

Clinicopathological features and prognostic analysis of 49 cases with crescentic glomerulonephritis

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Abstract. Rapidly progressive glomerulonephritis (RPGN), characterized by rapid kidney dysfunction caused by aggressive glomerulonephritis, is usually associated with crescentic glomerulonephritis (CrGN). In the present study, the data from patients with CrGN were retrospectively analyzed at a tertiary medical center in China with the aim of investigating the clinicopathological features and the association of the type of CrGN with the prognosis. The renal biopsies of 49 patients diagnosed with CrGN were obtained between December 2011 and July 2016. Of the 49 patients, 11 patients (22.45%) had type I CrGN, 19 (38.78%) had type II CrGN and 19 (38.78%) had type III CrGN. The majority of CrGN patients exhibited multiple-system involvement and 28 patients (57.14%) had kidney enlargement. Proportions of patients with acute kidney injury (AKI), acute kidney diseases without AKI, and chronic kidney disease were 28.57, 46.94 and 24.49%, respectively. Among the 3 types of CrGN, patients with type I CrGN tended to have a higher proportion of AKI with more cellular crescent formation, and higher serum creatinine and retinol binding protein. Circulating anti-GBM antibodies were present in all type I CrGN patients and anti-neutrophilic cytoplasmic autoantibodies were detected in 84.21% of patients with type III CrGN. Type III CrGN patients had a superior kidney survival, whereas type I CrGN patients had the worst kidney prognosis ($P < 0.001$). There was no significant difference in overall patient survival among the 3 types of CrGN. CrGN remains the primary cause of critical illness in RPGN patients.

There was much heterogeneity between the different subtypes of CrGN. Patients with type I tended to have an acute onset and had the poorest kidney survival.

Introduction

Rapidly progressive glomerulonephritis (RPGN) has been characterized by the rapid loss of kidney function and is usually caused by crescentic glomerulonephritis (CrGN) within a few weeks or months. CrGN is defined as crescents involving $>50\%$ of the glomeruli (1). CrGN can be divided into 3 types according to immunofluorescence microscopy: Type I is defined as a linear deposition of immunoglobulins along the glomerular basement membrane (GBM); type II is defined as glomerular immune complex deposition; and type III is defined as glomerular pauci-immune deposition (2). Epidemiologic data on CrGN have been reported by large national kidney biopsy registries from India (3), Japan (4), Saudi Arabia (5), the US (6), Spain (7) and China (8,9). The prevalence of CrGN ranges from 1.56 to 10% of total kidney biopsies.

The exact mechanism of immune-pathogenesis in crescent formation remains elusive. Studies have revealed that a key stage is the breakage of the GBM, allowing plasma proteins to enter the Bowman's capsule (10-12). A second key stage in crescent formation is the accumulation of fibrin within the Bowman's capsule, which provokes the proliferation of parietal epithelial cells. In addition, macrophages, CD4⁺ T cells and CD8⁺ T cells are important molecules that are involved in the immune-pathogenesis of crescent formation (10,13). The standard induction therapy for CrGN includes oral prednisone combined with cyclophosphamide (CTX) (10). Many physicians also frequently use pulse methylprednisolone prior to the administration of high dose oral steroids in addition to CTX. Plasmapheresis may be also used to remove circulating auto-antibodies or immune complexes. Early treatment is of vital importance for patients with CrGN (14). The prognosis of patients with CrGN is regarded as having been improved over the past few years. The 5-year cumulative renal survival rates of patients with type I, II and III CrGN have reached 17.6, 70.1 and 44.3%, respectively, in China (8). Certain clinicopathological features, including the subtype (8), oliguria and serum creatinine (SCr) (3), age and an elevated percentage of

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glomeruli with crescents (5), have a significant impact on the prognosis of patients with CrGN. The purpose of the present study was to assess the clinicopathological features and outcomes of patients with CrGN.

Patients and methods

Population and data collection. A total of 49 consecutive patients with biopsy-proven CrGN diagnosed between December 2011 and July 2016 at the Department of Nephrology of Xiangya Hospital of Central South University (Changsha, China) were recruited for the present retrospective study. During this period, 1,312 renal biopsies were performed. Patients with <10 non-sclerotic glomeruli in sampled renal tissue were excluded. CrGN was defined as the presence of crescents within the Bowman's space in >50% of the total glomeruli in the kidney biopsy (15).

