60TH ANZSN CONGRESS

ANZSN

SHAPING AOTEAROA & AUSTRALIAN KIDNEY HEALTH:

PAST, PRESENT AND FUTURE

30 AUG – 3 SEP 2025

PERTH, WA

1 Alamartine et al 2011

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KidneyVision
Morphometric Analysis Tools For Kidney Biopsy

POWERED BY

Australian National University

Canberra Health Services

ACT Government

Centre for Personalised Medicine

Dialysis and Kidney Transplantation in Australia 2022 Summary

BEAT CKD
BETTER EVIDENCE AND TRANSLATION IN CHRONIC KIDNEY DISEASE

ANZ DATA
AUSTRALIA & NEW ZEALAND DIALYSIS & TRANSPLANT REGISTRY

3,311
people started dialysis

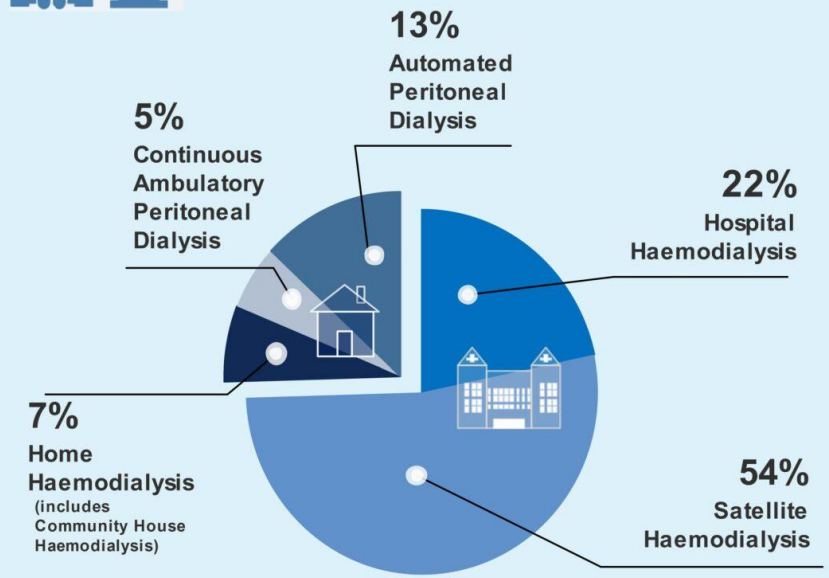
AND

938
people received a kidney transplant

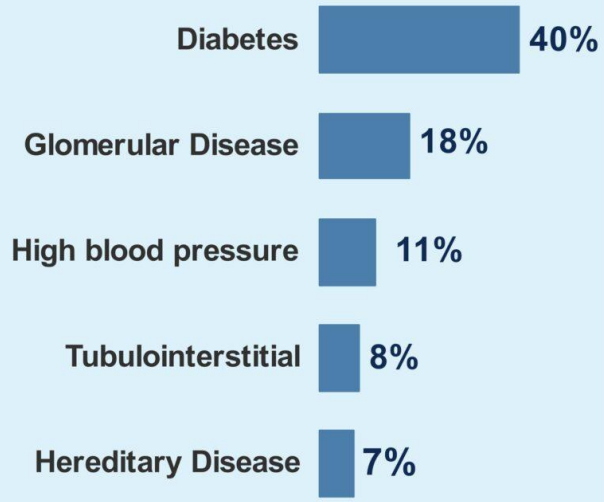
92
people received a kidney transplant before starting dialysis

13,507
Total number of people living with a kidney transplant

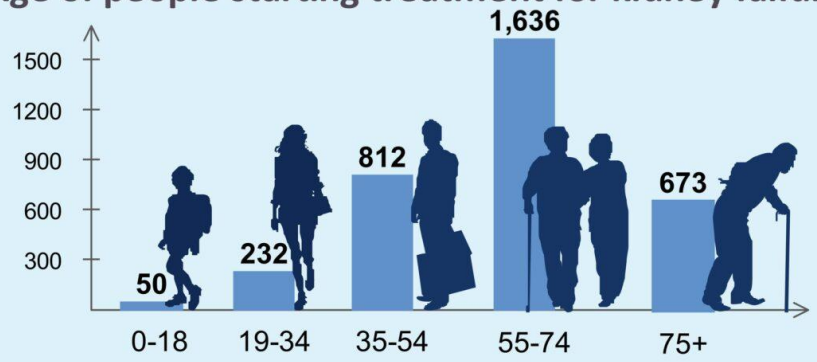
15,518
People in total receiving dialysis



Causes of kidney disease among people who received a transplant or started dialysis



Age of people starting treatment for kidney failure



Sources of kidney donation in 2022

Developed with members of the BEAT-CKD Consumer Advisory Board and National Kidney Consumer Council Research Network

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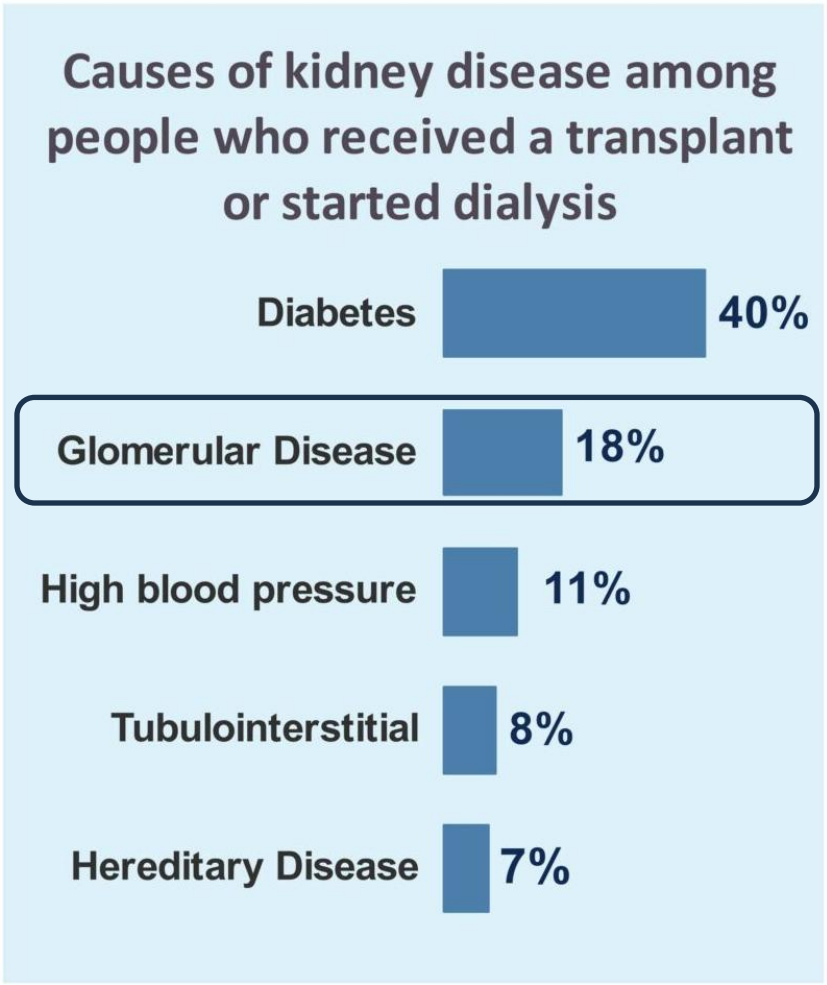
Source: ANZDATA. The Australia and New Zealand Dialysis and Transplant Registry (ANZDATA) collects information about people receiving dialysis or kidney transplant for end-stage kidney disease in Australia and New Zealand.


Causes of kidney disease among people who received a transplant or started dialysis
Diabetes
40%
Glomerular Disease
18%
High blood pressure
11%
Tubulointerstitial
8%
Hereditary Disease
7%

Top 10 Takeaways for Clinicians from the KDIGO 2021 Clinical Practice Guideline for General Principles for the Management of Glomerular Diseases

1 Kidney biopsy

The kidney biopsy is the "gold standard" for the diagnostic evaluation of glomerular diseases to facilitate the initiation or modification of treatment and/or to provide prognostic information. Under some circumstances, treatment may proceed without a kidney biopsy. (Figure 1)

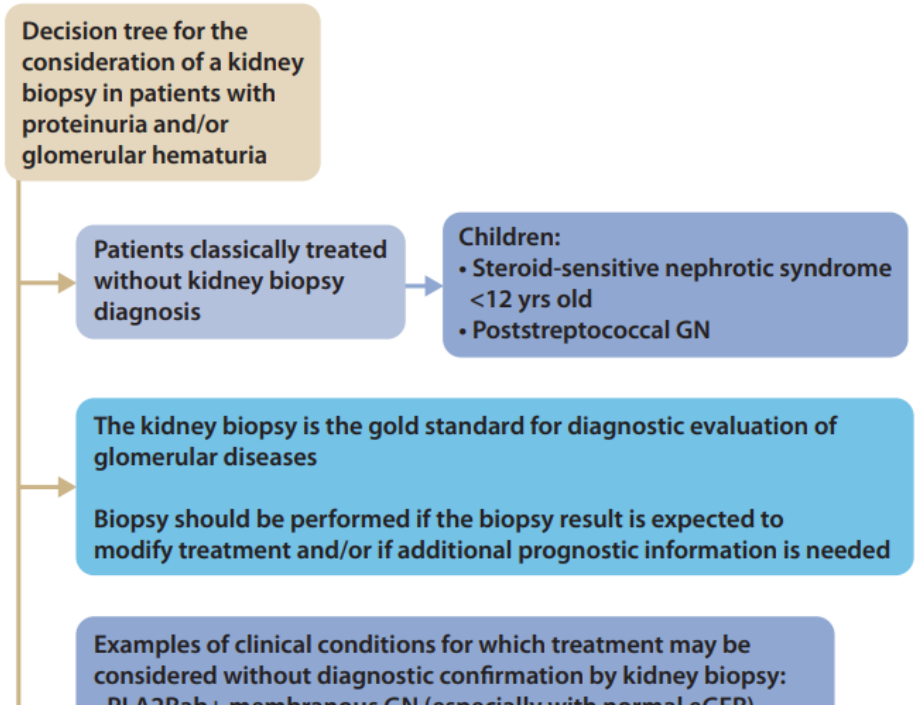
2 Proteinuria evaluation

In adults, the measurement of protein and creatinine on a 24-hour urine collection is the optimal way to determine total protein excretion; a reasonable compromise is to collect an "intended" 24-hour urine sample and calculate a PCR in an aliquot of the collection. For pediatrics, monitoring first morning PCR is an alternative. Random "spot" urine collections are not ideal due to variation over time in both protein and creatinine excretion.

3 Examination of the urine

Proteinuria should be quantified and followed sequentially. Hematuria should be assessed microscopically for acanthocytes and red blood cell casts in all forms of glomerular disease.

Treat edema, hypertension, and proteinuria



1

Kidney biopsy

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Background

- Kidney biopsy reports remain qualitative - inter-observer reliability
- Scoring system, e.g. MEST-C predicts kidney outcome[1]
- Still offers limited quantitative analysis, disease specific and labour-intensive[2,3,4,5]

[1] Alamartine et al., 2011
[2] Bellur et al., 2019; [3] Wilhelmus et al., 2015; [4] Furness et al., 2003; [5] Smith et al., 2019

Aims and Hypotheses

- Deep Learning can reliably extract information from kidney biopsy whole slide images
- The extracted information can improve the diagnosis and management of patients with glomerulonephritis and vasculitis
- Focus on H&E stain

Baseline Summary

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Characteristic	Normal N = 99	FSGS N = 45	ANCA N = 69	IgAN N = 75	Lupus N = 43	MCD N = 39	MN N = 64
Sex							
F	60 (61%)	15 (33%)	33 (48%)	25 (33%)	33 (77%)	21 (54%)	24 (38%)
M	39 (39%)	30 (67%)	36 (52%)	50 (67%)	10 (23%)	18 (46%)	40 (63%)
Age at Biopsy (years)	42 (32, 55)	51 (37, 63)	64 (53, 72)	35 (29, 39)	30 (24, 34)	50 (44, 70)	62 (44, 74)
eGFR at Biopsy (mL/min/1.73 m^2)	72 (57, 90)	58 (39, 87)	29 (16, 53)	66 (46, 87)	61 (33, 90)	88 (73, 90)	73 (43, 90)
Urine ACR at Biopsy (mg/mmol)	3 (2, 18)	296 (197, 506)	83 (39, 151)	104 (41, 212)	297 (139, 391)	414 (355, 725)	375 (177, 657)
Serum Creatinine at Biopsy (µmol/L)	91 (70, 108)	104 (72, 175)	186 (119, 271)	111 (86, 155)	115 (67, 180)	73 (67, 93)	102 (67, 131)
Serum Albumin at Biopsy (g/L)	43 (41, 45)	35 (26, 40)	34 (30, 37)	41 (35, 43)	32 (23, 36)	23 (17, 25)	29 (23, 37)

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Training Dataset and Annotated Structures

