

Histopathological and Immunofluorescence Findings on Kidney Biopsies in Patients with Crescentic Glomerulonephritis

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Abstract

Background: Regional variations in crescentic glomerulonephritis (CresGN) presentation and etiology are reported while accurate data is needed to guide healthcare planning, screening, diagnosis, and treatment.

Objective: This study aimed to characterize histopathological and immunofluorescence findings in kidney biopsies of patients with CresGN.

Methods: A descriptive cross-sectional study was conducted in the Department of Histopathology at the Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan, from April 15, 2023 to October 14, 2023. Convenience sampling was used to enroll 60 eligible adults diagnosed with CresGN. Biopsy specimens were processed into paraffin blocks, sectioned, stained, and analyzed using immunofluorescence. Descriptive statistics summarized categorical variables, including types of crescents, laboratory findings, and histopathological and immunofluorescence outcomes.

Results A total of 60 biopsy specimens were observed. Based on the histopathological findings, most of the patients had two cores (n=48, 80%) with a mean length of 0.7 ± 0.24 cm. The mean number of glomeruli was 14 ± 5 (ranging from 7 to 21). The most common crescent type was cellular (n=24, 40%). 55 out of 60 patients had negative antibodies along with C3 and C1q. However, five patients showed weak focal positivity for IgG and IgM antibodies along with similar reactivity for C3 and C1q. The pauci-immune group was the most common type of CresGN. According to Berden classification, the majority (n=25; 41.7%) belonged to a crescentic category.

Conclusion: Pauci-immune CresGN was the predominant subtype, with cellular crescents as the most frequent histopathological finding. These results emphasize the importance of detailed immunofluorescence and histological evaluation for accurate diagnosis and management of CresGN.

Key words: Crescentic glomerulonephritis, kidney biopsy, pauci-immune glomerulonephritis, immunofluorescence, histopathology.

Introduction

The etiology of CresGN involves multiple factors. The initial injury to the glomerular basement membrane (GBM) by a harmful agent leads to the leakage and accumulation of fibrin and

fibronectin into the urinary space.¹ This event subsequently triggers the proliferation of parietal epithelial cells and causes ruptures in the Bowman's capsule. These breaks permit a substantial influx of macrophages and fibrin,^{1,2} changes that ultimately result in the obstruction of the tubular outlet, glomerular scarring, and the loss of the affected nephrons.³

From a histopathological perspective, crescents are defined by the extra-capillary proliferation of parietal epithelial cells and the collection of macrophages and fibrin within the Bowman's space. While crescents may occupy a portion or the entirety of the Bowman's space, a minimum involvement of 50% of the Bowman's space circumference is required for the diagnosis of a crescent. For the diagnosis of crescentic

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Authors Contribution

BS conceptualized the project did the statistical analysis, drafting, revision & writing of manuscript. YS did the data collection. MM did the literature search and review the draft.

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glomerulonephritis, the presence of crescents in $\geq 10\%$ of glomeruli on light microscopy is required.⁴

Recent studies from South Asia have highlighted regional variations in CresGN presentation and etiology. A study from India, reviewing 200 CresGN cases from over 8,600 kidney biopsies, found immune-complex-mediated CresGN (type II) to be the most common subtype (46.5%), followed by pauci-immune (type III, 38%) and anti-GBM disease (type I, 15.5%).³ Another study from South China, which reviewed 528 cases of crescentic GN, reported a higher prevalence of immune-complex-mediated disease (type II, 62.7%) compared to pauci-immune (type III, 25.8%) and anti-GBM disease (type I, 11.6%). Among the immune-complex-mediated cases, lupus nephritis (34.3%) and IgA nephropathy (17.4%) were the most common etiologies. The study also noted that 5-year renal survival was poorest for type I (17.6%), followed by type III (44.3%), and best for type II (70.1%). These findings underscore the influence of geographical and genetic factors on CresGN subtype distribution.¹ In Pakistan, data on CresGN remain limited. Another study from SIUT Karachi reported that among 134 patients with pauci-immune necrotizing glomerulonephritis (PING), 66 (49.5%) were anti-neutrophil cytoplasmic antibodies (ANCA)-negative.⁵ Similarly, a study from Aga Khan University Hospital, Karachi demonstrated that from 977 renal biopsies over an 11-year period, IgAN was found in 50 patients (5.1%), with crescents observed in 38% of cases.⁶ That said, neither study fully explored immunofluorescence features or applied comprehensive histopathological subtyping according to standardized systems. Moreover, recent Pakistani studies have not yet combined detailed crescent typing with immunofluorescence subtyping in one cohort. Addressing this gap could help strengthen the evidence base for locally relevant diagnostic and treatment strategies.