Once patients provided written informed consent to participate in the study, baseline demographic data, including age, sex, duration of disease and clinicopathological, laboratory and ultrasonography parameters, were obtained from the electronic medical record system of the hospital. Details regarding the process of treatment and outcome, including SCr levels, dependence on dialysis, outcome concerning survival and cause of death, were also collected. Patients were evaluated at the time of diagnosis, at 1, 2 and 3 months, and then every 3 months until the end of the study. Patients were followed up from diagnosis until end-stage renal disease (ESRD) was reached or death or the final follow-up date (July 30, 2017). All follow-up data were collected from the hospital's electronic medical records and by contacting the individual patients directly.

Classification of CrGN. As described previously, each renal specimen was assessed by direct immunofluorescence, light and electron microscopy (16). These experiments had been performed with the samples at the time of diagnosis. CrGN was defined as $\geq 50\%$ of the total glomeruli having large crescents as evaluated by light microscopy. On the basis of the immunofluorescence microscopy results, CrGN was classified into 3 types. By definition, type I CrGN exhibited linear deposits of immunoglobulins (Ig) along the GBM, which was always accompanied by anti-GBM antibodies in the serum. Type II was characterized by granular immune-complex deposition on the glomerular tuft, while in type III, which is also referred to as pauci-immune CrGN, immunofluorescence was negative or deposits of Ig were rare (2).

Definitions. The definitions of acute kidney injury (AKI) and chronic kidney disease (CKD) are widely accepted, while acute kidney diseases and disorders (AKD) is a relatively novel concept (17). Hence, the criteria for AKI, AKD without AKI and CKD were used to illustrate the different clinical characteristics of patients with CrGN. AKI was defined as an increase in SCr by ≥ 0.3 mg/dl ($26.5 \mu\text{mol/l}$) within 48 h or an increase in SCr to 1.5 times the baseline value within 7 days or a urine volume of <0.5 ml/kg/h over 6 h. AKD without AKI was defined as an estimated glomerular filtration rate (eGFR) of <60 ml/min per 1.73 m^2 for <3 months, a decrease in eGFR $\geq 35\%$, an increase in SCr >50% or abnormalities of kidney

structure based on urinary markers and imaging studies for <3 months. CKD was defined as eGFR <60 ml/min per 1.73 m^2 or kidney structural damage for >3 months (8).

In addition to the major features of the kidney, certain extrarenal manifestations coexisted, including hematological disorders, serositis and pneumonia. For simplicity, multiple-system involvement (MSI) was uniformly defined to summarize the clinical manifestation, i.e. involvement of at least one other organ in addition to the kidney. It is worth mentioning that, since anemia in CrGN is one of the most common complications, it was not considered to be an organ-involving manifestation.

Statistical analysis. All data were analyzed using SPSS version 19.0 (IBM Corp.). Quantitative data were expressed as the mean \pm standard deviation, n (%) or median with interquartile range. All parameters were compared using the χ^2 test or Fisher's exact test for categorical data and one-way analysis of variance (ANOVA) or Kruskal-Wallis test for continuous data. The least-significant difference test and Bonferroni correction were used as post-hoc tests that followed ANOVA and the Kruskal-Wallis test respectively. Kaplan-Meier curves with log-rank tests were used to analyze patient survival as well as renal survival. $P < 0.05$ was considered to indicate statistical significance.

Results

Demographics and kidney manifestations. In the present retrospective study, CrGN accounted for 3.73% (49/1312) of the total patients receiving renal biopsies during the study period at the Department of Nephrology, Xiangya Hospital of Central South University (Changsha, China). Of the 49 cases identified, 11 (22.45%) patients were classified as type I, 19 (38.78%) as type II and the remaining 19 (38.78%) as type III. A total of 23 (46.94%) were females and 26 (53.06%) were males, with an average age of 44.51 ± 15.95 years at the time-point of diagnosis (Table I). The duration of symptoms prior to admission varied greatly from 7 days to 13 months, with a median duration of 86 days. However, no significant differences in the demographic data were determined among the 3 types of CrGN.

