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Trends in biopsy-confirmed kidney disease in the adult population of Central Poland: a single-region cohort of 13-year duration (2011–2023)

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Keywords: COVID, epidemiology, glomerulonephritis, IgA nephropathy, kidney biopsy

Abstract

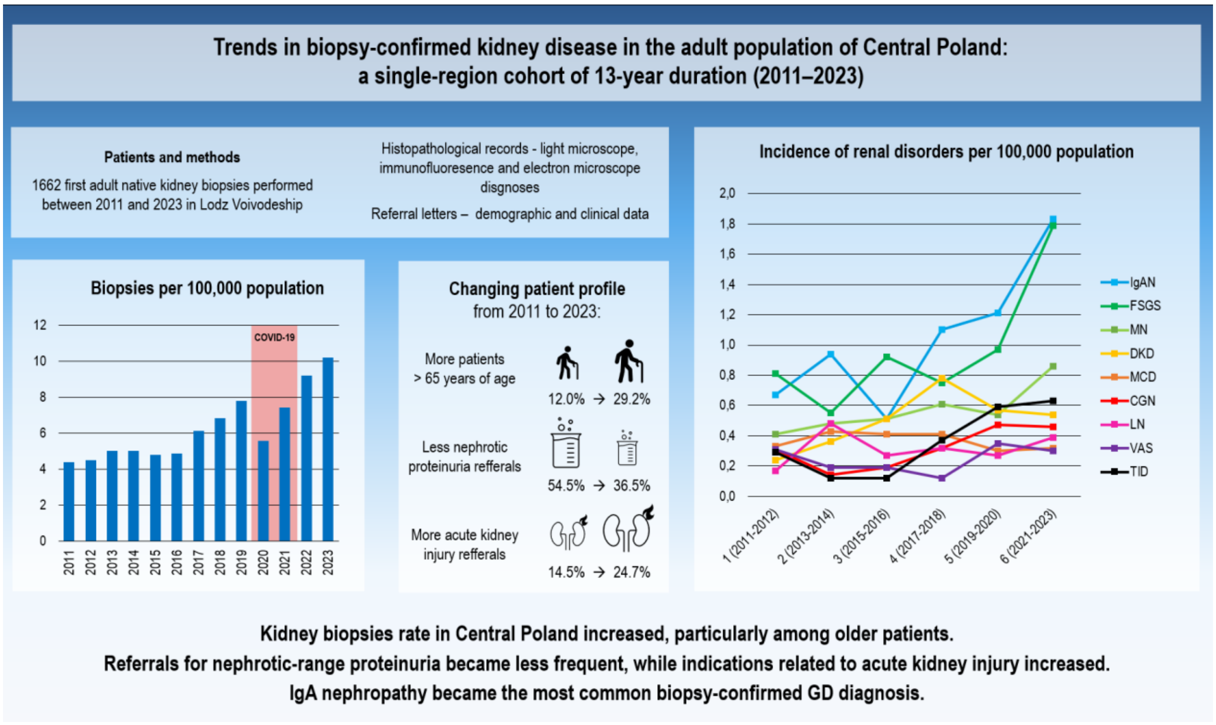
Introduction: Demographic, socioeconomic and environmental factors, including infections, vaccination and healthcare availability, may influence the spectrum of renal diseases.

Objectives: This study examines trends in biopsy-confirmed kidney disease in adult Polish population (2011-2023), with emphasis on shifts during and after the COVID-19 pandemic.

Patients and methods: We retrospectively analyzed 1,662 first native kidney biopsies performed in residents of the Lodz voivodeship (population: 2 million). Clinical and histopathological data were stratified by age, sex, and time period (pre-COVID, COVID, post-COVID) and compared with those reported by the same center in 1990–2010.

Results: Between 2011 and 2023, biopsy frequency increased from 43.9 to 102.2 per million population, with a temporary decline during COVID and a significant rise afterwards. The proportion of older patients increased, while nephrotic-range proteinuria became a less common biopsy indication. During COVID, patients presented with poorer renal function, and had higher rates of acute kidney disease. IgA nephropathy (IgAN) was the most frequent diagnosis (17.4%), with its proportion increasing during and after COVID, followed by focal segmental glomerulosclerosis (FSGS, 16.3%), membranous nephropathy (9.4%) and diabetic kidney disease (DKD, 8.0%). Minimal change disease frequency declined, other nephropathies remained stable, and a relative rise in tubulointerstitial disorders was observed. Compared with 1990–2010, the annual number of biopsies more than tripled, with a markedly older patient population and increased frequencies of FSGS, DKD and crescentic glomerulonephritis or necrotizing vasculitis.

Conclusions: Over three decades, biopsy frequency in the Lodz Voivodeship has increased, particularly among older adults, with IgAN becoming the most common diagnosis.



Introduction

Glomerular disorders (GD) constitute a heterogeneous group of kidney diseases resulting from damage of the glomerular filtration membrane, often immune-meditated, presenting with proteinuria or hematuria and potentially progressing to end-stage kidney disease (ESKD). Despite advances in serologic assessments and genetic testing, percutaneous kidney biopsy remains the gold standard for diagnostics and monitoring [1].

GD prevalence varies by geographical, environmental, racial, demographic, and socioeconomic factors [2,3]. Monitoring trends in biopsy-confirmed diagnoses is essential for clinical decision-making. Previous studies have shown changing GD patterns across time and regions [4]. These shifts may result from multiple contributing factors, including population migration, demographic aging, rising prevalence of metabolic diseases, improved access to novel diagnostic tools, as well as broader environmental influences like climate change and pollution [5]. Several countries [6-9] have established GD registries; however, Polish reports extend only up to the last decade [10-14].

The Lodz Voivodeship in central Poland has a predominantly Caucasian population of 2 million. Previously, we analyzed GD patterns of this region from 1990 to 2010 [14]. Since then, changes in diagnostic procedures and treatment, especially for immunological and infectious diseases, may have influenced prevalence of kidney diseases. The COVID-19 pandemic, which reached Poland in 2019, has been linked in some reports to various nephropathies, including collapsing glomerulopathy, membranous nephropathy (MN), IgA nephropathy, pauci-immune crescentic glomerulonephritis, and vasculitis as a result of COVID-19 infection or vaccination [15,16]. Other studies suggest that these associations may be coincidental or absent [17,18].

We aimed at evaluating trends in biopsy-confirmed nephropathies, including changes observed during the COVID and post-COVID periods, basing on all histopathological reports from first native kidney biopsies performed between 2011 and 2023 in the adult population, including demographic and clinical data from referral forms.