It is important to distinguish CresGN as a histopathological diagnosis from Rapidly Progressive Glomerulonephritis (RPGN), which is a clinical syndrome characterized by acute kidney injury and rapid decline in renal function. While CresGN is the most common histopathological finding in RPGN, not all cases of CresGN present with RPGN.^{2,7} Furthermore, ANCA-associated glomerulonephritis represents a subset of pauci-immune CresGN, but pauci-immune CresGN can also be ANCA-negative, and CresGN may also be immune-complex mediated or anti-GBM antibody-mediated.⁷⁻⁹ The present study focuses on the histopathological and immunofluorescence characterization of CresGN, irrespective of clinical presentation or ANCA status.

Immunofluorescence microscopy plays a central role in the classification of CresGN into pauci-immune, immune-complex mediated, and anti-GBM antibody-mediated subtypes. Pauci-immune CresGN is defined by the absence or only trace/weak focal deposition of immunoglobulins and complement components on immunofluorescence, distinguishing it from immune-complex mediated disease which shows strong, diffuse staining.^{4,7} While ANCA serology provides additional information regarding systemic vasculitis association, the immunofluorescence pattern remains the gold standard for the histopathological sub-classification of CresGN.^{4,8} This study utilized immunofluorescence as the primary modality for subtyping, recognizing that ANCA testing would be a valuable complementary investigation.⁸

Therefore, this study aimed to determine the histopathological and immunofluorescence findings on kidney biopsies in patients with CresGN in a local cohort. Specifically, this study sought to: (1) characterize the morphological types and distribution of crescents; (2) sub-classify CresGN based on immunofluorescence patterns; and (3) describe the histopathological features including interstitial fibrosis, tubular atrophy, and acute tubular injury. Clinicopathological correlation was not the primary aim of this descriptive cross-sectional study.

Methods

This descriptive cross-sectional study was designed to incorporate biopsy samples from all adult patients who received a diagnosis of CresGN. The research was conducted at the Department of Histopathology at the Sindh Institute of Urology and Transplantation (SIUT), located in Karachi, Pakistan, from April 15, 2023, to October 14, 2023.

Due to the rarity of CresGN, census based eligible cases available during the six-month investigation period were included using convenience sampling method. Written informed consent was obtained from all participants prior to inclusion in the study. During the study period, a total of 68 biopsy specimens with a diagnosis of CresGN were identified. Of these, 8 specimens were excluded: 3 were pediatric cases (<18 years), 4 had fewer than 7 glomeruli per section (<7 glomeruli), and 1 had incomplete clinical data. Thus, 60 biopsy specimens were included in the final analysis.

Adult patients (age ≥ 18 years) undergoing kidney biopsy at SIUT with histopathological confirmation of CresGN defined as the presence of cellular, fibrocellular, or fibrous crescents in $\geq 10\%$ of glomeruli on light microscopy (consistent with the

definition used in this study), with availability of complete clinical data (serum creatinine, urinalysis, immunofluorescence patterns), were included. However, pediatric patients (age <18 years), inadequate biopsy samples (<7 glomeruli per slide) for definitive diagnosis, secondary CresGN due to non-immune causes (e.g., severe hypertension, thrombotic microangiopathy), those with missing or incomplete clinical/histopathological data, repeat biopsies from the same patient (only the first diagnostic biopsy was included) were excluded.