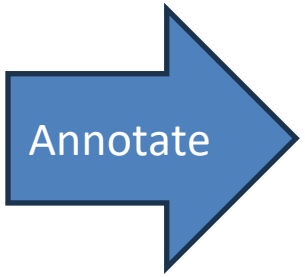
40 Normal WSIs

20 Lupus III/IV WSIs

20 ANCA-related WSIs

20 IgAN WSIs

20 FSGS WSIs

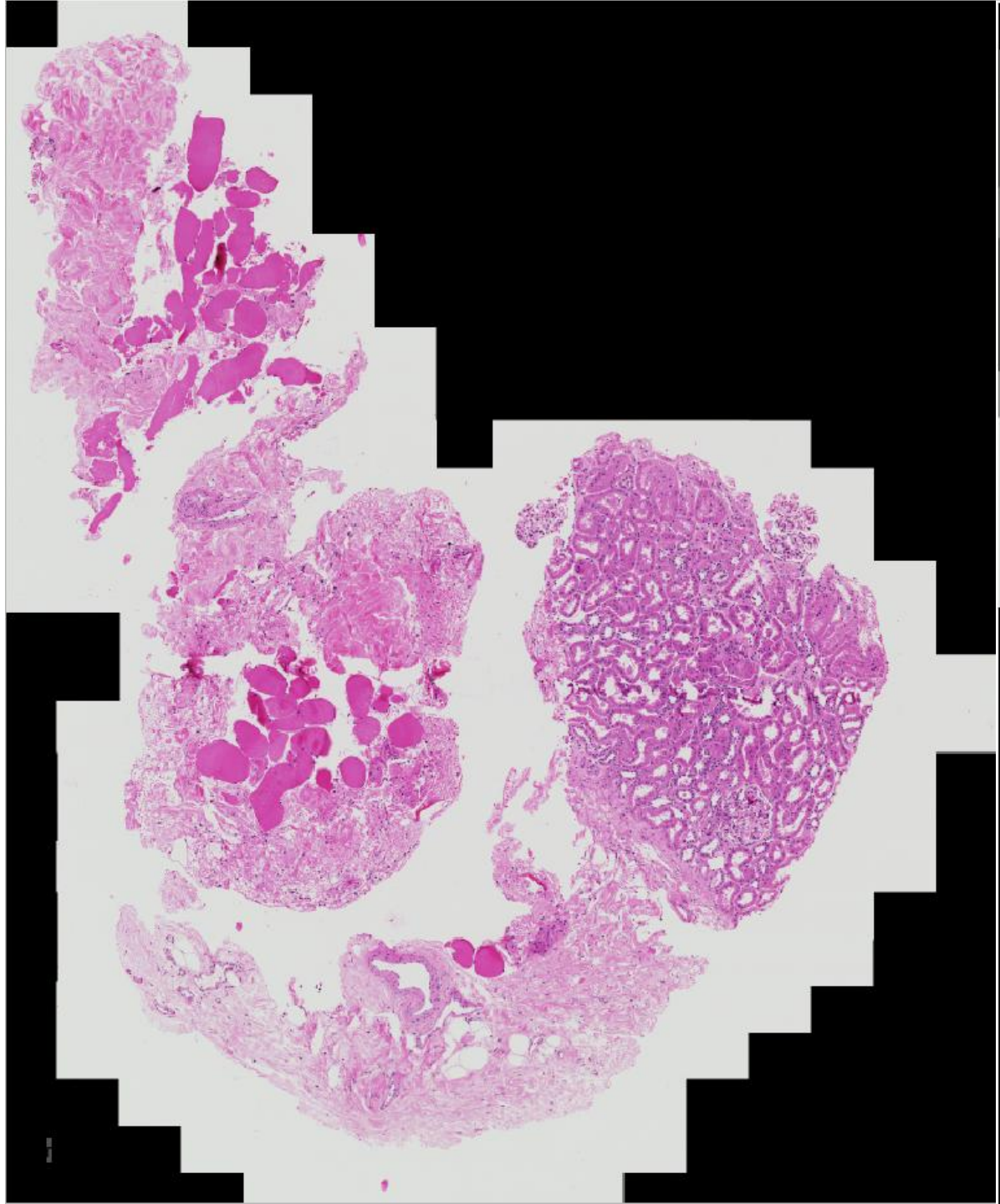


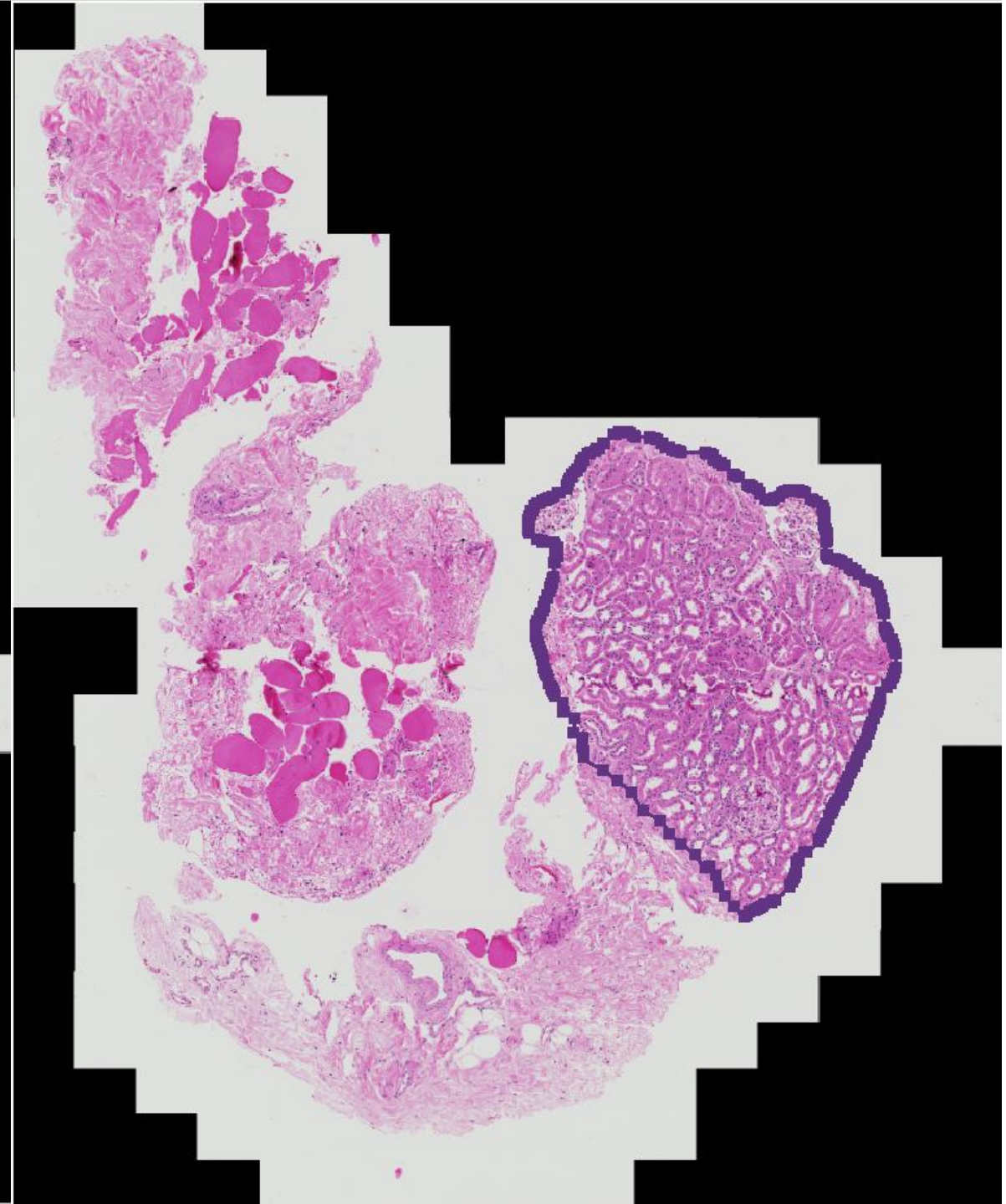
Structures	N
Proximal Tubules	69,503
Distal Tubules	48,433
Glomeruli	2,459
Arteries	2,612
Atrophic Tubules	8,892
Bowman Space	16,326
Sclerosis	295
Crescents	74
Capillary Lumen	129,094
Endothelial Nuclei	83,591
Mesangial Nuclei	61,242
Parietal Nuclei	21,163
Podocytes	25,455

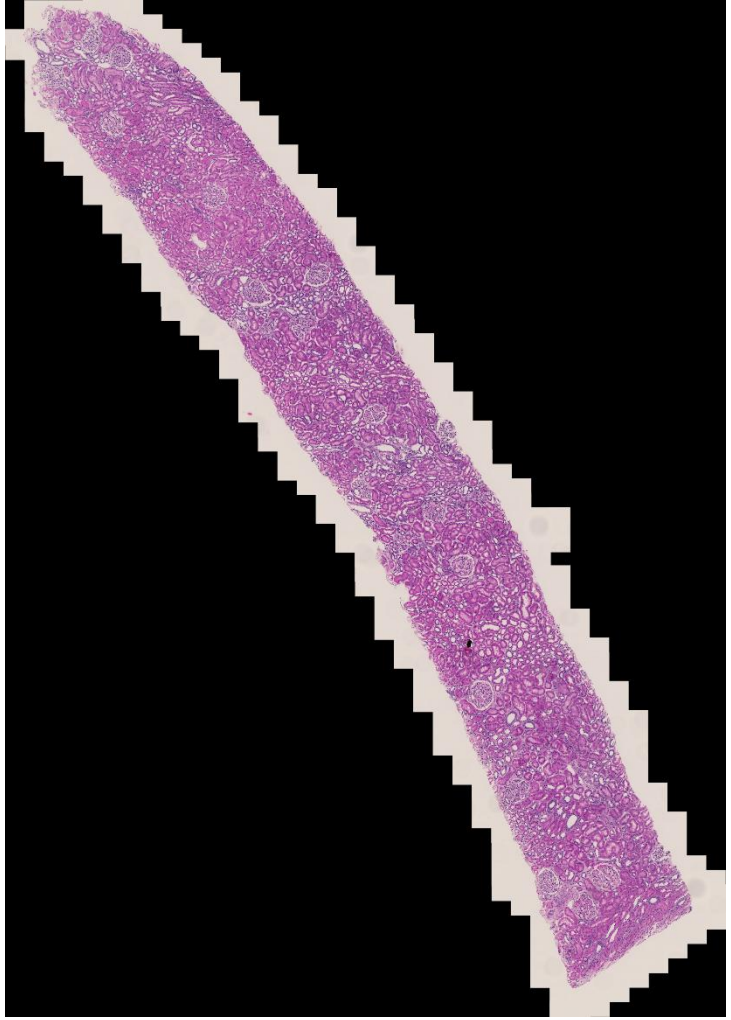
ANZSN

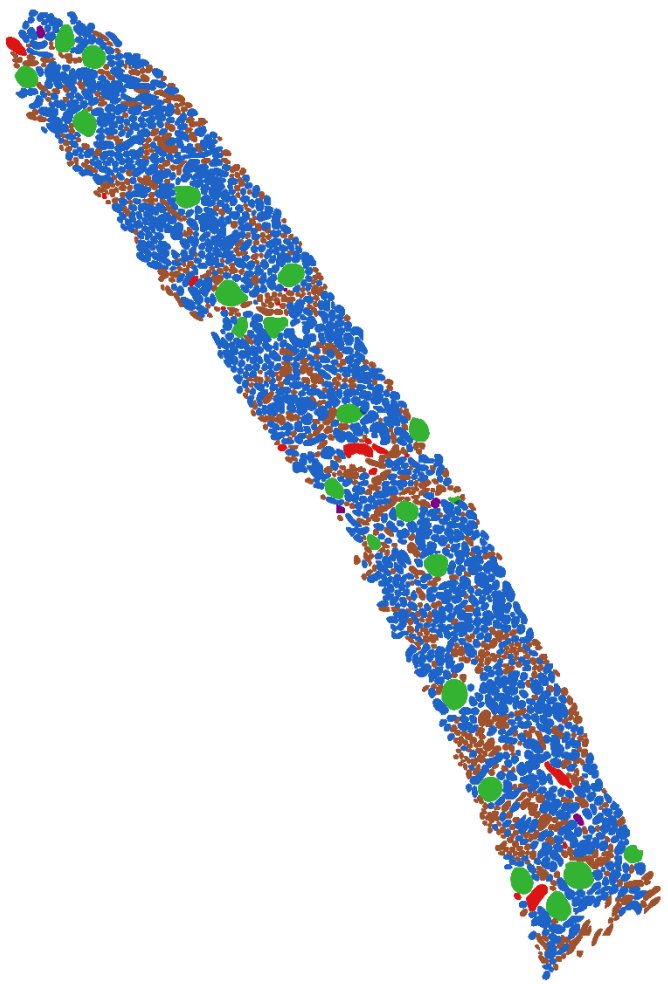
Methods

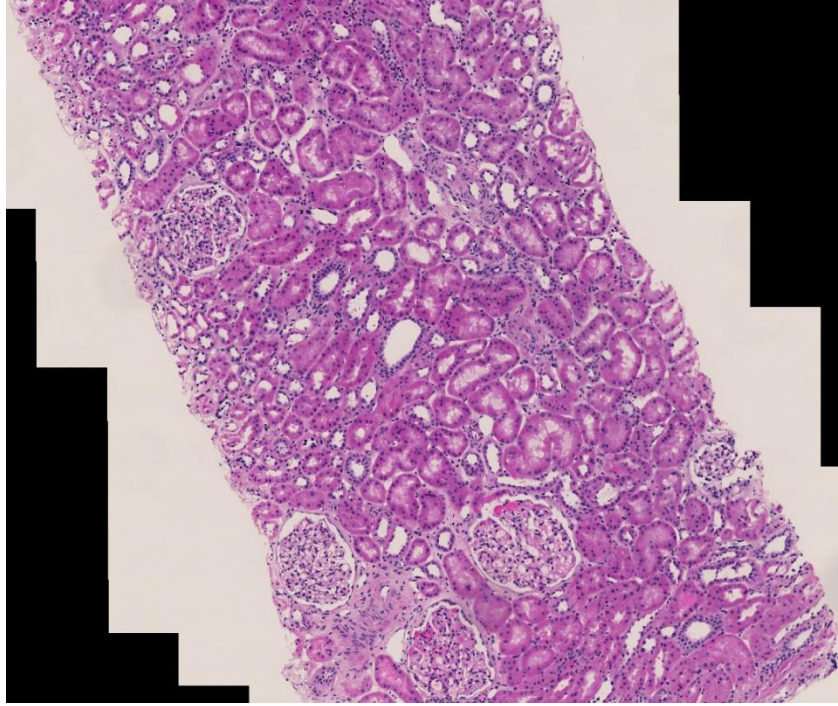
- Emulate pathologists' approach
- Lower magnification - region of interest (cortex)
- Higher magnification – tubules, artery, glomeruli, and interstitium
- Glomeruli assessment – essential for diagnosis