Concerning the clinical characteristics, MSI was observed in most CrGN patients (97.96%), 29 patients (59.18%) had hypertension and 9 (18.37%) had oliguria. Furthermore, all CrGN patients had hematuria, including microscopic or gross hematuria. The proportions of patients with AKI, AKD without AKI, and CKD were 28.57, 46.94 and 24.49%, respectively. In addition, patients with type I disease tended to have an acute onset, with 72.73% of patients presenting with AKI, which was significantly different from the other two groups ($P = 0.001$; Table I).

Laboratory and ultrasonography data. In general, patients with kidney diseases have varying degrees of anemia (15), and this was also observed in the CrGN patients of the present study. As presented in Table II, patients with type II CrGN had less severe anemia than the other two subtypes ($P < 0.05$ type II vs. type I; $P < 0.05$ type II vs. type III). The average baseline SCr level of all patients was $612 \pm 416 \mu\text{mol/l}$. In

Table I. Baseline demographic and clinicopathological characteristics of patients with crescentic glomerulonephritis.

Item	Total (n=49)	Type I (n=11)	Type II (n=19)	Type III (n=19)	P-value
Age (years)	44.51±15.95	37.09±15.14	43.74±18.06	49.58±12.80	0.113
Female sex	23 (46.94)	3 (27.27)	12 (63.16)	8 (42.11)	0.143
Duration of disease (days)	86 (30-100)	52 (17.5-60)	90 (25.5-90)	102 (32.5-120)	0.16
Hypertension	29 (59.18)	8 (72.73)	10 (52.63)	11 (57.89)	0.531
Oliguria	9 (18.37)	3 (27.27)	2 (10.53)	4 (21.05)	0.484
Anuria	3 (6.12)	1 (9.09)	1 (5.26)	1 (5.26)	0.905
AKI	14 (28.57)	8 (72.73)	3 (15.79) ^a	3 (15.79) ^a	0.001
AKD without AKI	23 (46.94)	2 (18.18)	11 (57.89)	10 (52.63)	0.09
CKD	12 (24.49)	1 (9.09)	5 (26.32)	6 (31.58)	0.404
MSI	48 (97.96)	10 (90.91)	19 (100)	19 (100)	0.224

Values for categorical variables are presented as n (%) and values for continuous variables as the mean ± standard deviation or median (interquartile range). ^aP<0.05 vs. type I. AKD, acute kidney diseases and disorders; AKI, acute kidney injury; CKD, chronic kidney disease; MSI, multiple-system involvement.

Table II. Laboratory and ultrasonography data by type of crescentic glomerulonephritis.

Parameter	Total (n=49)	Type I (n=11)	Type II (n=19)	Type III (n=19)
Hemoglobin (g/l)	83.98±20.87	78.18±22.35	94.74±19.98 ^a	76.58±16.87 ^b
Albumin (g/l)	28.1±5.05	26.98±3.77	28.15±5.61	28.71±5.64
Proteinuria (g/day)	2.32±2.49	2.90±3.85	2.91±2.43	1.39±1.14 ^{a,b}
Scr (μmol/l)	612±416	928±381	502±410 ^a	537±365 ^a
NAG (u/l)	28.3±18.7	23.9±11.8	31.0±22.3	26.9±17.0
RBP (mg/l)	14.9±19.3	36.6±27.0	16.3±20.5 ^a	6.7±6.7 ^a
C4 (mg/l)	253 (208-281)	309 (235-382)	239 (208-274) ^a	233 (194-264) ^a
C3 (mg/l)	898 (744-1,045)	1,039 (830-1,230)	882 (758-984)	829 (681-978)
IgG (g/l)	12.7 (7.9-16.5)	9.2 (7.0-10.0)	10.8 (6.7-14.3)	17.0 (13.9-20.2) ^{a,b}
IgA (mg/l)	2,611 (1,675-3,285)	2,193 (1,385-2,430)	2,678 (1,790-3,255)	2,807 (1,770-3,610)
IgM (mg/l)	1,232 (811-1,540)	1,124 (723-1,490)	1,298 (843-1,710)	1,228 (860-1,530)
ANCA positive	19/46 (41.30)	0/10 (0)	3/17 (17.65)	16/19 (84.21) ^{a,b}
GBM	12/32 (37.50)	11/11 (100)	0/9 (0) ^a	1/12 (8.33) ^a
MPO-ANCA positive	13/32 (40.63)	0/11 (0)	2/9 (22.22)	11/12 (91.67) ^{a,b}
PR3-ANCA positive	1/32 (3.13)	0/11 (0)	1/9 (11.11)	0/12 (0)
Kidney enlargement	28/49 (57.14)	8/11(72.73)	12/19 (63.16)	8/19 (42.11)