The biopsy tissues were preserved and processed using hematoxylin and eosin (H&E), as well as silver stain, and trichrome stain. Microscopic examination of the slides was conducted following standard protocols.

For immunofluorescence, fresh kidney biopsy tissue was embedded in OCT compound (Tissue-Tek), snap-frozen in liquid nitrogen, and stored at -80°C until processing. Frozen sections of 4-µm thickness were cut using a cryostat (Leica CM1950), air-dried, and fixed in acetone at 4°C for 10 minutes. Fluorescein isothiocyanate (FITC)-conjugated antibodies were used and sections were mounted with glycerol-PBS mounting medium and examined under a fluorescence microscope (Olympus BX53) equipped with appropriate filters.

Known positive renal biopsy sections and negative controls were included with each staining run. Positivity was graded semi-quantitatively on a scale of 0 to 3+ based on intensity and distribution as negative, 1+, 2+ and 3+. A staining intensity of ≥2+ in a diffuse or segmental distribution was considered significant for immune-complex deposition. The classification of CresGN into pauci-immune versus immune-complex mediated subtypes was based solely on immunofluorescence findings, which is the standard histopathological approach for subtyping.

Berden classification was applied to further sub-classify CresGN cases based on the proportion of crescentic, sclerotic, and mixed glomerular lesions.

Interstitial fibrosis and tubular atrophy (IF/TA) were graded semi-quantitatively as: mild (involving <25% of cortical area), moderate (25-50%), or severe (>50%) according to the Banff classification criteria. Acute tubular injury (ATI) was defined as the presence of tubular epithelial cell simplification, loss of brush border, tubular dilatation, and/or the presence of cellular debris within tubular lumens, and was graded as present or absent.

Relevant demographic data, laboratory numbers, test results, final diagnoses, and

immunofluorescence patterns for CresGN were recorded using a structured proforma. Each individual crescent observed in the biopsy specimen was counted and categorized as cellular, fibrocellular, or fibrous. Where a glomerulus contained multiple crescents, each crescent was counted separately. The total number of crescents per patient was calculated by summing all crescents across all glomeruli in the biopsy.

Data entry and analysis were performed using the Statistical Package for Social Sciences (SPSS) software (version 22.0). Descriptive statistics were used to summarize the data, with frequencies and percentages calculated for categorical variables, including types of crescents, laboratory findings, and histopathological and immunofluorescence outcomes.

Results

Based on the histopathological analysis, the majority of patients had two biopsy cores submitted for evaluation (n=48, 80%). The average length of these cores was 0.7 cm ± 0.24 cm, and they ranged from a minimum of 0.4 cm to a maximum of 1.2 cm. The mean number of glomeruli observed per sample was 14, ranging from 7 to 21. The cellular crescent was identified as the most frequently encountered type, present in 40% of cases. Furthermore, all biopsy samples exhibited some level of interstitial fibrosis and tubular atrophy (IF/TA) as well as acute tubular injury (ATI). Mild IF/TA was the most prevalent severity, identified in 28 cases (46.7%) (Table-1).

An analysis of the individual crescent types across all samples confirmed that the cellular crescent was the most common morphological variant. A total of 450 crescents were identified across 60 patients (Table-2).

Immunofluorescence findings were used to sub-classify CresGN. Based on immunofluorescence criteria, the pauci-immune group was the most common type, identified in 55 patients (91.7%). These cases showed no significant immunoglobulin or complement deposition (negative or only weak focal staining, defined as <2+ intensity). It is important to note that this classification is based solely on immunofluorescence findings, as ANCA serology was not available. Among these, five cases showed weak focal positivity for IgG, IgM, C3, and C1q (1+ intensity), but this was deemed insufficient for an immune-complex diagnosis (Table-3).