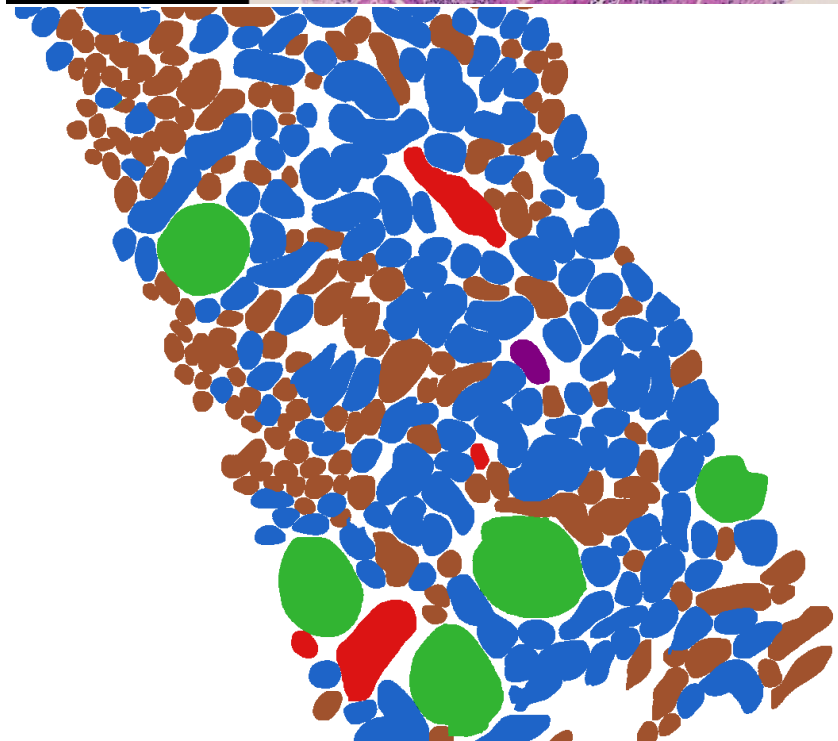




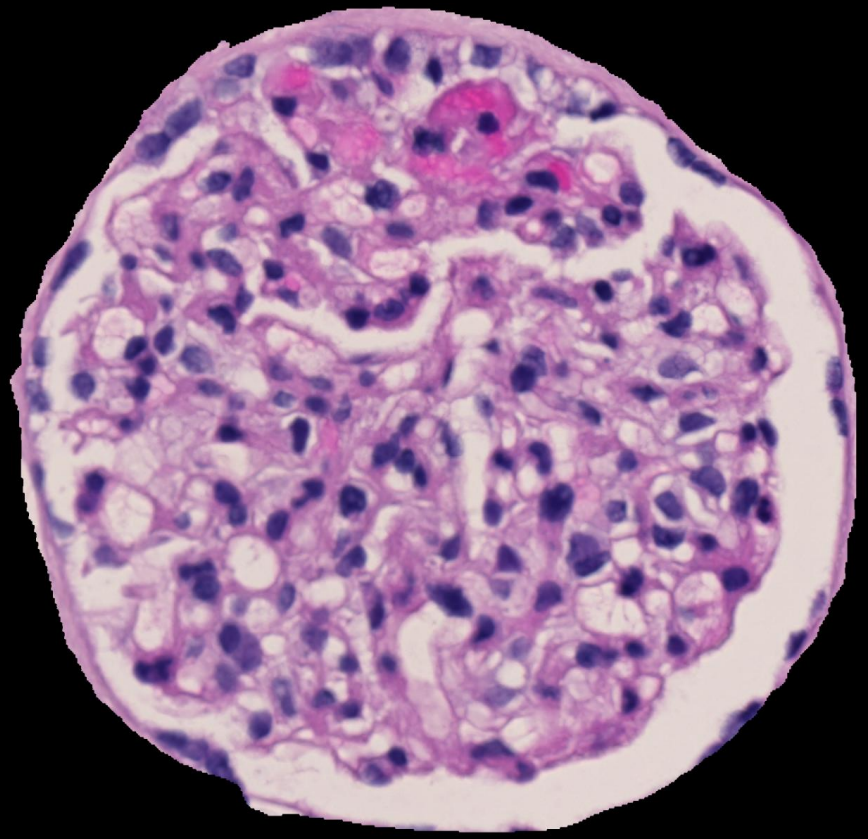


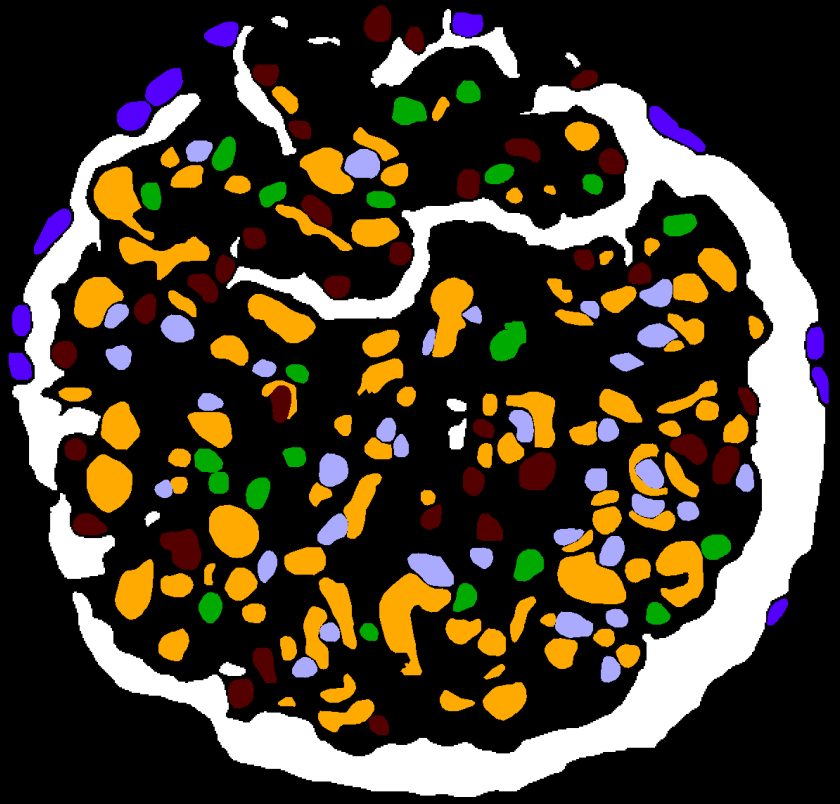




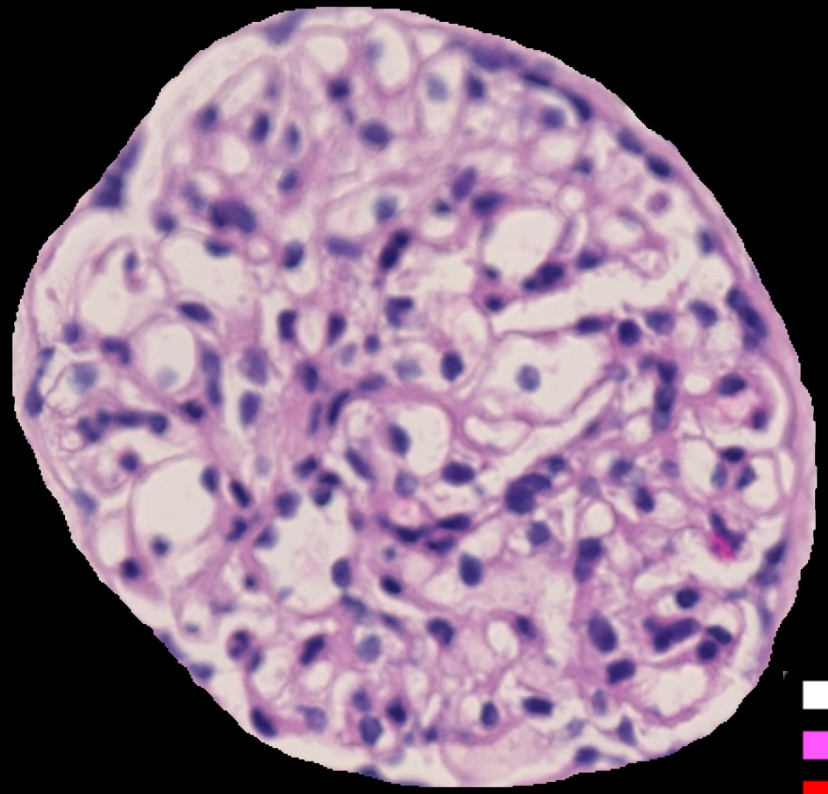


Instance segmentation





- Bowman Space
- Sclerosis
- Crescents
- Capillary Lumen
- Endothelial Nucleus
- Mesangial Nucleus
- Podocyte
- Parietal Nucleus



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Building Blocks Complete

- Model for cortex
- Model for major structures
- Model for fine glomerular structures

Performance Metrics

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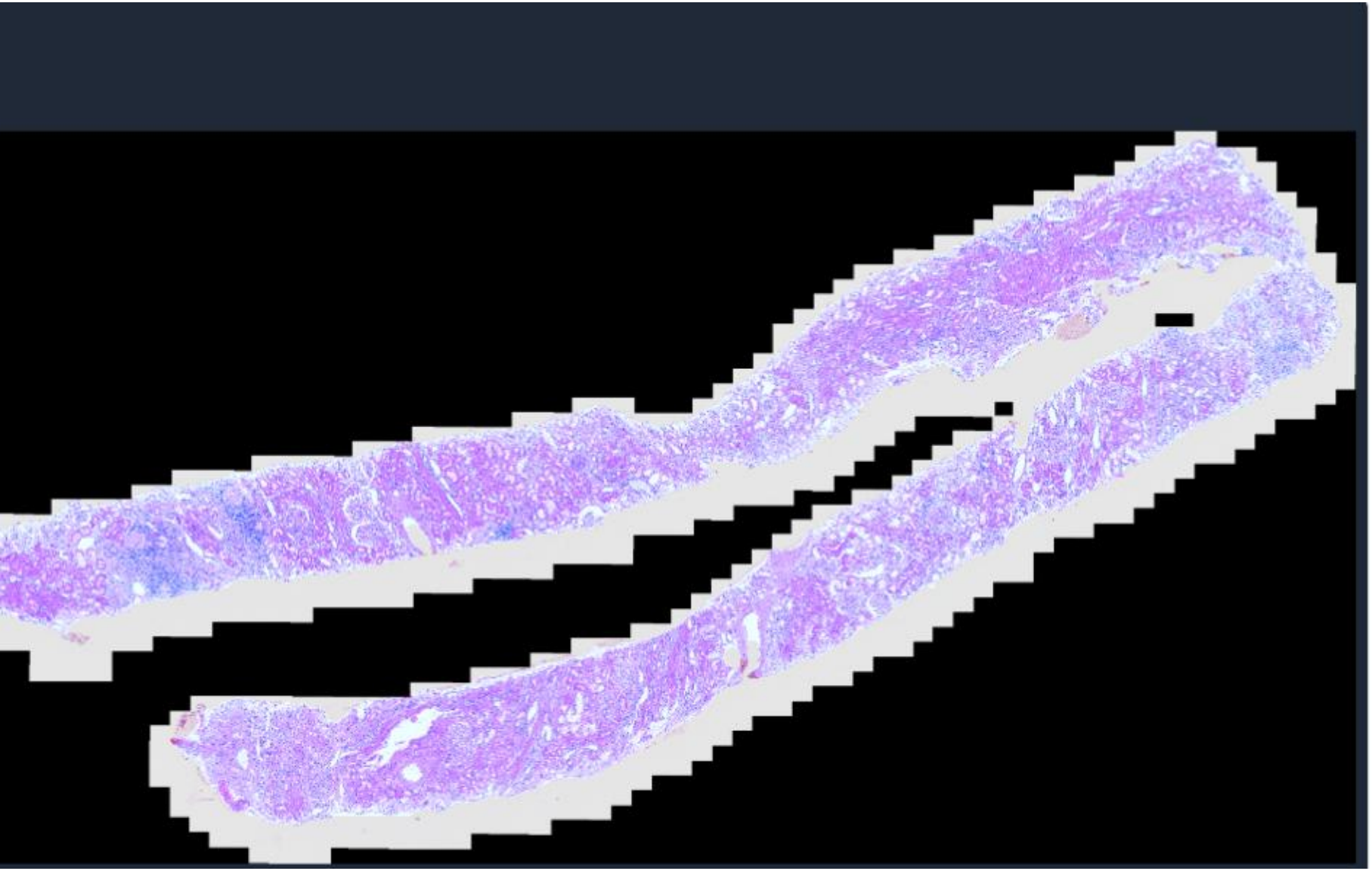
Metrics	Cortex	Distal Tubule	Proximal Tubule	Glomerulus	Artery	Atrophic Tubule
IoU	0.94	-	-	-	-	-
AP	-	0.62	0.75	0.81	0.39	0.26
Sensitivity	0.97	0.79	0.92	0.92	0.57	0.37
Positive Predictive Value	0.96	0.74	0.82	0.81	0.42	0.66