Values for categorical variables are given as n (%) and values for continuous variables as the mean ± standard deviation or median (interquartile range). ^aP<0.05 vs. type I and ^bP<0.05 vs. type II. Scr, serum creatinine; ANCA, antineutrophil cytoplasmic antibody; C3, complement 3; IgA, immunoglobulin A; GBM, glomerular basement membrane; MPO, myeloperoxidase; NAG, N-acetyl-b-D-glucosaminidase; PR3, proteinase 3; RBP, retinol binding protein.

accordance with the clinical presentation, the SCr level and the kidney tubular injury parameter retinol binding protein of patients with type I CrGN were markedly higher than those in patients with the other two types (P<0.05). Of the patients with type III CrGN, 84.21% had serum anti-neutrophilic cytoplasmic autoantibodies (ANCA), and they had a lower amount of proteinuria. As expected, circulating anti-GBM antibodies were detected in all patients with type I CrGN. In addition, patients with type I CrGN had a high level of serum complement 4 (P<0.05 type I vs. type II; P<0.05 type I

vs. type III) and patients with type III CrGN had a relatively high level of serum IgG (P<0.05 type III vs. type I; P<0.05 type III vs. type II). Finally, kidney enlargement was identified in 57.14% of patients. However, there were no obvious differences in kidney enlargement or serum albumin levels among the different types of CrGN.

Primary diseases of patients with type II CrGN. Regarding primary disease, the composition of the 19 patients with type II CrGN was as follows: 8/19 (42.11%) had IgA

Table III. Primary diseases of patients with type II CrGN.

Variables	n (% of Type II CrGN)
IgA nephropathy, n (%)	8/19 (42.11)
Lupus nephritis, n (%)	4/19 (21.05)
Anti-nuclear antibodies positive, n (%)	4/4 (100)
Anti-double stranded DNA antibodies positive, n (%)	3/4 (75)
Anti-Smith antibodies positive, n (%)	¼ (25)
ANCA-associated glomerulonephritis, n (%)	3/19 (15.79)
H-S purpura glomerulonephritis, n (%)	2/19 (10.53)
Hepatitis B virus-associated nephritis, n (%)	1/19 (5.26)
Idiopathic immune-complex CrGN, n (%)	1/19 (5.26)

CrGN, crescentic glomerulonephritis; IgA, immunoglobulin A; ANCA, anti-neutrophilic cytoplasmic autoantibodies; H-S, Henoch-Schönlein.

nephropathy, 4/19 (21.05%) had lupus nephritis, 3/19 (15.79%) had ANCA-associated glomerulonephritis, 2/19 (10.53%) had Henoch-Schönlein purpura glomerulonephritis, 1/19 (5.26%) had hepatitis B virus-associated nephritis and 1/19 (5.26%) had idiopathic immune-complex CrGN (Table III). All 4 patients diagnosed with lupus nephritis had serum anti-nuclear antibodies, 3 of whom had anti-double stranded DNA (anti-dsDNA) antibodies and 1 had positive anti-Smith antibodies.

Pathological characteristics. Renal biopsy from a representative case of type I CrGN revealed predominant cellular crescents and linear deposits of IgG along the GBM on immunofluorescence (Fig. 1). Among all of the subjects with CrGN, the mean overall percentages of glomeruli with crescents, cellular crescents and fibrous crescents were 65.84 ± 13.25 , 35.34 ± 17.81 and $30.49 \pm 15.71\%$, respectively (Table IV). Compared with the other two subtypes, patients with type I CrGN had a significantly higher percentage of cellular crescents ($P < 0.05$). Furthermore, patients with type II CrGN had a lower percentage of sclerosis than type III.

Treatment, and overall and renal survival. As presented in Table V, only 14 patients (28.57%) of the present cohort received plasma exchange, and even of the patients with type I CrGN, only 63.64% received plasma exchange. With regard to the treatment of plasma exchange between type I CrGN and type II CrGN, the difference was significant ($P < 0.05$). Of the total patients, 48 (97.96%) and 41 (83.67%) received corticosteroids and cyclophosphamide, respectively. A total of 35 patients (71.43%) were treated with intravenous pulses of methylprednisolone at diagnosis.