Patients and methods

We retrospectively analyzed records of all kidney biopsies performed in adult (≥18 years old) patients in central Poland (Lodz voivodeship) from 01.01.2011 to 31.12.2023, excluding transplant, disease monitoring and non-diagnostic (insufficient tissue sample) biopsies. Biopsies were performed in six nephrology units and evaluated at a single nephropathology center affiliated with the Medical University of Lodz by the same two consultant pathologists throughout the entire study period.

From uniform referral letters we obtained data on patients' age, sex, serum creatinine and presence of nephrotic or subnephrotic proteinuria and erythrocyturia. To ensure comparability, the estimated glomerular filtration (eGFR) rate was calculated at the time of analysis using the CKD-EPI (2009) equation, based on the serum creatinine concentration and age provided in the original referral forms. Clinical presentation was recorded as acute or chronic. Course of renal function impairment was recorded as rapidly progressive (RPGN: a ≥ 50% decline in GFR over

≤ 3 months, and evidence of glomerular injury, in the form of an active urinary sediment including hematuria), acute kidney disease (AKD: oliguria for > 6 h, rise in serum creatinine level by > 0.3 mg/dl in 2 days or by > 50% in 1 week, or GFR < 60 ml/min/1.73m^2, or markers of kidney damage for ≤ 3 months, or decrease in GFR by ≥ 35% or increase in serum creatinine by > 50% for ≤ 3 months), chronic kidney disease (CKD: GFR < 60 ml/min/1.73m^2 or markers of kidney damage for > 3 months), or without significant GFR decline (defined as $eGFR_{CKD\text{-}EPI}$ ≥ 60 ml/min/1.73m^2), based on referring clinicians' assessments [1,19].

Histopathological records included light microscopy diagnosis, immunofluorescence for IgG, IgM, IgA, C3, C1q, kappa and lambda light chains, and, when available, electron microscopy. Findings were classified as GD, tubulointerstitial disorders (TID), vasculopathies, miscellaneous (MIS), sclerotic kidney (ESKD), or normal morphology (NM); detailed diagnoses were as follows (adapted from Perkowska-Ptasińska et al.) [11].: GD including: mesangioproliferative nephropathy IgA (IgAN), mesangioproliferative nephropathy non-IgA (mesPGN non-IgA), focal segmental glomerulonephritis (FSGS), minimal-change disease (MCD), membranoproliferative glomerulonephritis (MPGN), membranous glomerulonephritis (MN), crescentic (crescents in > 50% of glomeruli) glomerulonephritis (CGN) types I (anti-GBM disease), II (complex-mediated) and III (pauci-immune), necrotizing vasculitis (VAS), lupus nephritis (LN), amyloidosis (AML), diabetic kidney disease (DKD), other GD (unclassified glomerular lesions and rare glomerulopathies – C3 glomerulonephritis, IgM nephropathy, C1q nephropathy, diffuse endocapillary glomerulonephritis, Henoch–Schönlein purpura, fibrillary glomerulonephritis, cryoglobulinemic glomerulonephritis, light chain nephropathy including monoclonal immunoglobulin deposition disease, Fabry disease, glomerulopathy in Alport syndrome, thin basement membrane nephropathy); TID including: acute tubulointerstitial nephritis (ATIN), chronic tubulointerstitial nephritis (CTIN), acute tubular necrosis (ATN), other TID (sarcoidosis, myeloma cast nephropathy and IgG4 disease); vasculopathies including: arterionephrosclerosis (hypertensive nephrosclerosis and aging nephropathy) (ANS), thrombotic microangiopathy (TMA), ischemic nephropathy, other vasculopathies (systemic sclerosis nephropathy); MIS including other nephropathies (lymphoma, polycystic kidney disease, renal cancer).

Patients were grouped by age: young (18–30), middle-aged (31–65), and older (>65). Data were divided into six periods: pre-COVID 2011-2012 (Period 1), 2013-2014 (Period 2), 2015-2016 (Period 3), 2017-2018 (Period 4), COVID 2019-2020 (Period 5) and post-COVID 2021-2023 (Period 6).

Biopsy rates per million population (pmp) were calculated using the Lodz Voivodeship adult population data from the Polish Central Statistical Office [20]. The number of inhabitants showed a declining trend, from 2,096,160 (2011) to 1,957,448 (2023), with a stable male to female ratio, approximately 1:1.13.

Additionally, we compared the current cohort with the previously published 1990–2010 data from the same center, where biopsies were evaluated by the same two consultant pathologists as in the present study [14].

Statistical analysis

Percentages were calculated excluding missing values. Continuous variables were tested for normality with the Shapiro–Wilk test and presented as means with standard deviation or medians with interquartile ranges, depending on distribution. Normally distributed data were compared using the unpaired Student's t-test, and non-normal or ordinal variables with the Mann–Whitney U test. Categorical variables were reported as counts and percentages and compared with Chi-square tests, with continuity corrections when required. For trend analyses, the Cochrane–Armitage test was used. Group comparisons with more than two categories (e.g., diagnosis subtypes) employed the Kruskal–Wallis test, followed by pairwise Wilcoxon rank-sum tests with Bonferroni correction for post-hoc analysis.

All p-values <0.05 were considered statistically significant, and tests were two-sided. Analyses were performed using STATISTICA 13.1 (TIBCO Software, Palo Alto, CA), Microsoft Excel version 22.06 (Microsoft Corporation, Redmond, WA), and R version 4.1.1 (R Foundation for Statistical Computing). Figures were generated in R 4.1.1.

The study complied with the Declaration of Helsinki and its amendments. No personal or identifiable data were included.

Results

Biopsies inclusion

During 2011-2023 a total of 2,438 kidney biopsies were evaluated in the same histopathological center. Of these, we excluded 394 (16.2%) graft biopsies, 189 (9.3%) repeated biopsies for disease monitoring, and 44 (2.4%) from individuals under 18 years of age. Among the remaining cases, 149 (8.2%) were excluded as non-diagnostic; ultimately, 1662 biopsy reports were included in the final analysis.

Frequency of kidney biopsies

The annual biopsy count increased significantly, both as absolute number of biopsies per year (92 in 2011 vs 200 in 2023, $P<0.001$) and standardized pmp (43.9 vs 102.2, $P<0.001$). The frequency was stable from 2011 to 2016, then increased, with a sharp transient decline observed during 2019-2020 (Figure 1).