Metrics	Bowman Space	Sclerosis	Crescents	Capillary Lumen	Endothelial Nucleus	Mesangial Nucleus	Podocyte	Parietal Nucleus
Sensitivity	0.81	0.90	0.85	0.55	0.66	0.60	0.65	0.69
Positive Predictive Value	0.86	0.88	0.76	0.82	0.81	0.74	0.77	0.82

“Black Box”

- Interface for visualisation
- Human-in-the-loop
- Object segmentation

KidneyVision Demonstration



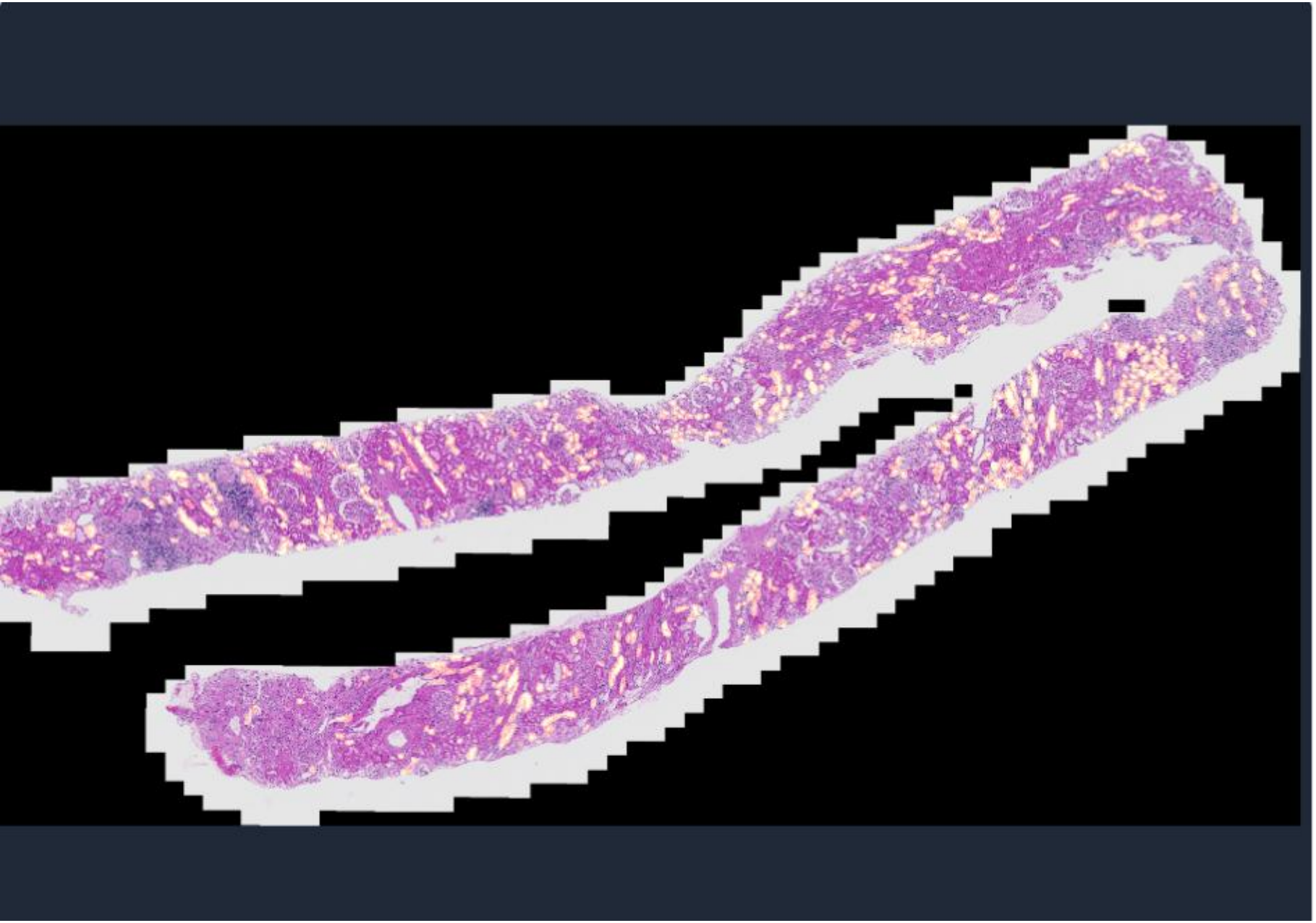
Class Overlay

- ○ All
- ◉ Cortex
- ○ Distal tubule
- ○ Glomerulus — Show fine detail
- ○ Proximal tubule
- ○ Artery
- ○ Atrophic Tubule
- ○ None

Cortex Metrics

Area

10.05 mmÂ²



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- ◉ Distal tubule
- ○ Glomerulus — Show fine detail
- ○ Proximal tubule
- ○ Artery
- ○ Atrophic Tubule
- ○ None

Distal tubule Metrics

Density (within cortex)

65.9 instances per mm^2

Healthy median: 76.6 instances per mm^2

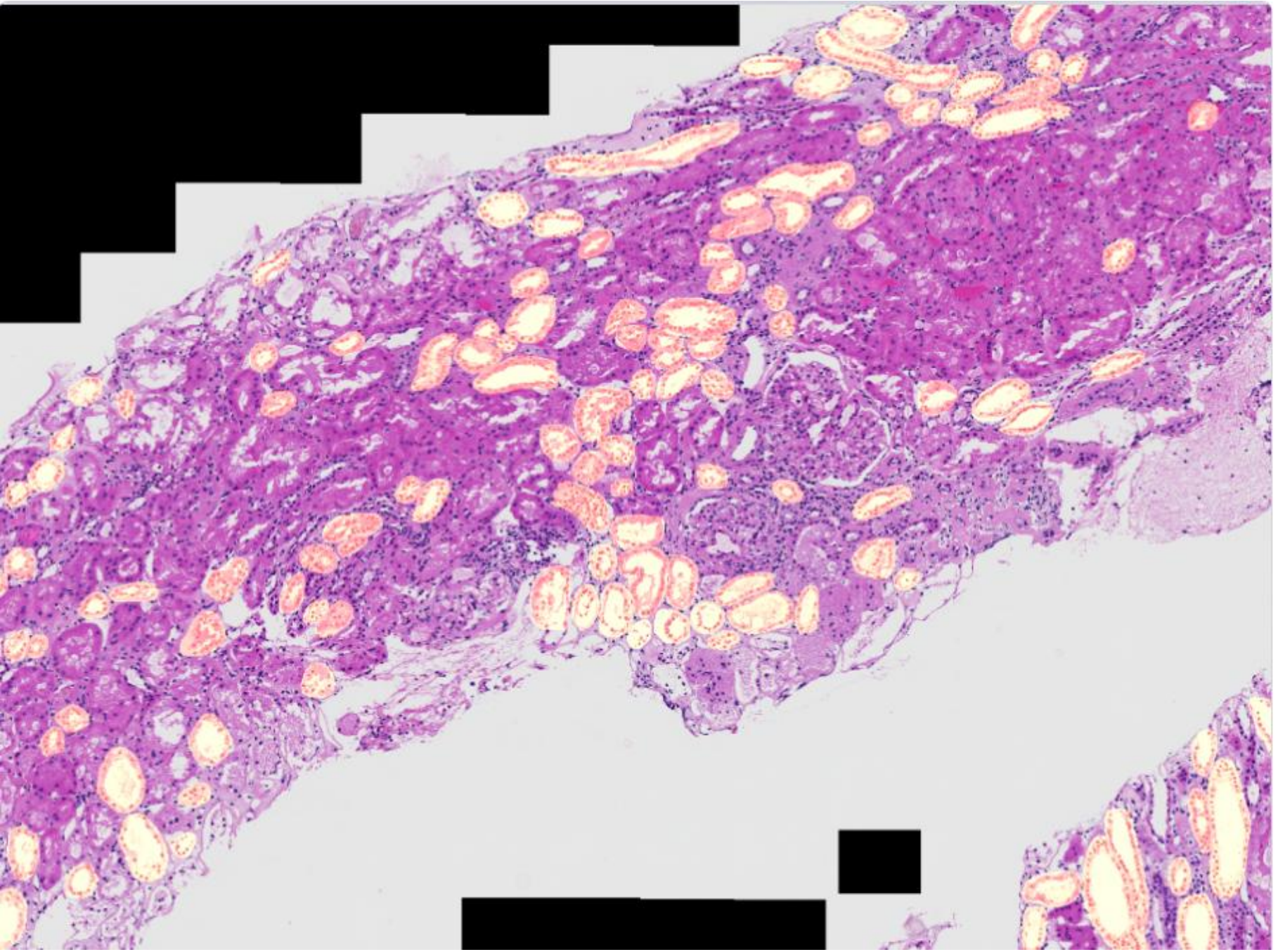
NORMAL

Median size

0.003 mm^2

Healthy median: 0.002 mm^2

NORMAL



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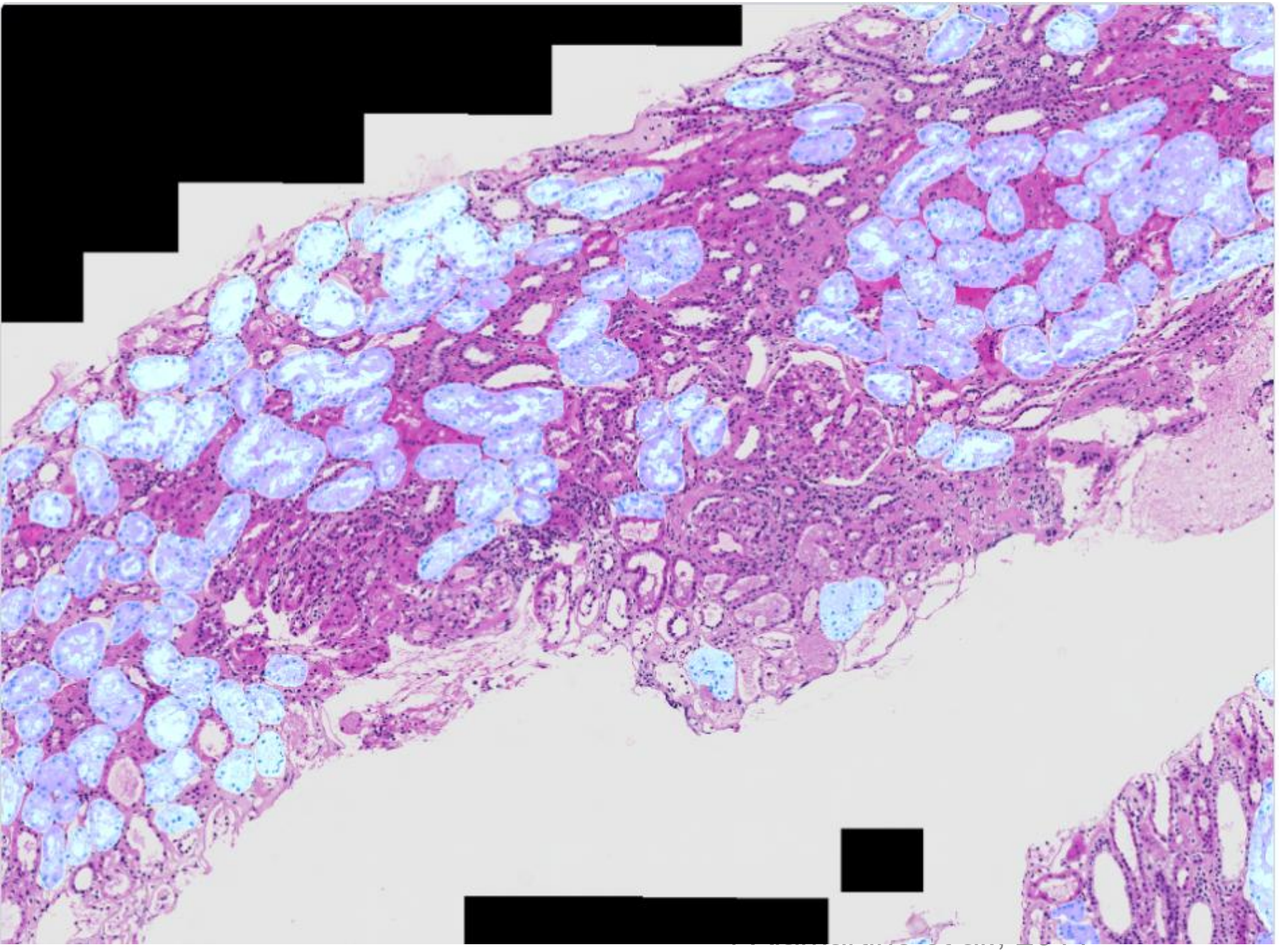