The renal survival of the patients is presented in Fig. 2. Patients with type III CrGN had superior renal survival, whereas those with type I CrGN had the poorest renal prognosis ($P = 0.002$, type I vs. type II; $P < 0.01$, type I vs. type III; $P = 0.15$, type II vs. type III). Regarding patient survival, no significant difference was present among the 3 types of CrGN (Fig. 3).

Discussion

Validation studies of epidemiologic data on CrGN have been performed in certain countries (4). In the present retrospective study, CrGN accounted for 3.73% of the total patients receiving renal biopsies during the study period at our center, which is higher than previously reported rates from China (8,9,15), but was similar to results from an Indian study (3). In addition, an equal proportion of pauci-immune and immune complex GN was encountered in patients with CrGN at our center, followed by anti-GBM disease. This result was different from that of several previous studies, by which pauci-immune CrGN was reported to be the predominant type (3,4,6,7). In Europe, the annual incidence of renal vasculitis was reported to be 10-20 per 1 million individuals (18); the incidence in China is currently not available. According to a study by Chen *et al* (19) >400 patients with ANCA-associated vasculitis (AAV) were diagnosed during an 8-year period in their referral diagnostic center in Peking University First Hospital in China. Anti-GBM disease is considered a rare disease, with an incidence of 1-2 cases per million per year in China (20). While the incidence in China is not available, >30 anti-GBM-positive sera from new patients are screened annually at Peking University First Hospital (21), indicating that, relative to other hospitals worldwide, hospitals in China encounter more patients with anti-GBM disease. The present study reported a higher proportion of patients with type I CrGN among the CrGN cases studied compared with the results of previous studies (3,4,6,7) and further supports the notion that hospitals in China may encounter more patients with anti-GBM disease. In type II CrGN, IgA nephropathy was the most common primary disease, which is consistent with previous studies (16,21-25).

In certain severely ill patients, renal biopsy cannot always be smoothly and quickly performed. Thus, specific serum markers [serum myeloperoxidase (MPO-ANCA) or proteinase 3 (PR3-ANCA)] are important and are correlated with AAV. Of those patients with granulomatosis with polyangiitis (Wegener's granulomatosis), 90% have PR3-ANCA and patients with microscopic polyangiitis have the highest frequency of MPO-ANCA (26). ANCA themselves are deemed to be pathogenic in these diseases (27). Serum ANCA is considered a basis for the recognition of ANCA-associated vasculitis, which frequently presents as type III CrGN. However, it was also detected in a small number of patients with type I and II CrGN. It was reported that patients with negative ANCA had better renal outcomes (8,28,29). However, others have reported that patients without ANCA had higher levels of proteinuria, more severe glomerular lesions and poorer renal outcomes (8). In the present study, the majority of patients with type III CrGN were MPO-ANCA-positive, which was similar to the result of a previous study from China (8). In the present cohort, serum ANCA was detected in 17.65% of cases with type II CrGN, which is higher than the percentage reported in the above previous study (8). Lin *et al* (15) reported that glomerular necrosis and crescent formation were associated with ANCA in immune-complex CrGN. Furthermore, ANCA and immune complex deposition possibly act synergistically (15). The renal survival in patients with type II CrGN in the present study was lower than that previously reported (3,8,9), perhaps due to a higher ratio of serum ANCA in type II CrGN.

Table IV. Pathological characteristics of patients with crescentic glomerulonephritis.

Item	Total (n=49)	Type I (n=11)	Type II (n=19)	Type III (n=19)
Cellular crescents (%)	35.34±17.81	48.31±18.69	32.67±16.61 ^a	30.52±15.51 ^a
Fibrous crescents (%)	30.49±15.71	22.46±13.18	31.58±16.65	34.06±15.18
Sclerosis (%)	19.45±18.16	21.53±25.48	12.63±13.84	25.05±15.56 ^b
Crescents (%)	65.84±13.25	70.77±14.67	64.24±13.22	64.58±12.43

Values are expressed as the mean ± standard deviation. ^aP<0.05 vs. type I, ^bP<0.05 vs. type II.

Table V. Treatment of patients with crescentic glomerulonephritis.