Evolution of clinical characteristics and nephropathy patterns across study periods

The study cohort was predominantly male (57.5%, n=955) and middle-aged (median age 54 [40-64] years).

During the study period, the share of older adults among biopsied patients increased markedly, while the proportion of middle-aged individuals declined; the percentage of young adults and the overall sex distribution remained stable.

The relative frequency of nephrotic proteinuria referrals decreased, with subnephrotic proteinuria and erythrocyturia remaining stable. The lowest kidney function was noted during COVID pandemic, and second-lowest post-COVID. Clinical courses shifted toward acute patterns, particularly during COVID and post-COVID periods, with AKD increasing and CKD decreasing; RPGN prevalence remained stable.

Histopathological records showed a slight decline in the share of GD among all biopsy diagnoses, accompanied by a relative increase in TID frequency; the prevalence of vasculopathies remained stable. Among GD subtypes, IgAN became the most common, increasing in frequency especially during the COVID and post-COVID period; frequency of rare glomerulopathies (Table S1) also increased, while MCD frequency decreased. The ratio of other nephropathies remained stable.

Detailed characteristics of patients and biopsies over different periods are presented in Table 1 and Figure 2. Incidence of most common nephropathies is presented in Figure 3.

Age- and sex-related differences in clinical characteristics and nephropathy patterns

No significant age-group differences were noted in sex distribution or in presence of certain urinary abnormalities.

Older patients, compared with middle-aged and young individuals, more frequently reported an acute disease onset (50.7% vs 36.5% vs 39.1%, $P<0.001$), more often experienced AKD (26.5% vs 17.6% vs 18.5%, $P=0.009$) and RPGN (14.1% vs 7.0% vs 3.8%, $P<0.001$), and less often presented with normal kidney function (17.6% vs 37.4% vs 61.8%, $P<0.001$). Significant differences were found in age distribution of nephropathies, with frequency of IgAN (30.2 vs 18.2 vs 8.7%, $P<0.001$), MCD (13.7 vs 5.6 vs 2.7%, $P<0.001$) and LN (10.4 vs 5.3 vs 1.9%, $P<0.001$) declining, and CGN (4.4 vs 4.3 vs 8.2%, $P=0.02$), VAS (0.6 vs 3.8 vs 6.3%, $P=0.001$), AML (0.6 vs 2.9 vs 9.8%, $P<0.001$), DKD (2.2 vs 7.8 vs 11.7%, $P<0.001$) and TID (3.3 vs 5.8 vs 7,6%, $P=0.04$) rising with age. In younger patients the most common nephropathies were IgAN, FSGS and MCD, in middle-aged IgAN, FSGS and MN and in older individuals FSGS, DKD and MCD.

In sex comparison, males had worse kidney function ($P<0.001$), more frequently exhibited nephrotic proteinuria (45.6 vs 38.9%, $P=0.009$) and CKD (40.3 vs 31.3%, $P<0.001$), and less often normal kidney function (29.9 vs 43.1%, $P<0.001$). IgAN (21.6 vs 11.9%, $P<0.001$) and DKD (9.7 vs 5.7%, $P=0.003$) were more frequent in males, LN (2.8 vs 8.2%, $P<0.001$) and MCD (4.4 vs 7.8%, $P=0.005$) in females.

Female and older patients more often exhibited normal renal morphology with no detectable changes on biopsy. Detailed data of patients and biopsy characteristics stratified by age and sex are presented in Table S2.

Changes in clinicopathologic associations

No statistically significant differences were observed in the distribution of nephropathy subtypes in the different periods across the groups categorized by age, sex, or clinical characteristics (Figure S3).

Comparison with 1990-2010 nephropathy patterns

Comparing the prevalence of GD with previous periods (1990-2000 and 2001-2010) reported from the same region [13], the incidence of biopsy-confirmed GD diagnoses in the current study (2011–2023) more than tripled, with an average of 138.5 cases per year–contrasting with 39.6 per year during 1990–2000 and 30.7 per year during 2000–2010.

Over 30 years, kidney biopsies and GD diagnoses became more common in older patients, reflected in rising median age (39 [24-48] vs 45 [32-54] vs 54 [40-64] years, $P<0.001$) and a higher proportion of individuals over 65 years of age (1.9 vs 6.6 vs 22.1%, $P<0.001$); the relative share of younger patients declined (30.6 vs 22.8 vs 11.0%, $P<0.001$). The male to female ratio remained consistent.

Since 1990, there have been significant shifts in the prevalence of different biopsy-confirmed GDs, including increased incidence of FSGS, DKD and CGN+VAS. The prevalence of other nephropathies, including LN, MN and MCD rose, paralleling the overall increase in biopsy count, but their relative proportions remained stable. Although the absolute number of mesPGN diagnoses per year did not decrease, its relative frequency (as a share of all GDs) declined due to an increase in other diagnoses. Both the number and the proportion of IgAN among the mesPGN increased steadily over time (Figure 4).

Discussion

Over the years, the patterns of renal disorders diagnosed via biopsy and patient characteristics may evolve, affecting disease prevalence estimates and clinical decisions. This retrospective study analyzes 13-year trends in biopsy-proven renal pathologies from a single histopathological center in Lodz, which evaluated kidney biopsies from approximately 2 million inhabitants, receiving specimens from six nephrology units.

During this period, the mean annual biopsy count in the region increased significantly, from 44 pmp in 2011 to 102 pmp in 2023, aligning with the trends observed in other European registries [9,12,21-24]. The frequency of biopsied patients over 65 rose significantly, while nephrotic proteinuria referrals declined, suggesting a broadening of biopsy criteria. This can also be attributed to the Lodz region being one of the fastest-aging areas in Poland, with the ratio of inhabitants aged 18–65 to those above 65 decreasing from 3.41 in 2011 to 2.22 in 2023 [20]. Given this demographic trajectory, the observed patterns may be extrapolated to other aging and depopulating high-income countries of Central and Western Europe, which is further supported by similar global reports demonstrating an increasing rate of older patients undergoing kidney biopsy [9,23,25-28]. This trend underscores the need for effective CKD screening strategies. Recent analyses from Poland alert that early detection remains insufficient and preventive programs are lacking, while coordinated primary-care-based approaches - including pharmacist-led screening and patient education -may play an increasingly important role in identifying CKD at earlier stages [29].

Regarding histopathologic diagnoses, GDs remained the predominant category, accounting for nearly 90% of all cases, although there was a relative, numerically small, increase in TID. IgAN was the most frequent GD in our population, consistent with other European reports [22-25,27].

