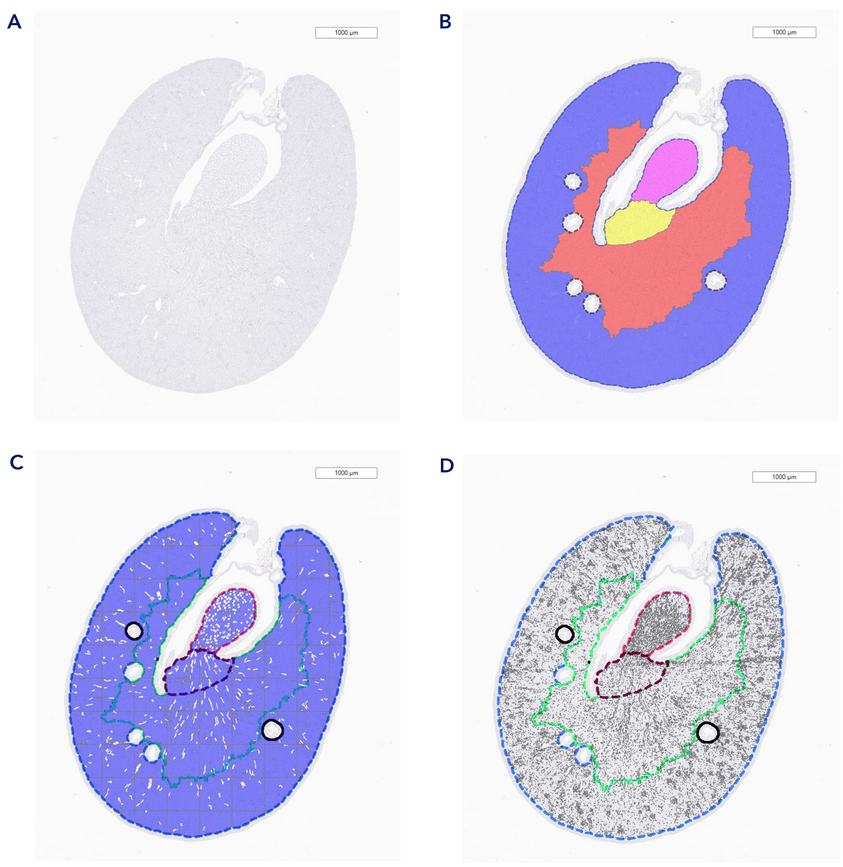

Figure 5. AI-Assisted kidney compartment analysis. (A) Mouse kidney without overlays. **(B)** Mouse kidney with AI-generated overlay showing cortex (blue), outer medulla (red), inner medulla (yellow) and papilla (purple). **(C)** The overlay is converted into compartments. **(D)** Maker analysis, where a specific is detected and highlighted.

6 Image analysis in kidney compartments shows changes in distribution

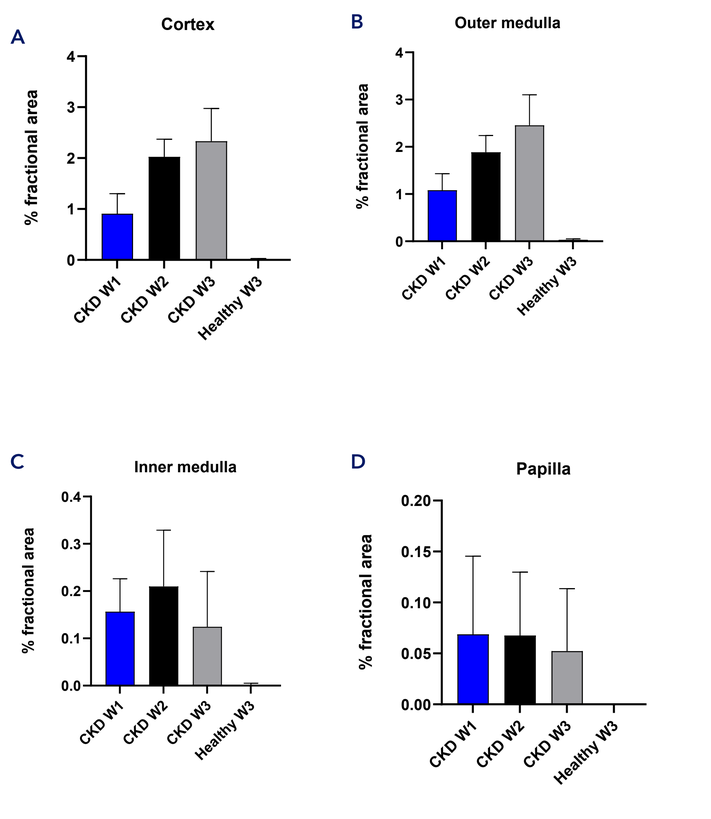

Figure 6. Kidney compartment analysis data. Analysis of the fractional area (%FA) stained with KIM1 in four different compartments. **(A)** Cortex **(B)** Outer medulla **(C)** Inner medulla **(D)** Papilla