Item	Total (n=49)	Type I (n=11)	Type II (n=19)	Type III (n=19)	P-value
Plasma exchange	14 (28.57)	7 (63.64)	1 (5.26) ^a	6 (31.58)	0.003
Cyclophosphamide	41 (83.67)	10 (90.91)	15 (78.95)	16 (84.21)	0.885
Corticosteroids	48 (97.96)	11 (100)	19 (100)	18 (94.74)	1.000
Methylprednisolone pulse	35 (71.43)	10 (90.91)	15 (78.95)	10 (52.63)	0.056
Other immunosuppressive agents	9 (18.37)	2 (18.18)	5 (26.32)	2 (10.53)	0.522

Values are expressed as n (%); ^aP<0.05 vs. type I.

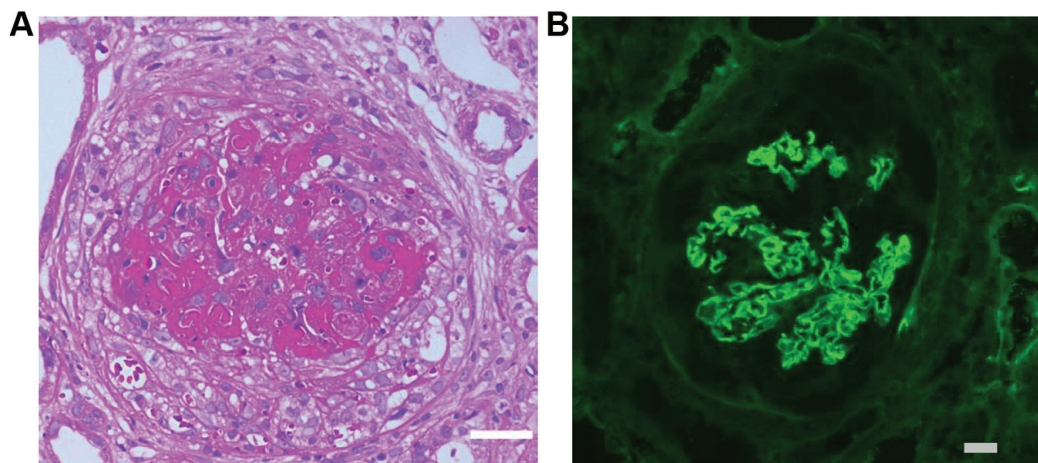


Figure 1. (A) Renal biopsy from a case of type I crescentic glomerulonephritis exhibiting predominantly cellular crescents (H&E staining; scale bar, 40 μ m). (B) Linear deposits of IgG along the glomerular basement membrane (green) on immunofluorescence (scale bar, 40 μ m).

Several clinical characteristics were reported to be associated with renal outcome in CrGN, including oliguria and SCr (3,8). A clinical grading system for patients with RPGN based on SCr and other clinical manifestations has been established to predict the prognosis (4). The average SCr concentration of patients at our center was much higher than that of patients from Spain (7), India (3), the US (6) and Japan (4). Patients with pauci-immune CrGN had higher SCr levels than those with immune complex CrGN at presentation in certain studies from the US (6) and Saudi Arabia (5), which was consistent with the present results. The medium proteinuria did not reach the standard of nephrotic syndrome, which was lower than that in studies from Saudi Arabia (5) and the US (6). Oliguria was similar to another study from China (8).

The association between histopathological features and prognosis has been previously reported (3,5). The percentage of sclerosed glomeruli is one of the independent predictors of renal death (5,8). The percentage of sclerosed glomeruli was determined to be significantly different between the pauci-immune and immune complex CrGN, but renal survival was comparable in the two groups in the present study. The average percentage of sclerosed glomeruli in the current study was lower than that in another study from Saudi Arabia (5). There were no significant differences in the proportions of glomeruli exhibiting crescents and fibrous crescents between the three groups in the current study, which was consistent with the results of previous studies (3,5,8).