It was the most common nephropathy throughout most periods and its frequency showed a consistent upward trend since 1990. However, it is important to note that between 1990 and 2010, immunofluorescence analysis was not routinely used in Poland, which likely led to a substantial underdiagnosis of IgAN among cases classified as mesPGN - as reported by Kurnatowska et al., the proportion of IgAN within mesPGN was 27.5% in 1990–2000 and 48.3% in 2001–2010, compared to 86.6% in our current cohort [14]. In this context, the steady decline in overall mesPGN diagnoses (including both IgAN and non-IgAN forms) observed between 1990 and 2023 appears particularly noteworthy. This trend, also observed in other countries [25,27] is likely attributable to an increasing occurrence of other GD, and a demographic shift toward older biopsied patients, among whom IgAN is less prevalent. It is worth noting that the share of IgA nephropathy among all GD in our region during 2011–2023 (20.6%) closely aligns with the rates reported in Lithuania for 1994–2012 (20.2%) and 2013–2022 (19.1%), as well as in the Czech Republic for 1994–2011 (20.2%) and Romania for 2008–2017 (20.4%) [23,24,30,31].

In 2011-2023 we noted an increase in the absolute number of FSGS and DKD diagnoses, paralleling the overall rise in biopsy frequency, while their relative percentages remained stable. However, when compared with earlier reports (1990–2010), both FSGS and DKD proportions showed a marked increase [14], consistent both with previous Polish [12] and international studies which demonstrate rising frequencies of secondary GD, particularly FSGS, since the early 2000s [9,25,27,32-37]. This trend is often linked to environmental and lifestyle factors, resulting in the global rise in obesity and DM prevalence, also observed in Poland [37-39]. It should be noted that as immunological data were inconsistently available in our cohort, distinguishing between primary and secondary FSGS was not feasible; therefore, the significant rise in biopsy-confirmed FSGS incidence observed since the 1990s should be interpreted as potentially reflecting shifts in both forms of the disease. Regarding indications for kidney biopsy in diabetic patients, it is important to note that biopsy is not standard for DKD diagnosis and is primarily performed when clinical presentation is atypical. In our cohort, most DKD diagnoses were made in patients presenting with nephrotic syndrome, with about 30% showing AKD courses in referral letters.

In our cohort the third most common nephropathy was MN, with the frequency (9.7%) similar to that reported in Spain, Czech Republic and Romania [24,25,40] while across other registries its prevalence ranged widely from 4.7 to 17.3% [21-23,25,28]. It should be noted that during the analyzed period, MN was diagnosed primarily on the basis of kidney biopsy, as the antiphospholipase A2 receptor (anti-PLA2R) antibody testing was not routinely available in Poland.

In our cohort, biopsied patients were predominantly male, consistent with other European registries [6,22,25,27,40]. Males also exhibited a more severe course of GD, with worse kidney function at diagnosis and with more frequent nephrotic-range proteinuria. The strongest male predominance was found for IgAN and DKD, while female for LN. Interestingly, female predominance was also observed in MCD, particularly in recent years – a trend not previously reported in Polish or other countries' registries [12]. However, lately a multicenter (United States, Canada, Poland, Italy) study by Chen et al. [41] described that MCD seems to be common in males during childhood and in females in adulthood.

Our analysis indicated that older patients were more frequently biopsied due to acute onset of the disease, had lower $eGFR_{CKD\text{-}EPI}$ values, and a higher prevalence of AKD or RPGN, which aligns with previous findings indicating a predominance of aggressive or rapidly progressive pathologies among older individuals [9,42,43]. Several GD types, such as CGN, VAS, AML, DKD and TID, were more frequent in older, while IgAN, MCD and LN in younger patients, consistent with reports from other countries [9,12,21,24].

During the COVID-19 pandemic, a notable decrease in biopsy procedures was observed, dropping from 78 pmp in 2019 to 56 pmp in 2020, presumably due to limited hospital access and patient apprehension about hospitalization, which trend was reported internationally [31].

Between 2021 and 2023 biopsy frequency increased, surpassing pre-pandemic levels. Characteristically, mean kidney function among biopsied patients was most severely reduced during the COVID period and remained markedly impaired in the post-COVID period, with a shift from chronic to acute presentations; this suggests that the pandemic introduced a selection bias in biopsy referrals under constrained clinical conditions. In our cohort, the main change in GD patterns during the COVID and post-COVID periods was an increase in IgAN diagnoses, which is particularly noteworthy given the unchanged age and sex distribution. Moreover, a numerical increase was noted in CGN type I (anti-GBM disease) and type II (immune complex–mediated GN); both described in the literature as potentially associated with COVID-19–related immunological mechanisms [15].

Recent studies from other countries also reported a change in patients' profile and biopsy results during and after COVID-19 pandemic, which could be attributed either to infection itself or vaccination. Based on the international COVID-19 vaccination registry, the development of GD was reported as a very rare adverse event, with temporal associations most frequently observed with IgAN and MCD incidence [44].

In Shenzhen, China, a significant increase in the incidence of IgAN (from 39.9% to 46.3%), accompanied by more severe renal injury and higher proportions of M1 and E1 in Oxford classification was reported during the pandemic [45]. In Taiwan, IgAN and ANCA-associated RPGN were identified as the most common histopathological diagnoses among patients with COVID-19 vaccine-associated GD [46]. In Japan, patients with prior or subsequent IgAN diagnosis frequently experienced exacerbation of hematuria and transient proteinuria following COVID-19 vaccination [47]. In Turkey, a reduced kidney biopsy rate and an increased incidence of acute kidney injury were also reported during the pandemic; the post-pandemic population showed a lower frequency of FSGS and, interestingly, of IgAN, and a higher prevalence of ANS [17]. Patients biopsied during the pandemic in India were younger and exhibited worse kidney function, higher prevalence of RPGN, lower rate of MN and higher rate of diffused glomerulosclerosis [18].

The key strength of our study is its methodological consistency. Building on previous research from our center [14], it offers a longitudinal analysis of renal disorders patterns based on kidney biopsies over the last 33 years, making it the longest comprehensive analysis in Central Europe. Throughout this period, all biopsy specimens were evaluated by the same two nephropathologists, ensuring reproducibility and reducing interpretative variability. To maintain diagnostic uniformity, each biopsy referral was submitted using an identical standardized form throughout the study.