Class Overlay

- ○ All
- ○ Cortex
- ○ Distal tubule
- ○ Glomerulus — Show fine detail
- ◉ Proximal tubule
- ○ Artery
- ○ Atrophic Tubule
- ○ None

Proximal tubule Metrics

Density (within cortex)

79.4 instances per mm²

Healthy median: 117.1 instances per mm²

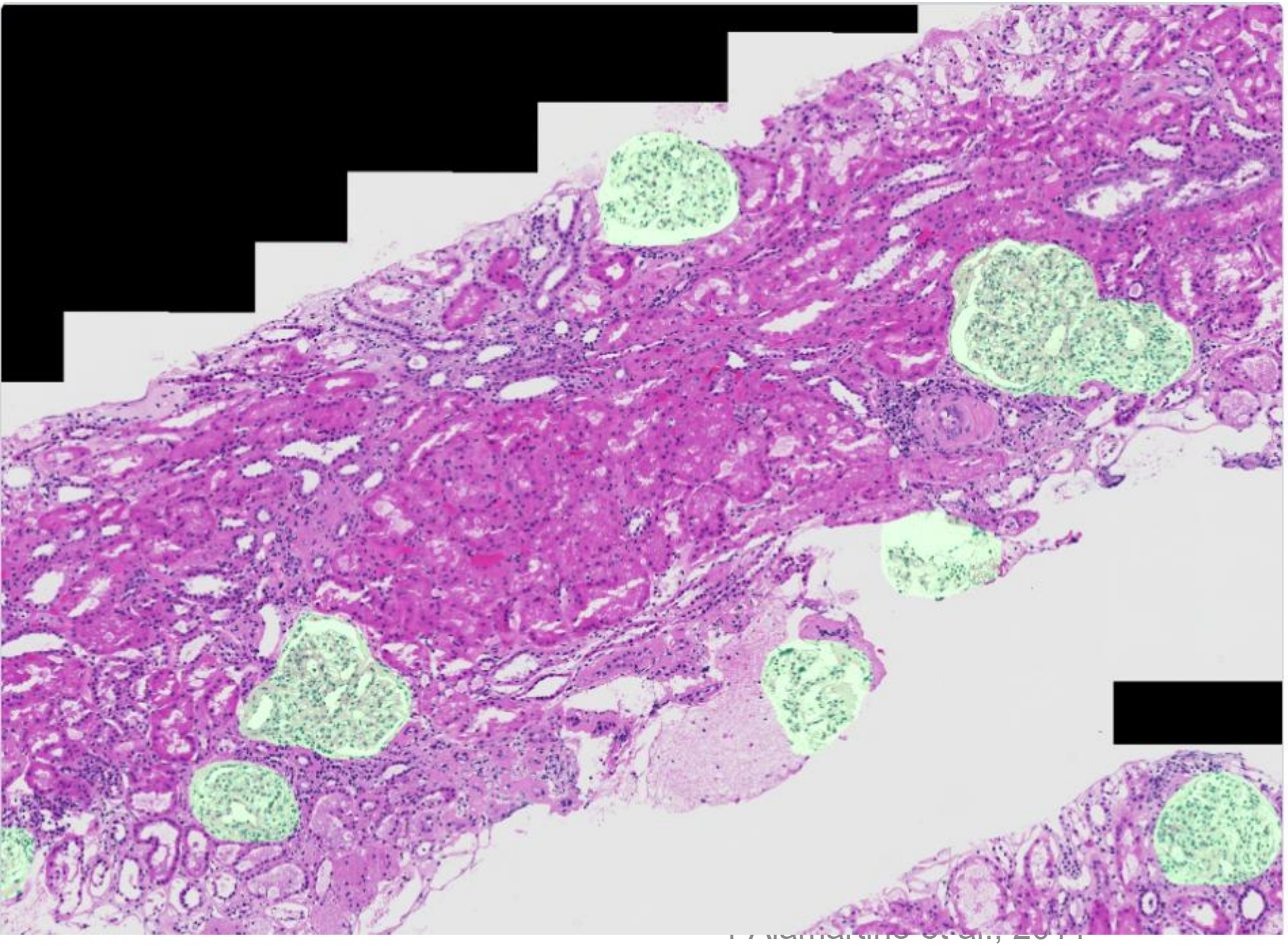
OUTSIDE RANGE

Median size

0.005 mm²

Healthy median: 0.004 mm²

NORMAL



Class Overlay

- ○ All
- ○ Cortex
- ○ Distal tubule
- ◉ Glomerulus — Show fine detail
- ○ Proximal tubule
- ○ Artery
- ○ Atrophic Tubule
- ○ None

Glomerulus Metrics

Density (within cortex)

6.27 instances per mm²

Healthy median: 4.50 instances per mm²

NORMAL

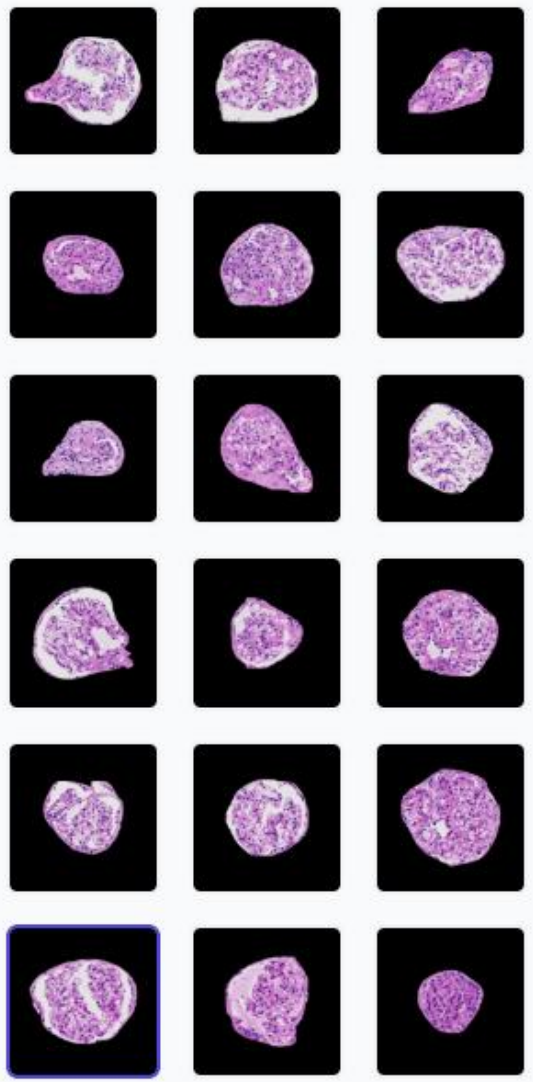
Median size

0.027 mm²

Healthy median: 0.023 mm²

NORMAL

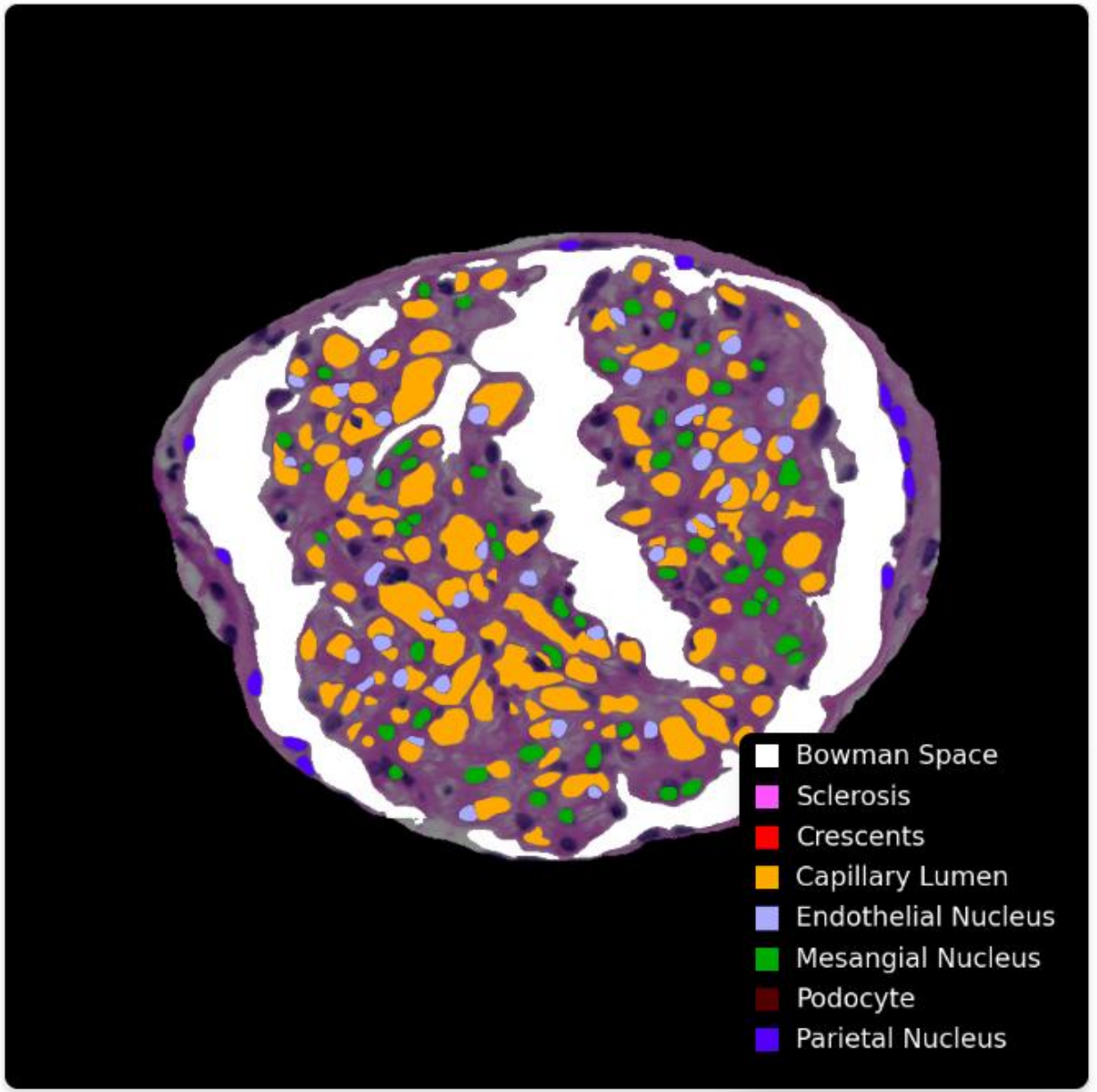
Instances



Instance 22

Toggle Segmentation Overlay

Include in slide analysis



Glomerulus Metrics

Filter by Class

- (•) Bowman Space
- ( ) Capillary Lumen
- ( ) Crescents
- ( ) Endothelial Nucleus
- ( ) Mesangial Nucleus
- ( ) Parietal Nucleus
- ( ) Podocyte
- ( ) Sclerosis