Table 1: Histopathological findings of the participants. (n=60)

Variables	Category	N	%
Number of cores	One	12	20.0
	Two	48	80.0
Components of renal parenchyma	Cortex only	4	6.7
	Cortex and Medulla both	56	93.3
Crescent type	Fibrous and Fibrocellular	8	13.3
	Fibrocellular and Cellular	16	26.7
	All Fibrous	12	20.0
	All Cellular	24	40.0
Interstitial fibrosis and tubular atrophy (IF/TA)	Not present	8	13.3
	Mild (<25%)	28	46.7
	Moderate (25-50%)	16	26.7
	Severe (>50%)	8	13.3
Acute tubular injury (ATI)	Present	60	100.0
	Absent	0	0.0

Table 2: Summary of crescent types in the study cohort. (n=60)

Crescent Type	Frequency of Total Crescents	Mean per Patient ($\pm$ SD)	Percentage of Total Crescents
Cellular	295	4.9 $\pm$ 6.1	65.6
Fibrous	90	1.5 $\pm$ 4.1	20.0
Fibrocellular	65	1.1 $\pm$ 1.6	14.4
Total crescents	450	7.5 $\pm$ 5.8	100

Table 3: Immunofluorescence-based sub-classification of CresGN. (n=60)

CresGN Subtype	n	%	Key Immunofluorescence Pattern
Pauci-immune	55	91.7	Negative for immunoglobulins and complements; or weak focal (1+) positivity for IgG, IgM, C3, and C1q
Immune-mediated (C3-dominant)	5	8.3	Moderate (2+) staining for C3 only; negative for immunoglobulins and C1q
Immune-complex	0	0	Strong, diffuse staining for immunoglobulins and/or complements

A further sub-classification of CresGN according to Berden classification (based on the proportion of crescentic, sclerotic, and mixed lesions) showed that the majority of cases (n=25, 41.7%) belonged to the crescentic category, followed by the mixed category (n=20; 33.3%) and sclerotic category (n=15; 25%).

Discussion

This study used a crescent threshold of $\geq 10\%$ of glomeruli for the diagnosis of CresGN, consistent with standard clinical practice. However, it is worth noting that some earlier studies have used higher thresholds (e.g., $\geq 50\%$ crescent involvement) which may select for more severe cases. This methodological difference may contribute to variations in reported CresGN prevalence and subtype distribution across studies. Furthermore, current study included biopsies with a minimum of 7 glomeruli, rather than the more stringent 10 glomeruli threshold used in some centers, was necessary due to the limited specimen sizes encountered in clinical practice. This

pragmatic approach may have introduced some heterogeneity in the assessment of crescent percentage but reflects the reality of diagnostic renal biopsy practice in present setting.

On further subtyping of CresGN, it was found that 55 out of 60 patients had pauci-immune CresGN with no significant immunoglobulin or complement deposition. Interestingly, five patients in this cohort showed positivity of C3 only. This was classified as C3-dominant CresGN. Its differentials include post-infectious GN and C3 glomerulopathy, which can be confirmed by electron microscopy. Similar to the current study results, one study demonstrated that pauci-immune CresGN is the most common form of CresGN.⁸

Likewise, studies conducted previously on CresGN patients also showed that the majority had crescentic changes in their glomeruli, and the crescent type was mainly cellular.^{10,11} CresGN linked with ANCA-associated small-vessel vasculitis usually shows negative or only faint deposits of immunoglobulins.¹² A similar result was shown in this study, suggesting a pauci-immune CresGN. However, it is important to note that pauci-immune

CresGN is characterized by the absence of significant immunoglobulin and complement deposition on immunofluorescence, and while most commonly associated with ANCA-associated vasculitis, a subset of cases may be ANCA-negative.⁹