Limitations

This study has several limitations. First, its retrospective design and reliance on biopsy referral forms meant that some clinical information was incomplete. Key clinical descriptors, such as acute vs chronic presentation - were based on subjective assessments by referring clinicians, introducing inter-center variability and potential misclassification or missing-data bias.

Secondly, to better compare the described trends with preexisting reports, we adapted the heterogenic classification proposed by Perkowska-Ptasińska et al. [12], which included specific diseases, pathological patterns and etiologic compartments, without subdivision of GD into primary and secondary forms. As immunological data (including serum: antiPLA2R, complement, ANA, ANCA and anti-GBM antibodies) were inconsistently available, also in our study distinguishing between primary and secondary nephropathies, especially FSGS and MN was not feasible.

Moreover, the study represents a biopsy-based cohort rather than a population-level epidemiological registry. As the changes in biopsy rates, referral patterns, diagnostic capabilities (including EM availability and serological tests) and clinical thresholds over time likely influenced the observed distribution of diagnoses, the described patterns should be interpreted as trends in biopsy-confirmed diagnoses within a changing referral context, not as the actual incidence.

The comparison with historical data from 1990–2010 must be viewed cautiously due to evolving diagnostic methods and biopsy indications, which limit the direct comparability of long-term trends. The earlier study included only GDs, whereas the present one encompassed all biopsy diagnoses; however, given that GDs accounted for approximately 90% of cases, this discrepancy is likely negligible. Additionally, because a different classification system was used in the earlier period, CGN and VAS had to be grouped in the recent data to enable comparison. Importantly, given the substantial evolution of diagnostic approaches, classification frameworks, biopsy practices, and pathological evaluation over time, these comparisons should be interpreted as descriptive observations rather than quantitative estimates of changes in disease incidence,

Interpretation of findings from the COVID-19 period is constrained by the absence of patient-level data on SARS-CoV-2 infection or vaccination. Therefore, the observed differences represent ecological associations and should be considered as hypothesis-generating rather than explanatory.

Conclusions

Between 2011-2023 in central Poland, the number of kidney biopsies increased significantly, particularly among older patients; referrals for nephrotic-range proteinuria became less frequent, while indications related to acute kidney injury increased. IgAN became the most common biopsy-confirmed GD, with its proportion increasing particularly during the COVID and post-COVID periods, followed by FSGS, while the frequency of MCD decreased. A trend towards an increase in tubulointestitial disease diagnoses was observed, whereas that of vasculopathies remained relatively stable. No substantial differences were observed after stratifying by sex, age, or referral indication; therefore, these shifts may mostly reflect changing biopsy indications and referral patterns.

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Table 1 Distribution of clinical and histopathological characteristics across time periods.

	Period 1 2011-2012 (n=186)	Period 2 2013-2014 (n=210)	Period 3 2015-2016 (n=201)	Period 4 2017-2018 (n=266)	Period 5 2019-2020 (n=271)	Period 6 2021-2023 (n=528)	*P*	Total (n=1662)
Age, years	54 [41-63]	47 [34-59]	56 [41-64]	58 [43-66]	55 [40-65]	53 [40-66]	<0.001	54 [40-64]
Age category, n (%)								
Young	16 (8.6%)	40 (19.0%)	24 (11.9%)	21 (7.9%)	27 (10.0%)	54 (10.2%)	0.14	182 (11.0%)
Middle-aged	140 (75.2%)	140 (66.6%)	137 (68.2%)	175 (65.8%)	178 (65.7%)	338 (64.0%)	0.02	1108 (66.6%)
Older	30 (16.1%)	30 (14.3%)	39 (19.4%)	67 (25.2%)	66 (24.4%)	136 (25.8%)	<0.001	368 (22.1%)
Sex								
Male, n (%) / Female, n (%)	124 (66.6%) / 62 (33.3%)	116 (55.2%) / 94 (44.8%)	107 (53.2%) / 94 (46.7%)	156 (58.6%) / 110 (41.4%)	157 (57.9%) / 114 (42.1%)	295 (55.9%) / 233 (44.1%)	0.16	955 (57.5%) / 707 (42.5%)
Male : Female ratio	2.00 : 1	1.23 : 1	1.14 : 1	1.42 : 1	1.38 : 1	1.27 : 1	–	1.35 : 1

Kidney function								
Serum creatinine, mg/dL	1.56 [0.99–3.55]	1.32 [0.90–2.50]	1.60 [0.96–3.26]	1.69 [1.00–3.50]	1.86 [1.04–3.50]	1.69 [1.05–3.16]	0.01	1.66 [1.00–3.23]
$eGFR_{CKD\text{-}EPI}$, mL/min/1.73 m²	49.3 [19.3–86.7]	55.5 [29.1–92.0]	43.4 [20.8–86.0]	42.0 [17.1–76.6]	37.9 [16.8–76.1]	42.7 [18.8–76.8]	0.003	44.2 [19.3–81.0]
No data, n (%)	11 (5.9%)	4 (1.9%)	21 (10.4%)	20 (7.5%)	14 (5.2%)	4 (0.7%)	–	74 (4.5%)
Urinary abnormalities, n (%)								
Nephrotic proteinuria	84 (46.4%)	105 (50%)	78 (39.2%)	121 (46.7%)	104 (39.8%)	208 (39.5%)	0.01	700 (42.7%)
Subnephrotic proteinuria	64 (35.4%)	81 (38.6%)	63 (31.7%)	87 (33.6%)	81 (31.0%)	191 (36.2%)	0.80	567 (34.6%)
Erythrocyturia	57 (31.5%)	92 (43.8%)	39 (19.6%)	66 (25.5%)	97 (37.1%)	161 (30.6%)	0.46	512 (31.2%)
No data	5 (2.7%)	0	3 (1.5%)	7 (2.6%)	7 (2.6%)	1 (0.1%)	–	23 (1.4%)
Course of disease, n (%)								
Acute / Chronic	42 (36.8%) / 72 (63.2%)	53 (42.4%) / 72 (57.6%)	52 (39.4%) / 80 (60.6%)	54 (28.3%) / 137 (71.7%)	88 (42.3%) / 120 (57.7%)	189 (45.1%) / 230 (54.9%)	0.007	478 (40.2%) / 711 (59.8%)