Bowman Space - Area percentage

26.3 %

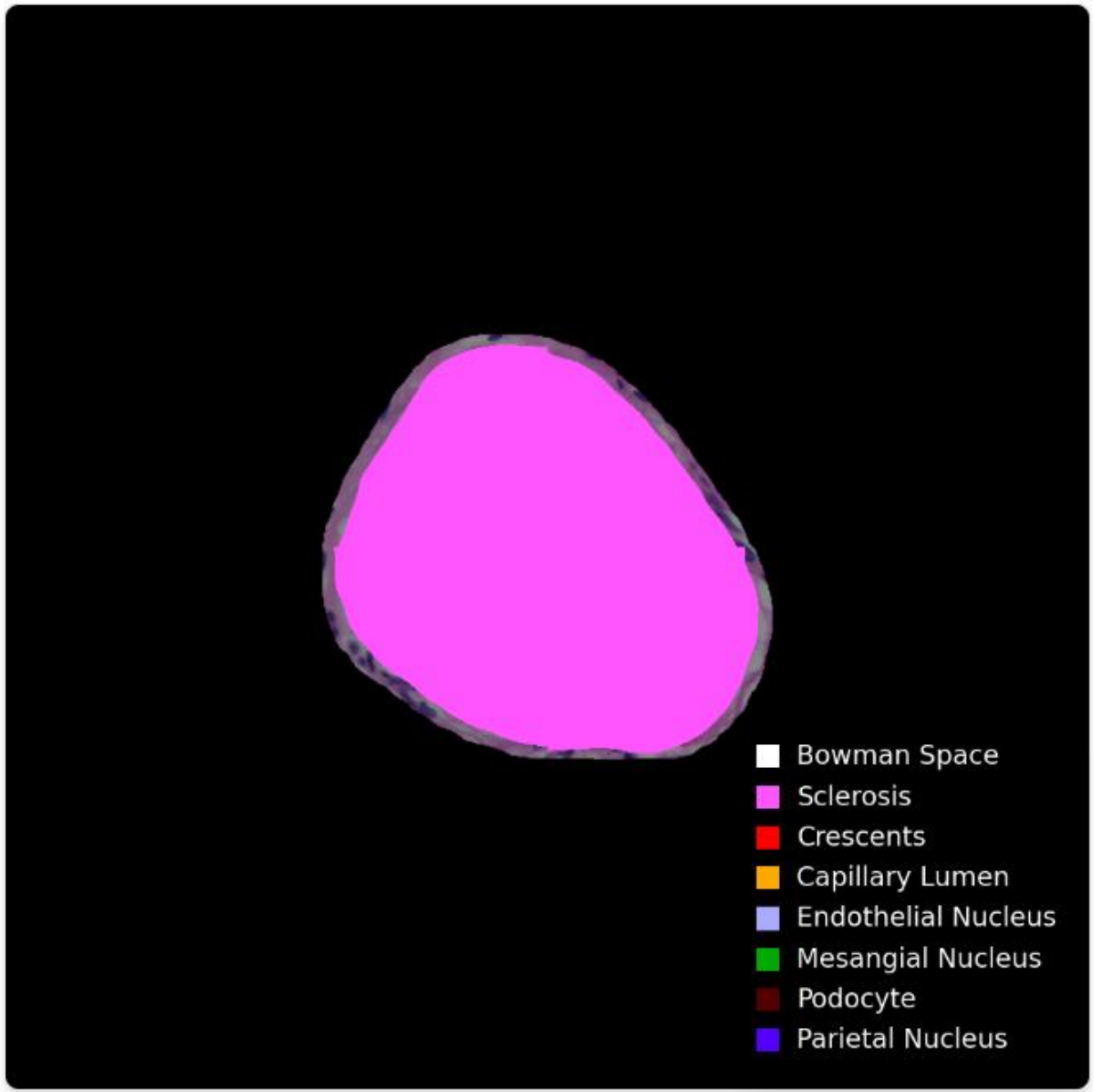
NORMAL

Instances

Instance 26

Toggle Segmentation Overlay

Include in slide analysis



Glomerulus Metrics

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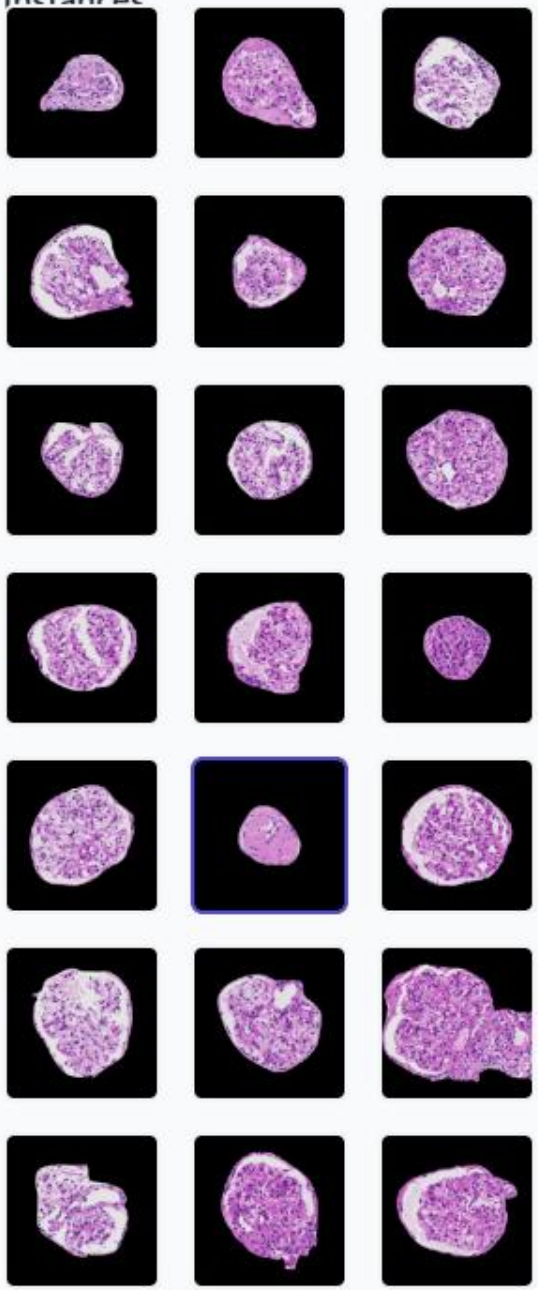
- Podocyte
- Sclerosis

No metric data available for this filter

Instances

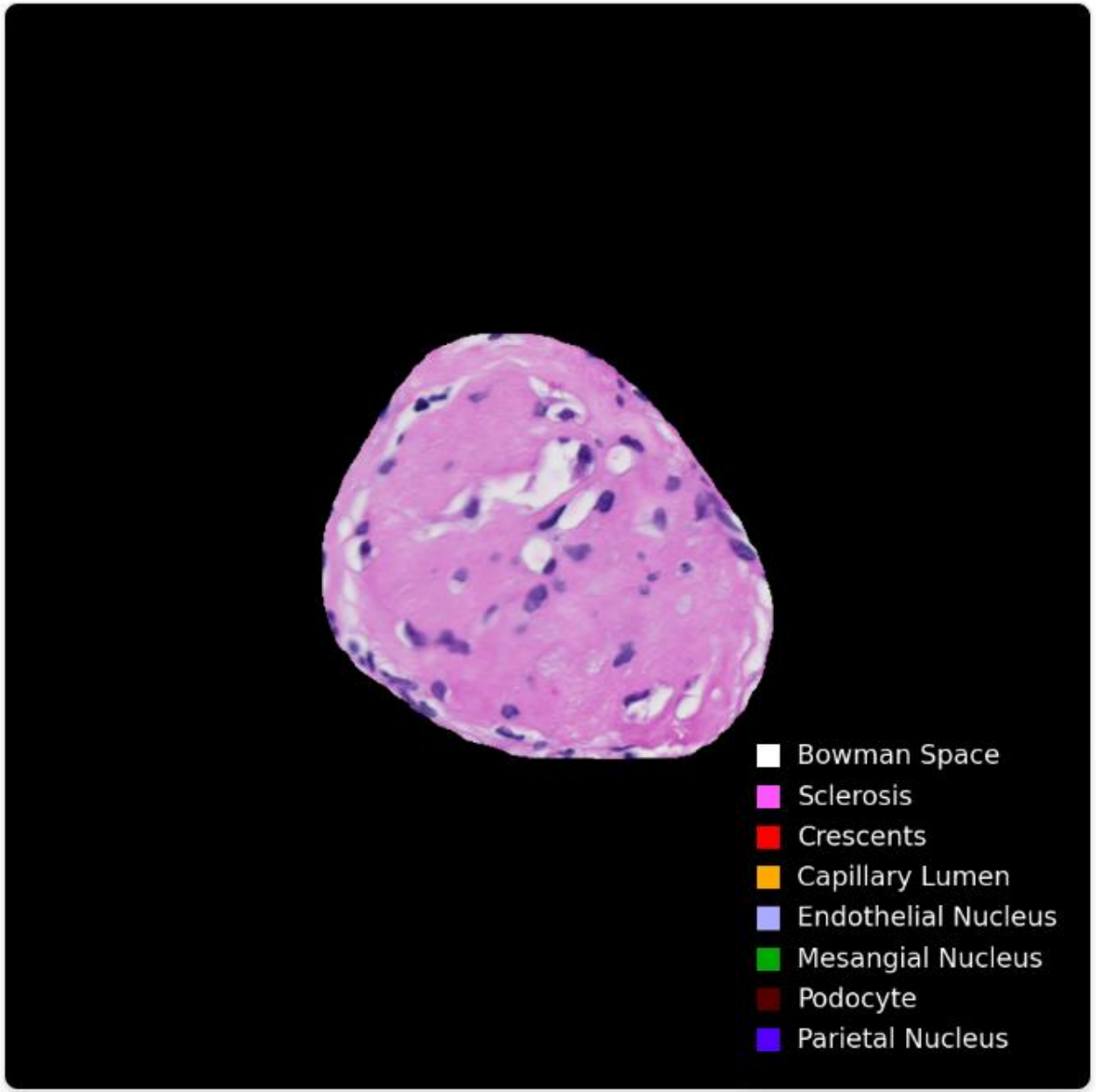


-95354_A06-02-kidney_0#

Instance 26

Toggle Segmentation Overlay

Include in slide analysis



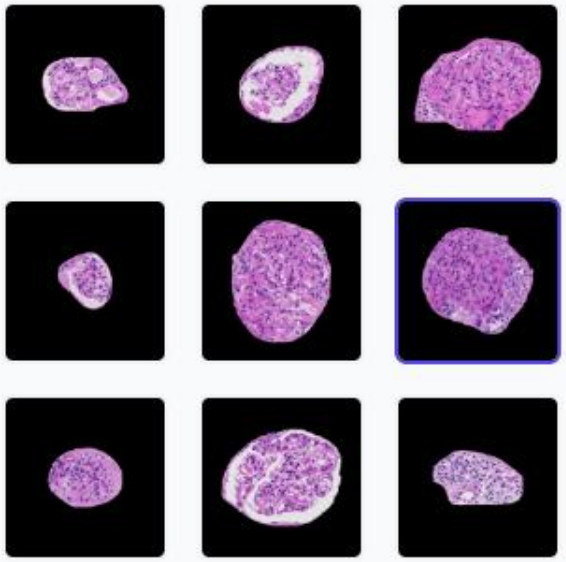
Glomerulus Metrics

Filter by Class

- Bowman Space
- Capillary Lumen
- Crescents
- Endothelial Nucleus
- Mesangial Nucleus
- Parietal Nucleus
- Podocyte
- Sclerosis

No metric data available for this filter

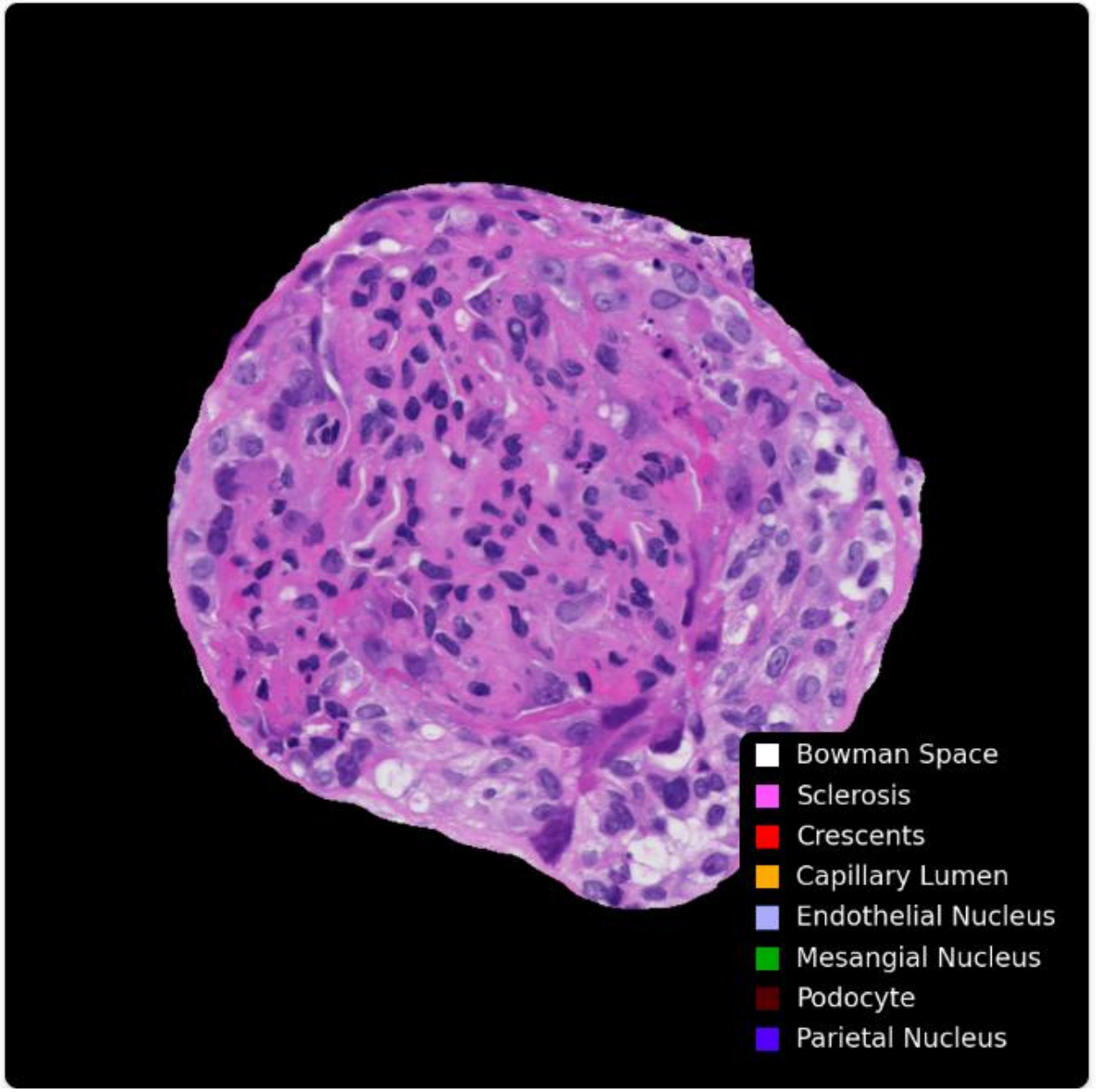
Instances



Instance 5

Toggle Segmentation Overlay

Include in slide analysis



Glomerulus Metrics

Filter by Class

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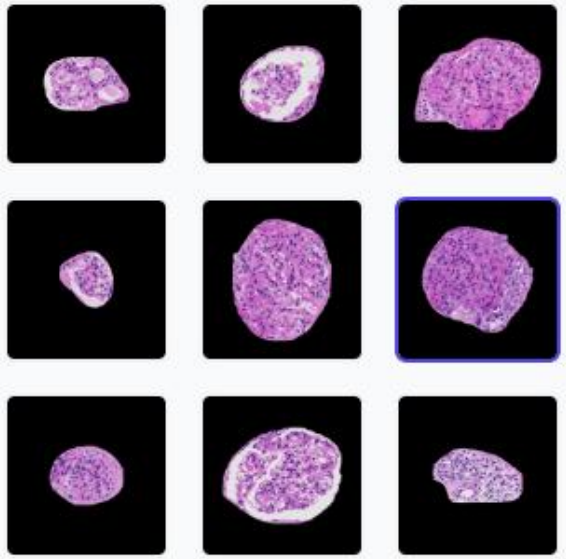
- Crescents
- Endothelial Nucleus
- Mesangial Nucleus
- Parietal Nucleus
- Podocyte
- Sclerosis