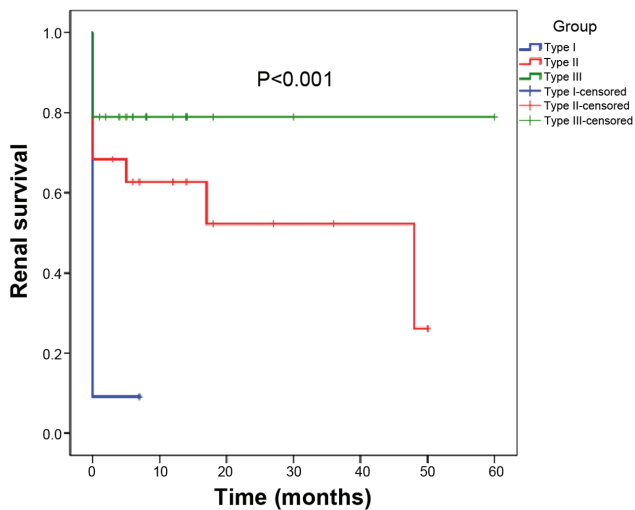


Figure 2. Renal survival of patients with different types of crescentic glomerulonephritis. Time (months) refers to the time since the start of treatment. $P=0.002$, type I vs. type II; $P<0.01$, type I vs. type III; $P=0.15$, type II vs. type III.

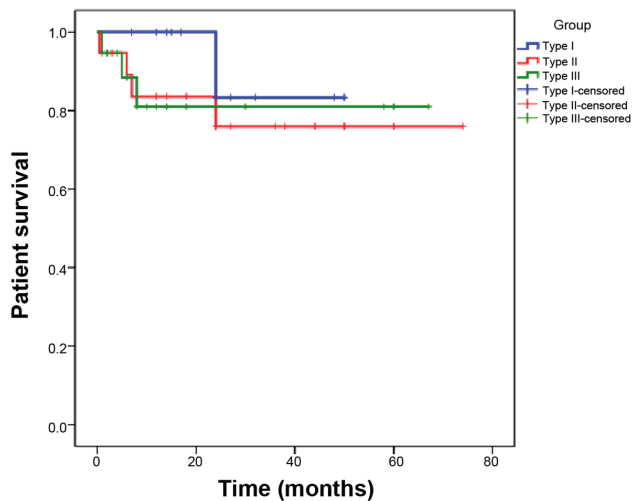


Figure 3. Survival of patients with different types of crescentic glomerulonephritis. Time (months) refers to the time since the start of treatment.

Renal replacement therapy in ESRD patients has a high cost (30). In the present study, patients with type I CrGN had the poorest renal prognosis, which has also been confirmed by previous studies (3,6,8). The 1-year kidney survival rate in the present study was lower than that reported previously (31,32). This discrepancy in results may be explained by the higher initial average SCr concentration in the present study compared to those in the previous studies (8,31). The low proportion of patients who received plasma exchange and less intensive immunosuppressive therapy may be another important reason.

Determining which type of CrGN between pauci-immune CrGN and immune complex CrGN is associated with better renal survival remains elusive. Several studies have indicated that the renal prognosis of patients with type II CrGN was superior to that of patients with type III CrGN (3,8), which is in contrast to the results reported by Han *et al* (33). Of note, in

the present study, renal survival in patients with type III CrGN was better than that in patients with type II CrGN, although the difference did not reach statistical significance. This comparison warrants further investigation in larger studies in the future.

The present study has several limitations. First, due to inclusion of only a small number of patients in the present study, there may have been a selection bias. Furthermore, follow-up was limited and a longer follow-up may be required in future studies. However, with the extension of the follow-up period, the number of cases lost to follow-up is expected to increase.

In conclusion, the present retrospective study reported that CrGN occurred in 3.37% of the total patients receiving renal biopsies during the study period at our center, which is higher than the rates reported by previous studies from China (8,15). Type I CrGN had the poorest renal prognosis. The 1-year kidney survival rate in the present study was much lower than those reported by previous studies (31,32). The results of the present study highlight the requirement for better treatments for this disease. A large national investigation on CrGN is required to improve the clinical management of these patients in the near future.

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Availability of data and materials

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

Authors' contributions

YZ, JBC, TW and JJP designed the study, analyzed the data and wrote the manuscript. TM, QQL, XA, HLY, JXP, ZZP, WSP, XZL, XCX, QLZ and PX contributed to patient enrollment and follow-up. WL and HLY analyzed the pathological data. YZ and JBC analyzed the data. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The present study was approved by the ethics review committee of Xiangya Hospital Central South University (reference no. 201403061). All patients provided written informed consent to participate in the study.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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