No data	72 (38.7%)	85 (40.5%)	69 (34.3%)	75 (28.2%)	63 (23.2%)	109 (20.6%)	–	473 (28.5%)
Course of renal function impairement, n (%)								
RPGN	20 (12.3%)	11 (6.0%)	17 (9.4%)	17 (7.4%)	19 (8.2%)	42 (8.4%)	0.50	126 (8.3%)
AKD	26 (16.0%)	31 (17.0%)	24 (13.3%)	35 (15.2%)	59 (25.4%)	123 (24.7%)	<0.001	298 (19.6%)
CKD	49 (30.2%)	55 (30.2%)	66 (36.7%)	96 (41.7%)	91 (39.2%)	197 (39.6%)	0.007	554 (36.5%)
No eGFR decline	70 (43.2%)	100 (54.9%)	65 (36.1%)	82 (35.7%)	75 (32.3%)	147 (29.6%)	<0.001	539 (35.5%)
No data	21 (11.3%)	13 (6.2%)	29 (14.4%)	36 (13.5%)	27 (10.0%)	19 (3.6%)	–	145 (8.7%)
Histopathologic type, n (%)								
GD	162 (87.1%)	188 (89.5%)	182 (90.5%)	228 (85.7%)	217 (80.1%)	434 (82.2%)	<0.001	1411 (84.9%)
IgAN	28 (15.1%)	39 (18.6%)	21 (10.4%)	45 (16.9%)	49 (18.1%)	108 (20.5%)	0.04	290 (17.4%)
FSGS	34 (18.2%)	23 (11.0%)	38 (18.9%)	31 (11.7%)	39 (14.4%)	106 (20.1%)	0.12	271 (16.3%)
MN	17 (9.1%)	20 (9.5%)	21 (10.4%)	25 (9.4%)	22 (8.1%)	51 (9.7%)	0.93	156 (9.4%)
DKD	10 (5.4%)	15 (7.1%)	21 (10.4%)	32 (12.0%)	23 (8.5%)	32 (6.1%)	0.31	133 (8.0%)

MCD	14 (7.5%)	18 (8.6%)	17 (8.5%)	17 (6.4%)	12 (4.4%)	19 (3.6%)	0.001	97 (5.8%)
CGN	13 (7.0%)	6 (2.9%)	8 (4.0%)	13 (4.9%)	19 (7.0%)	27 (5.1%)	0.69	86 (5.2%)
Type I	0	0	1	1	1	4	–	7
Type II	1	1	1	1	0	3	–	7
Type III	12	5	6	10	18	20	–	71
LN	7 (3.8%)	20 (9.5%)	11 (5.5%)	13 (4.9%)	11 (4.1%)	23 (4.4%)	0.15	85 (5.1%)
AML	8 (4.3%)	7 (3.3%)	11 (5.5%)	18 (6.8%)	6 (2.2%)	20 (3.8%)	–	70 (4.2%)
VAS	13 (7.0%)	8 (3.8%)	8 (4.0%)	5 (1.9%)	14 (5.2%)	18 (3.4%)	0.91	66 (4.0%)
mesPGN non-IgA	4 (2.2%)	9 (4.3%)	6 (3.0%)	11 (4.1%)	7 (2.6%)	8 (1.5%)	–	45 (2.7%)
MPGN	4 (2.2%)	11 (5.2%)	4 (2.0%)	5 (1.9%)	7 (2.6%)	13 (2.5%)	–	44 (2.6%)
Other GD	10 (5.4%)	12 (5.7%)	16 (8.0%)	13 (4.9%)	8 (3.0%)	9 (1.7%)	0.11	68 (4.8%)
TID	12 (6.5%)	5 (2.4%)	5 (2.5%)	15 (5.6%)	24 (8.9%)	37 (7.0%)	0.02	98 (5.9%)
CTIN	6 (2.2%)	2 (1.0%)	2 (1.0%)	8 (3.0%)	7 (2.6%)	21 (4.0%)	–	46 (2.8%)

ATIN	2 (1.1%)	1 (0.5%)	1 (0.5%)	4 (1.5%)	8 (3.0%)	8 (1.5%)	–	24 (1.4%)
ATN	3 (1.6%)	2 (1.0%)	1 (0.5%)	0	7 (2.6%)	4 (0.8%)	–	17 (1.0%)
Other TID	1 (0.5%)	0	1 (0.5%)	3 (1.1%)	7 (2.6%)	4 (0.8%)	–	11 (0.7%)
Vasculopathies	7 (3.8%)	8 (3.8%)	8 (4.0%)	16 (6.0%)	21 (7.7%)	27 (5.1%)	0.16	87 (5.2%)
ANS	5 (2.7%)	4 (1.9%)	4 (2.0%)	3 (1.1%)	2 (0.7%)	7 (1.3%)	–	61 (3.7%)
TMA	1 (0.5%)	3 (1.4%)	4 (2.0%)	12 (4.5%)	19 (7.0%)	18 (3.4%)	–	21 (1.26%)
Other vasculopathies	1 (0.5%)	1 (0.5%)	0	1 (0.3%)	0	0	–	5 (0.3%)
MIS	0	0	1 (0.5%)	0	1 (0.4%)	4 (0.8%)	–	6 (0.4%)
ESKD	1 (0.5%)	1 (0.5%)	1 (0.5%)	0	1 (0.4%)	9 (1.7%)	–	13 (0.8%)
NM	4 (2.2%)	8 (3.8%)	4 (2.0%)	7 (2.6%)	7 (2.6%)	17 (3.2%)	–	47 (2.8%)

Abbreviations: AKD, acute kidney disease; AML, amyloidosis; ANS, arterionephrosclerosis; ATIN, acute tubulointerstitial nephritis; ATN, acute tubular necrosis; CGN, crescentic glomerulonephritis; CKD, chronic kidney disease; CTIN, chronic tubulointerstitial nephritis; DKD, diabetic kideny disease; ESKD, end-stage kidney disease; FSGS, focal segmental glomerulonephritis; GD, glomerular disorder; IgAN, mesangioproliferative nephropathy IgA; LN, lupus nephritis; MCD, minimal-change disease; MIS, others; MN, membranous glomerulonephritis; MPGN, membranoproliferative glomerulonephritis; NM, normal kidney morphology; mesPGN non-IgA, mesangioproliferative nephropathy non-IgA; RPGN, rapid progressive glomerulonephritis; TID, tubulointerstitial disorder; TMA, thrombotic microangiopathy; VAS, necrotizing vasculitis.