Crescents - Area percentage

66.5 %

OUTSIDE RANGE

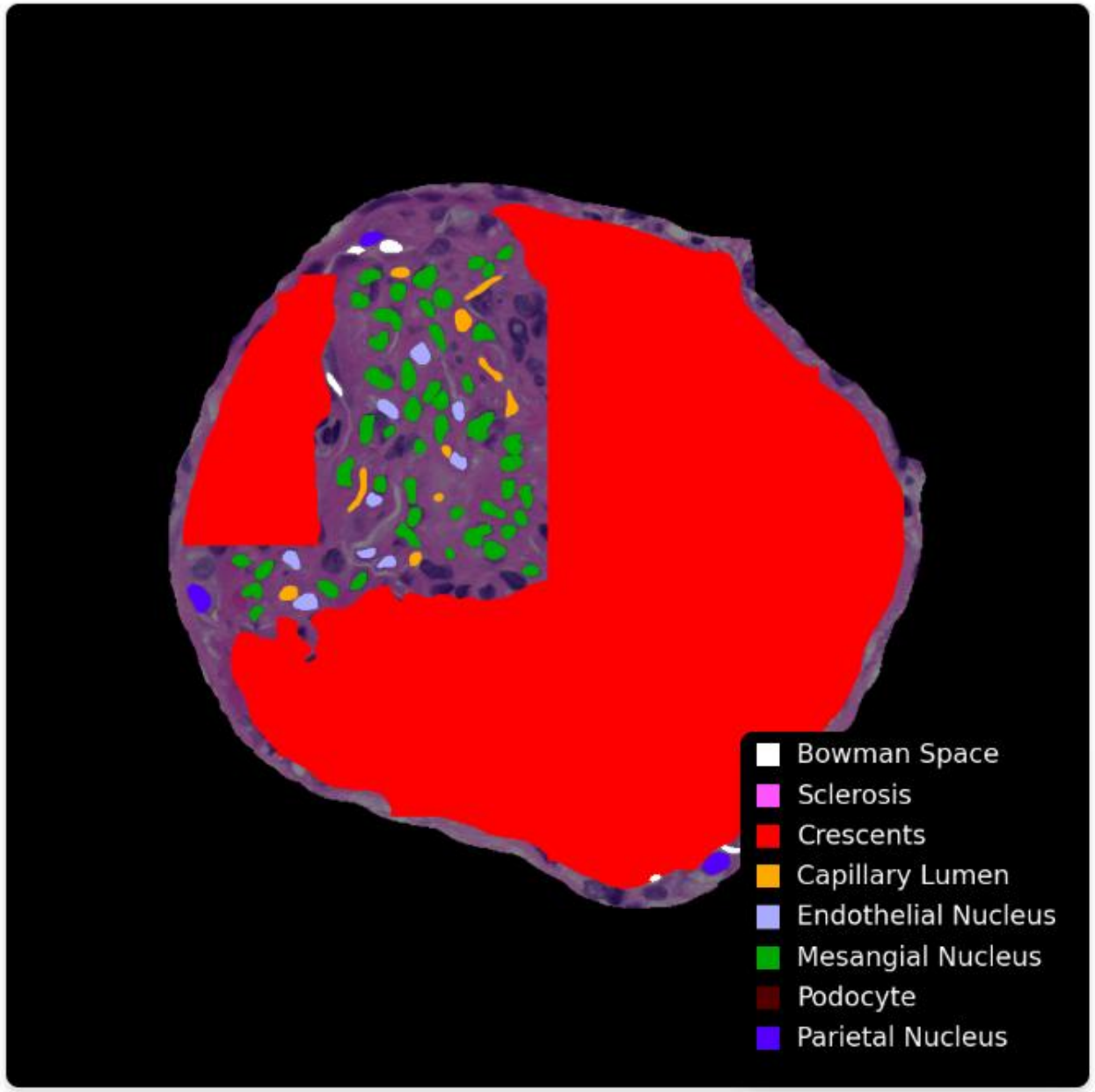
Instances



Instance 5

Toggle Segmentation Overlay

Include in slide analysis



Glomerulus Metrics

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OUTSIDE RANGE

“The Cake”

- Polygons – coordinates
- The rest is Mathematic

Clinical Implication

Morphological Difference Between Sex

60TH ANZSN CONGRESS

Glomerulus Morphology per Sex in Normal Biopsy

Characteristic	F N = 1,577[1]	M N = 1,138[1]	p-value[2]
Area (µm²)	22,716 (16,237, 29,739)	24,892 (17,537, 32,151)	<0.001

[1] Median (Q1, Q3)

[2] Wilcoxon rank sum test

Glomerulus Density per Sex in Normal Biopsy

Characteristic	F N = 60[1]	M N = 39[1]	p-value[2]
Glomerular Density (per mm²)	2.18 (1.69, 2.67)	2.27 (1.79, 2.71)	0.7
Unknown	6	2	

[1] Median (Q1, Q3)

[2] Wilcoxon rank sum test

Glomerulus Morphology per Sex

Characteristic	F N = 5,146[1]	M N = 5,289[1]	p-value[2]
Area (µm²)	24,571 (16,842, 33,571)	25,664 (17,593, 34,739)	<0.001

[1] Median (Q1, Q3)

[2] Wilcoxon rank sum test

Glomerulus Density per Sex

Characteristic	F N = 211[1]	M N = 223[1]	p-value[2]
Glomerular Density (per mm²)	2.10 (1.52, 2.61)	2.02 (1.51, 2.55)	0.3
Unknown	26	30	

[1] Median (Q1, Q3)

[2] Wilcoxon rank sum test

Correlates with Kidney Function

60TH ANZSN CONGRESS

ANZSN

Spearman Correlation of Major Structures with eGFR at Biopsy		
Variables	Correlation	p-value
Atrophic Tubular Density (per mm^2)	-0.5650352	< 0.001
Glomerular Density (per mm^2)	0.1781555	< 0.001
Distal Tubular Density (per mm^2)	0.3642204	< 0.001
Proximal Tubular Density (per mm^2)	0.6288194	< 0.001

Correlates with Kidney Function

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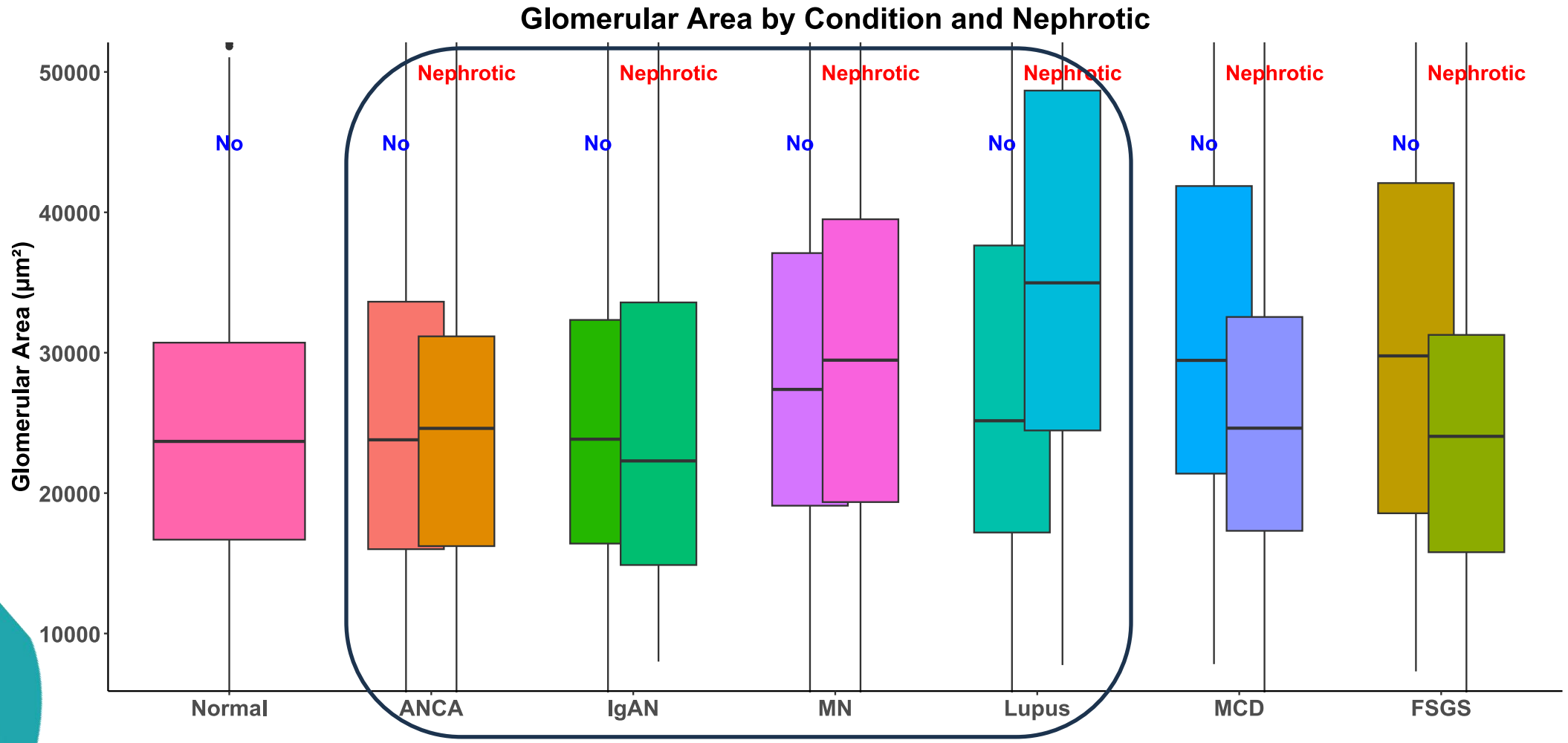
Enlarged Glomerular Area in Albuminuria