Another study reported that pauci-immune CresGN is one of the most commonly occurring forms of CresGN, mostly associated with ANCA-associated small-vessel vasculitis, but some patients could be negative for ANCAs.¹⁰ Another study reported that ANCA-negative pauci-immune CresGN could occur in 5 to 10% of cases. Furthermore, complement levels might remain normal in all types of CresGN except in the immune-mediated type.⁷

The differences regarding the renal prognosis and histopathology of ANCA-positive and ANCA-negative pauci-immune CresGN are still controversial. Some studies have reported that patients with ANCA-negative CresGN showed better renal outcomes.^{3,13} Whereas other studies have reported that patients with ANCA-negative CresGN showed more severe glomerular lesions, higher levels of proteinuria, and poorer renal outcomes.^{1,14,15} Still, some other studies showed no difference between the two types of pauci-immune CresGN.¹⁶

Another study showed a higher prevalence of pauci-immune CresGN (38.78%) followed by immune-mediated CresGN among the patients, where 57.14% of patients had kidney enlargement.¹⁷ While in the current study, almost all patients had normal-sized kidneys on ultrasound. The former study included only 28.57% individuals with AKI; however, the current study included all AKI patients, which is reflected in the differences in the results of the two studies.

The result of the current study is similar to that of several previous studies, which reported pauci-immune CresGN to be the most predominant subtype of CresGN.¹⁸⁻²⁰ In Europe, the annual incidence of pauci-immune CresGN was reported to be 10 to 20 individuals per 1 million population.^{21,22} Furthermore, pauci-immune CresGN was found to be the most common CresGN in China (n=33/56; 58.9%),²³ and in Japan, a nationwide survey of 4,179 RPGN cases conducted over five periods (1989–2015), the proportion of AAV (pauci-immune) increased steadily from 64.0% in 1989–1998 to 77.1% in 2012–2015.¹⁸ While it was not the most common form in India (n=76/200; 38%)³, South China (n=136/528; 25.8%)¹ and Egypt (n=33/101; 32.7%).²⁴

Differences in CresGN subtype prevalence across studies may reflect variations in diagnostic

criteria, patient selection, geography, and genetic predisposition. Lower crescent thresholds ($\geq 10\%$) may include milder disease than criteria requiring $\geq 50\%$ glomerular involvement. Referral patterns and biopsy timing may also influence the observed spectrum. As our cohort included only patients with biopsy-confirmed AKI, it may represent a more severe disease spectrum than unselected CresGN populations. These findings highlight the importance of detailed serological and immunofluorescence testing for accurate CresGN subtyping, which guides prognosis and treatment. For example, aggressive immunosuppression may be prioritized in pauci-immune GN with active crescents, whereas different approaches may be appropriate for immune-complex disease. However, without long-term follow-up, these therapeutic implications remain speculative and require confirmation in longitudinal studies.

This study had several limitations. ANCA serology was not performed; therefore, although immunofluorescence suggested pauci-immune predominance, ANCA-associated and ANCA-negative pauci-immune CresGN could not be distinguished. The single-center, convenience-sampling design may have introduced selection bias and overrepresented severe cases, limiting generalizability. The small sample size (n=60) reduced statistical power for subgroup analyses. The cross-sectional design and six-month recruitment period prevented assessment of long-term outcomes and may have introduced temporal bias. Additionally, the sample size was not statistically calculated but based on available cases. These limitations should be considered when extrapolating the findings to the broader Pakistani population.

Conclusion

Conclusively, cellular crescents were the most frequent morphological type, and pauci-immune crescentic glomerulonephritis was the predominant subtype based on immunofluorescence. These findings highlighted the importance of comprehensive histopathological and immunofluorescence analysis for accurate diagnosis and subtyping, which is critical for guiding management. Future studies incorporating ANCA serology and long-term follow-up are recommended to further characterize the clinical outcomes of these patients.

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Availability of Data: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical Approval: The Ethical Review Committee of Sindh Institute of Urology and Transplantation, Karachi approved the study via letter no. SIUT-ERC-2022/A-389 dated 30/07/2022.

Conflict of Interest: None declared.

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