SI conversion factors: to convert serum creatinine from mg/dL to µmol/L, multiply by 88.4; to convert creatinine clearance (eGFR) from ml/min to ml/s, multiply by 0.0167

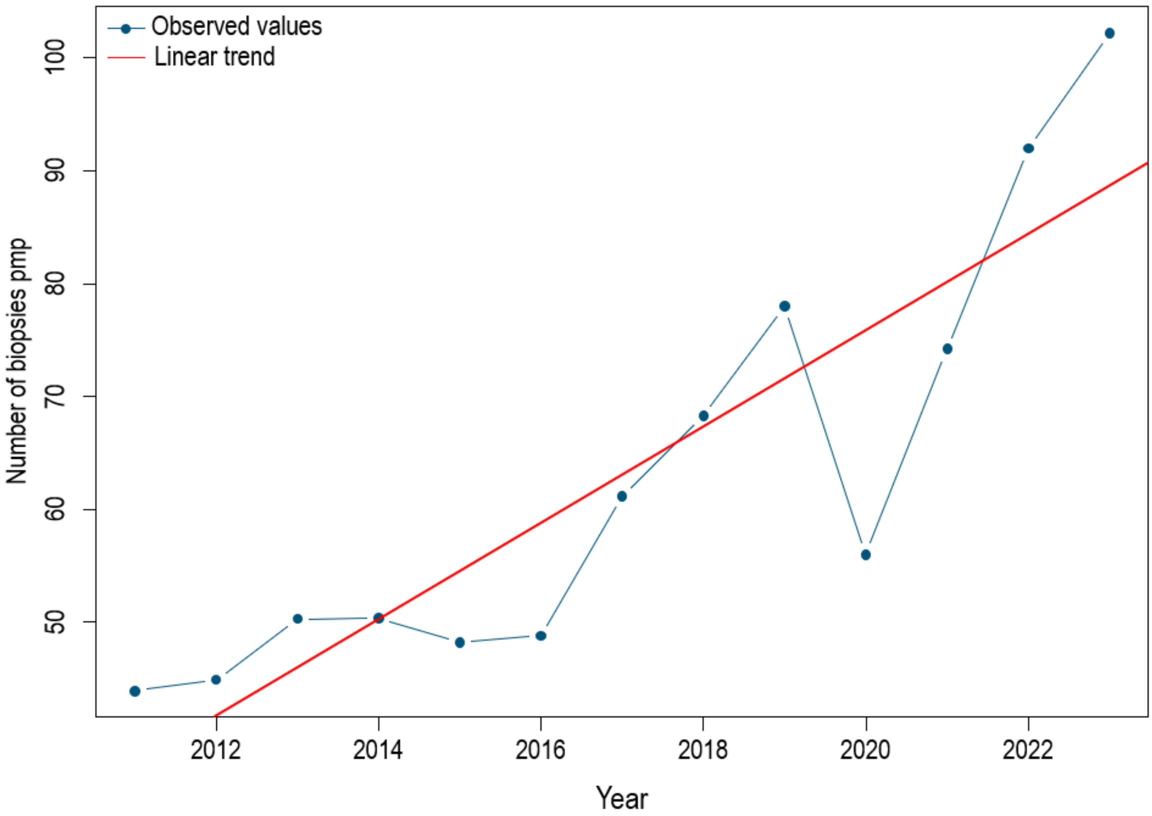

Figure 1 Annual biopsy frequency per milion population in the Lodz Voivodeship between 2011 and 2023.

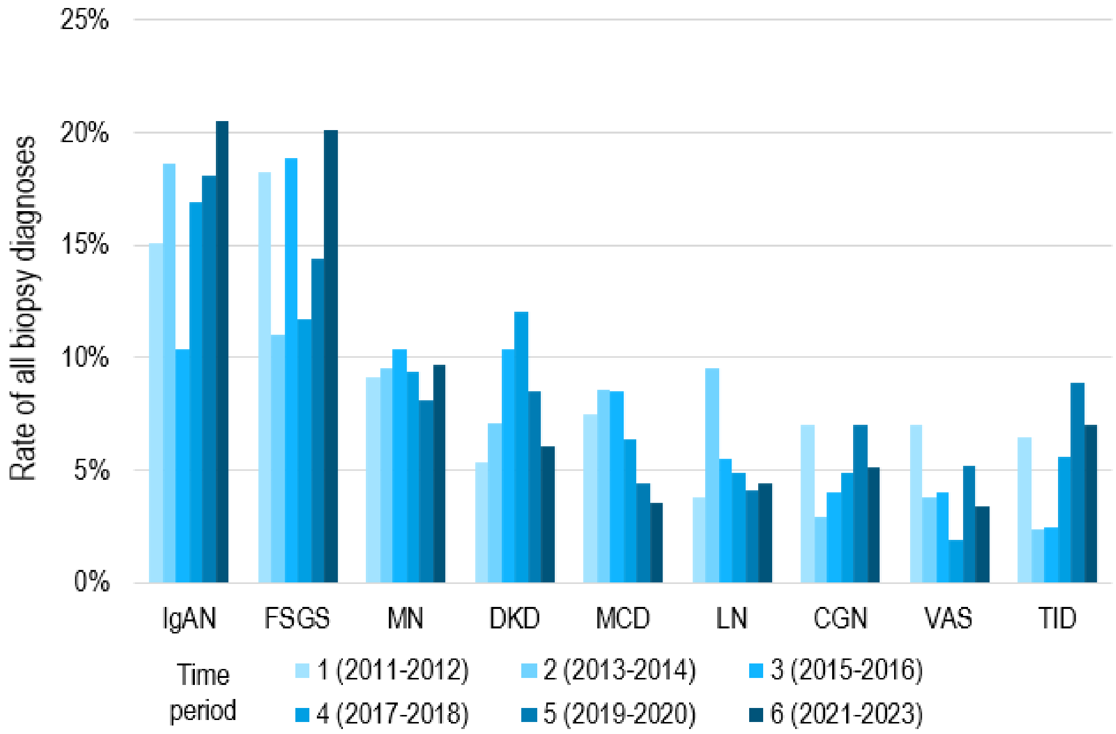

Figure 2 Rates of the most common biopsy-confirmed renal disease diagnoses across the defined time periods in the study population.

Abbreviations: CGN, crescentic glomerulonephritis; DKD, diabetic kidney disease; FSGS, focal segmental glomerulonephritis; GD, glomerular disorder; IgAN, mesangioproliferative nephropathy IgA; LN, lupus nephritis; MCD, minimal-change disease; MN, membranous glomerulonephritis; TID, tubulointerstitial disorders; VAS, necrotizing vasculitis.