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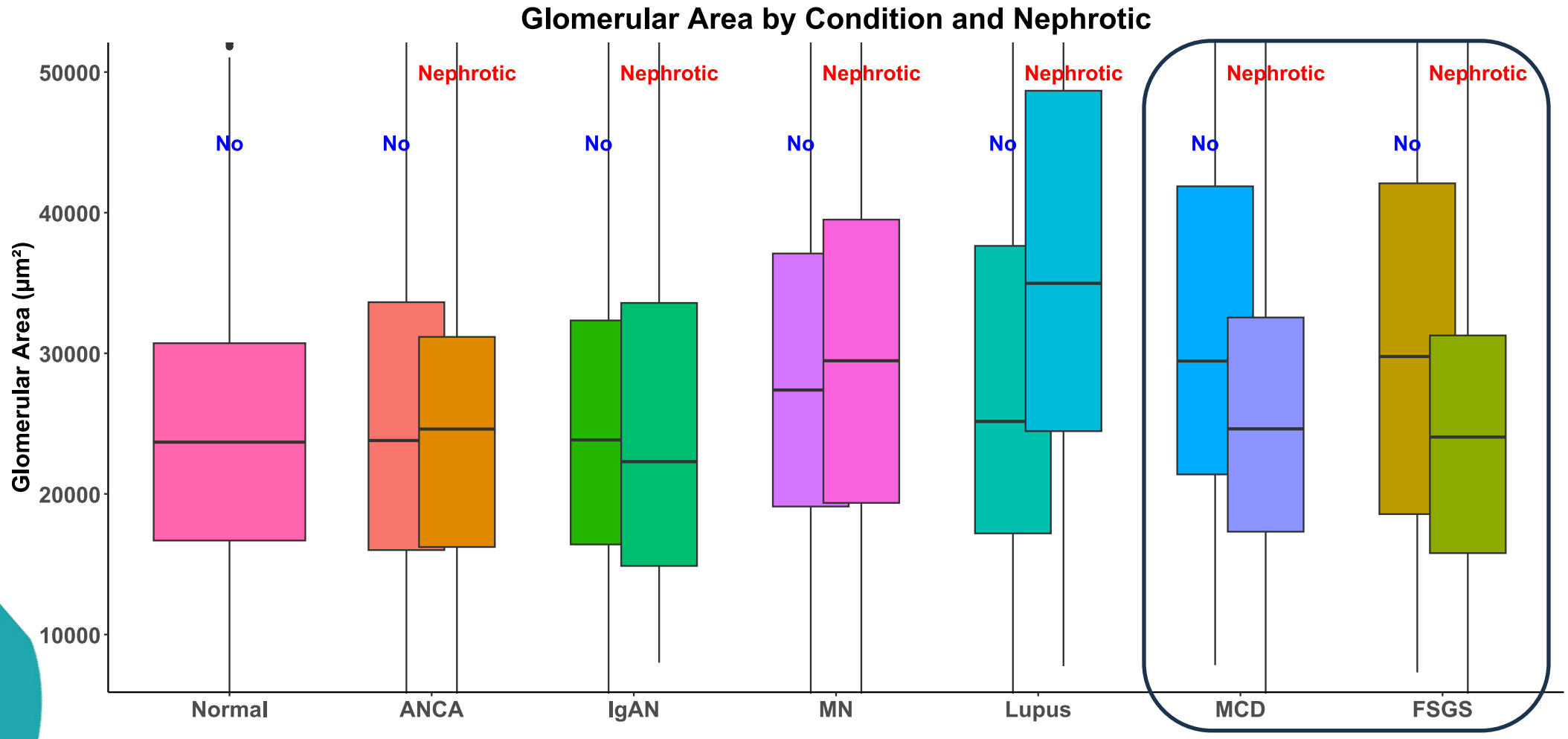
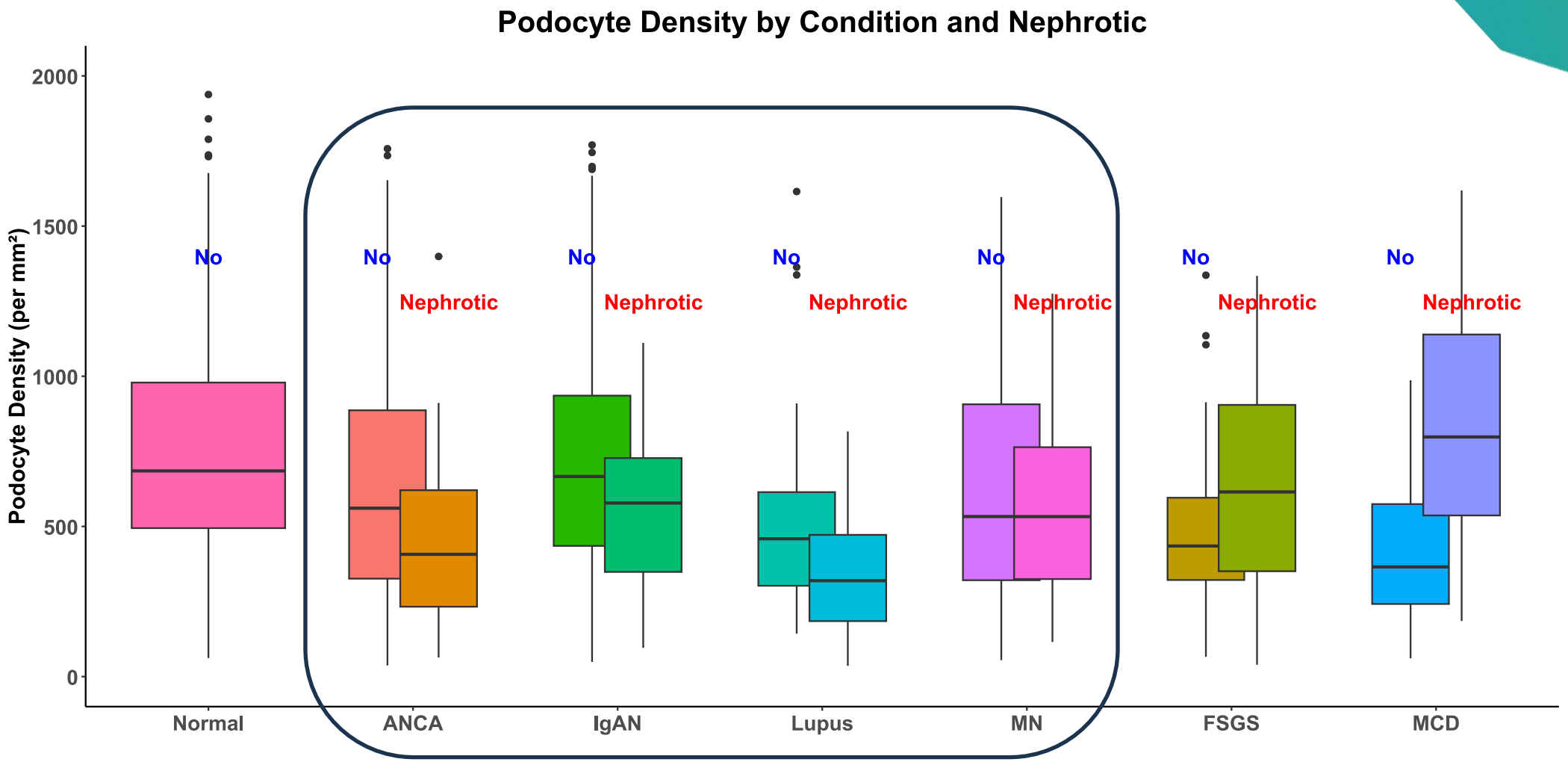


Reduced Podocytes Density in Albuminuria



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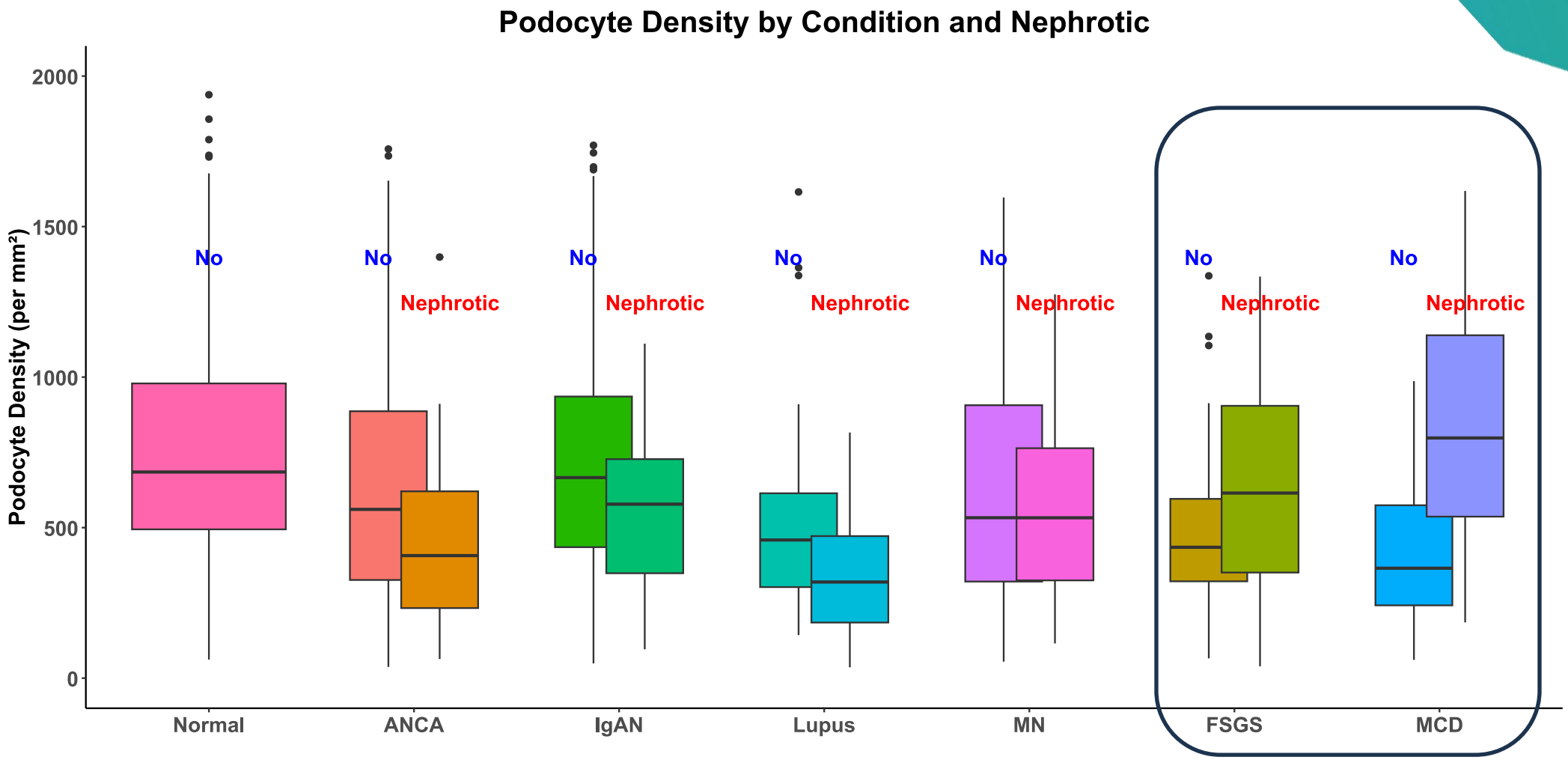
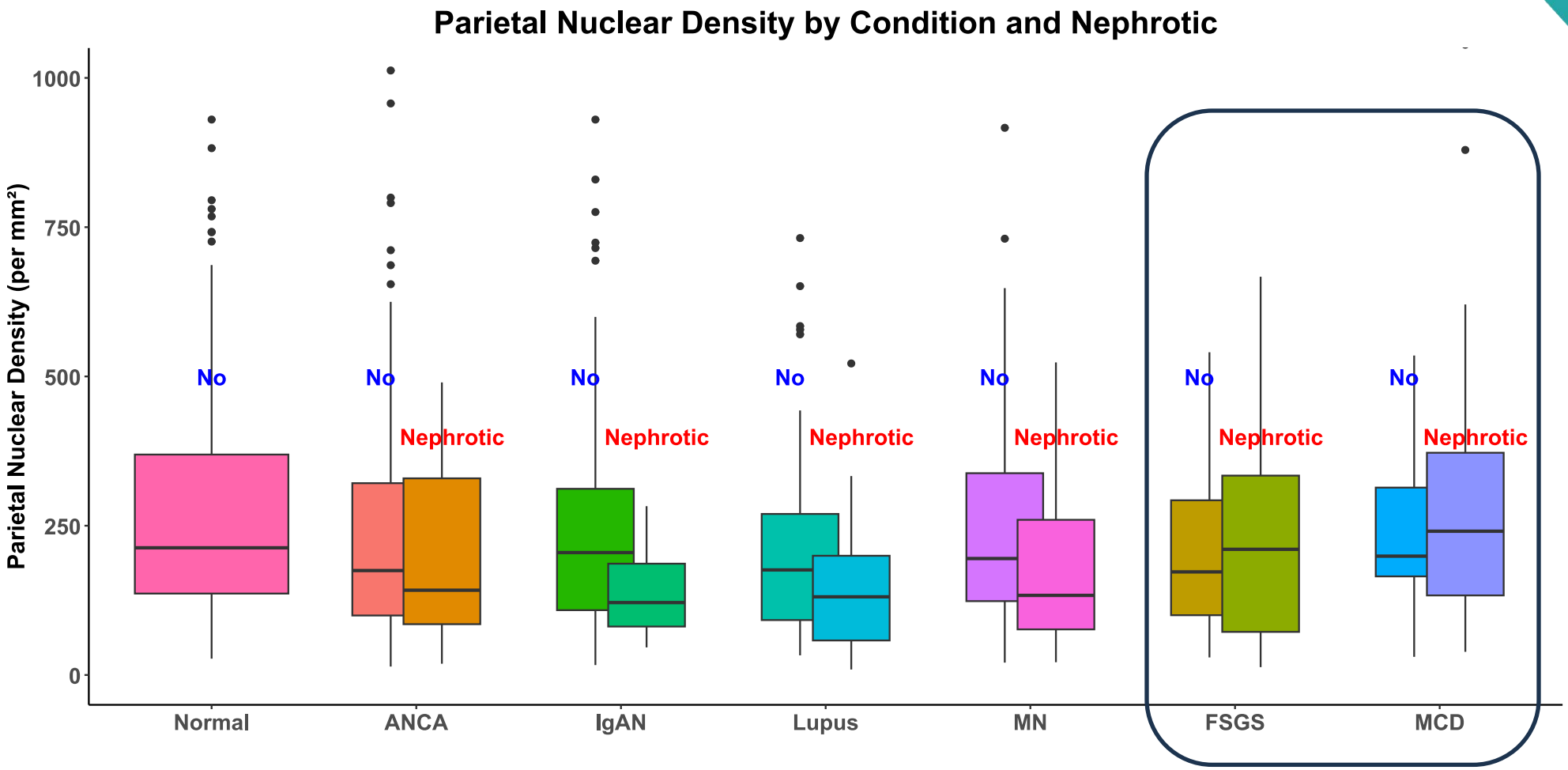


Similar Trend of Parietal Nucleus Density



Conclusion

- KidneyVision is an algorithm designed to extract morphological information to supplement conventional medical kidney biopsy analysis.
- The morphometric data provides valuable information in phenotyping glomerulonephritis and vasculitis

Future Aims

- Collaboration with other centres – GN/vasculitis biopsy
- Collaboration with transplant centres – implantation biopsy for updating reference range
- Incorporating other stains and diagnostic modality

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