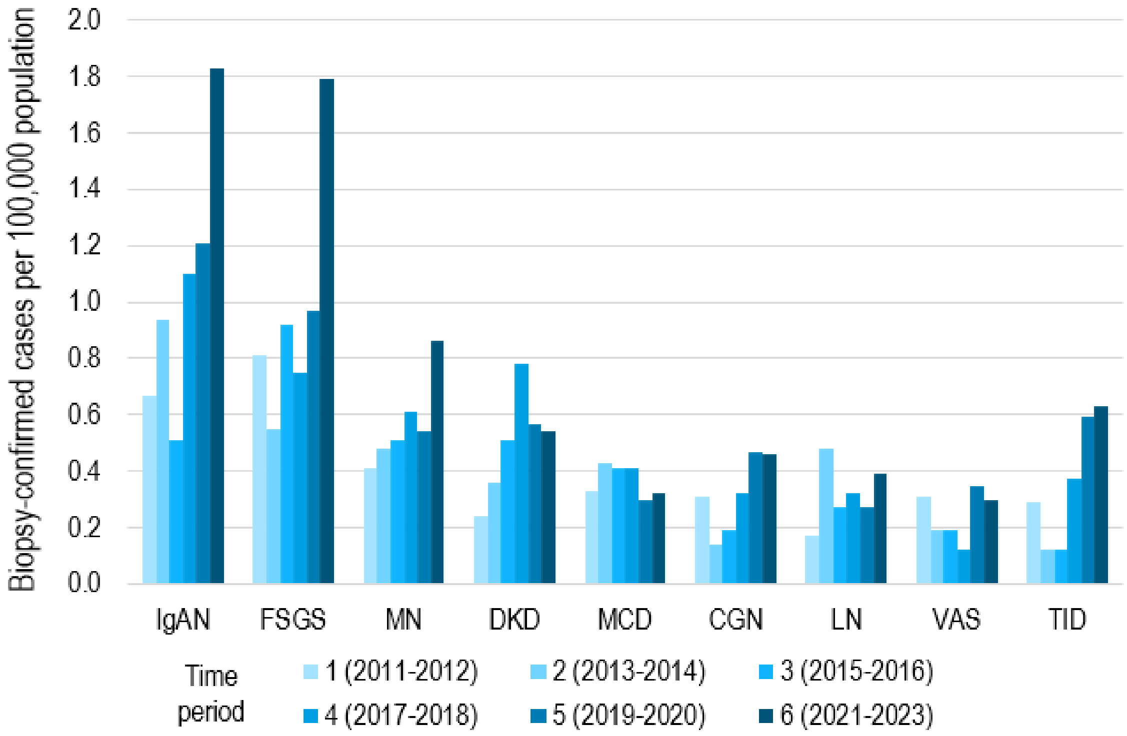

Figure 3 Incidence of the most common biopsy-confirmed renal disease diagnoses across the defined time periods in the Lodz voivedeship.

Abbreviations: CGN, crescentic glomerulonephritis; DKD, diabetic kidney disease; FSGS, focal segmental glomerulonephritis; GD, glomerular disorder; IgAN, mesangioproliferative nephropathy IgA; LN, lupus nephritis; MCD, minimal-change disease; MN, membranous glomerulonephritis; TID, tubulointerstitial disorders; VAS, necrotizing vasculitis.

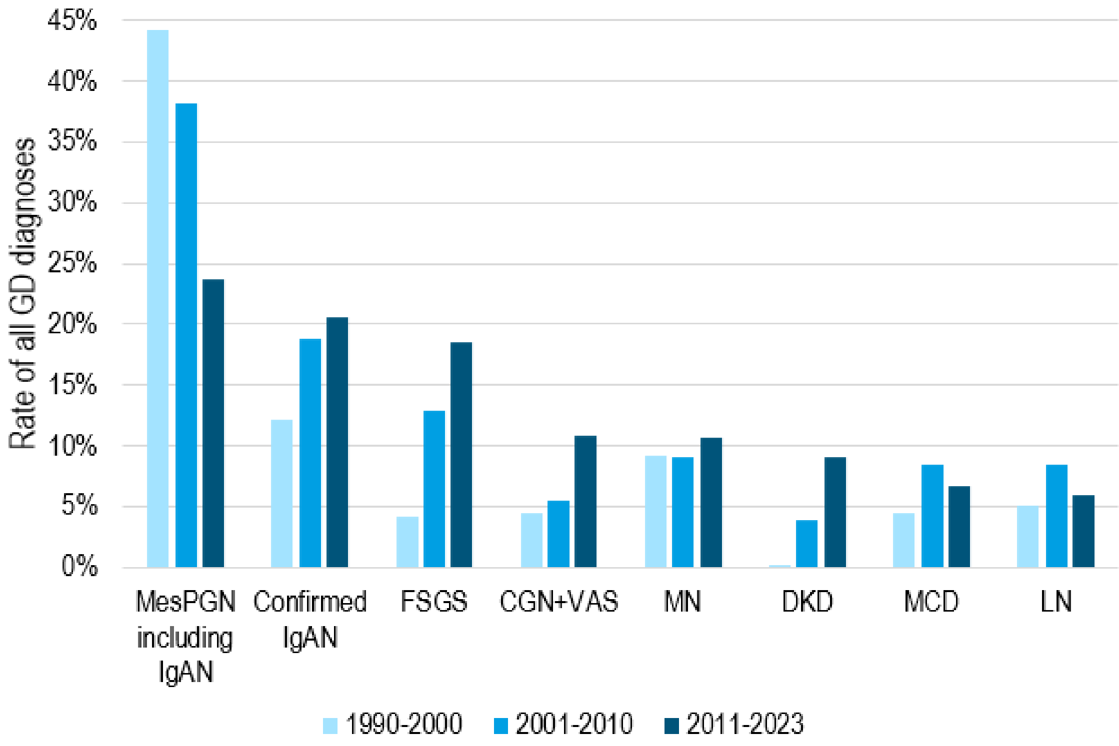

Figure 4 Rates of the most common glomerular disease diagnoses from 1990 to 2023 in the Lodz voivodeship.

Abbreviations: CGN+VAS, crescentic glomerulonephritis and necrotizing vasculitis; DKD, diabetic kidney disease; FSGS, focal segmental glomerulonephritis; GD, glomerular disorder; IgAN, mesangioproliferative nephropathy IgA; LN, lupus nephritis; MCD, minimal-change disease; mesPGN, mesangioproliferative nephropathy; MN, membranous glomerulonephritis.

Short title: Kidney biopsy trends in Central Poland 2011-2023.