Identifying Chronic Kidney Disease Stage 3 With Excess Disease Burden

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ABSTRACT

OBJECTIVES: Chronic kidney disease (CKD) is a widely prevalent disease with heterogeneous disease progression. Prior study findings suggest that early referral to nephrologists can improve health outcomes for patients with CKD. Current practice guidelines recommend nephrology referral when patients are diagnosed with CKD stage 4. We tested whether a subset of patients with CKD stage 3 and common medical comorbidities demonstrates disease progression, cost, and utilization patterns that would merit earlier referral.

STUDY DESIGN: Retrospective study of Medicare fee-for-service beneficiaries with CKD stages 3 through 5 and end-stage kidney disease.

METHODS: We identified 7 comorbidities with high prevalence in patients with progressive CKD and segmented beneficiaries with CKD stage 3 based on the presence of these comorbidities. Outcomes including costs, utilization, and disease progression were then compared across beneficiaries with different stages of CKD.

RESULTS: We identified that beneficiaries with CKD stage 3 and at least 1 of the selected comorbidities (CKD stage 3-plus) represented 35.4% of all beneficiaries with CKD stage 3. The CKD stage 3-plus cohort had cost and utilization patterns that were more similar to beneficiaries with CKD stages 4 and 5 than to beneficiaries with CKD stage 3 without the selected comorbidities.

CONCLUSIONS: Our findings demonstrate the use of a claims-based algorithm to identify patients with CKD stage 3 who have high costs and are at risk of disease progression, highlighting a potential subset of patients who might benefit from earlier nephrology intervention.

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Chronic kidney disease (CKD) is present in approximately 15% of adults in the US and is expected to increase as the population ages and the prevalence of CKD risk factors (eg, diabetes) continues to grow.[1] Clinicians categorize the severity of CKD into 5 stages, ranging from stage 1 to stage 5 (including end-stage kidney disease [ESKD], which requires dialysis), using a laboratory value of a patient's estimated glomerular filtration rate (eGFR).[2] Although only a small proportion of cases ultimately progress to ESKD, managing ESKD remains costly. In 2020, Medicare spent $122.5 billion on kidney disease, with $37.1 billion spent on the care of individuals with ESKD, who represent 1% of Medicare beneficiaries but 6.1% of its total budget.[3]

Earlier nephrologist intervention can improve management of this population and may reduce associated costs. Many individuals who initiate dialysis treatment in the US do so through a "crash start" at an emergency department.[4] Moreover, more than 80% of those starting hemodialysis do so with temporary catheter access, which is liable to cause infections.[3] Nephrologist engagement for patients with CKD is associated with improved patient dialysis preparation,[5,6] higher first-year survival rates after dialysis initiation,[7] and increased registration for transplant waiting lists.[8] The Kidney Disease: Improving Global Outcomes (KDIGO) group recommends nephrologist engagement for patients starting at CKD stage 4.[8] Reinforcing that recommendation, CKD stage 4 is the earliest that Medicare beneficiaries become eligible for the Comprehensive Kidney Care Contracting (CKCC) value-based payment (VBP) model from the Center for Medicare and Medicaid Innovation. This VBP model recognizes the role that nephrologists play as the principal care provider for the population with late-stage kidney disease by making them accountable for clinical and financial outcomes.

However, initiating nephrologist engagement at CKD stage 4 may not always be early enough. Some patients with CKD stage 3 experience rapid disease progression, a reality that the *International Classification of Diseases* (*ICD*) codes for CKD stage fail to capture.[9]

Identifying patients at risk of rapid progression is a perennial challenge in kidney disease management. Models to predict progression to ESKD have been developed but require additional laboratory

testing.[10,11] Such testing may not always be practical in a primary care setting. Even when this testing is practical, a model built around *ICD* codes would improve management of this population. Payers, who may not always have timely access to laboratory values, could identify this high-risk cohort through claims and dedicate resources appropriately. For instance, they may include a subset of the CKD stage 3 population in VBP models such as CKCC, whose alignment today relies on claims history.

TAKEAWAY POINTS

Medicare beneficiaries with chronic kidney disease (CKD) stage 3 and at least 1 of 7 selected comorbidities have similar costs and utilization to beneficiaries with CKD stages 4 and 5.

- Although current guidelines recommend that nephrology intervention begin at CKD stage 4, intervention at CKD stage 3 may reduce health care costs and poor outcomes for this cohort.
- Existing literature has demonstrated the efficacy of earlier intervention for costs and outcomes relative to status quo, but no study has specified when intervention may be appropriate at CKD stage 3.
- Our claims-based algorithm is readily feasible for managed care practitioners.

Using Medicare fee-for-service (FFS) claims data, we assessed patterns of CKD progression in Medicare beneficiaries with CKD stage 3 and above. We specifically assessed whether the presence of various comorbidities was associated with CKD progression and overall health care costs. Our findings provide clinicians and policy makers with a claims-based algorithm to identify patients most likely to experience progression to severe disease.

METHODS

Data Source

We developed a retrospective study using 100% CMS FFS claims data from January 1, 2020, through December 31, 2021, accessed through the CMS Virtual Research Data Center. Claims data included demographic data as well as cost and utilization data, including inpatient, outpatient, skilled nursing, home health, hospice, and professional fees. Use of CMS Medicare FFS data was approved by the IntegReview institutional review board.

Study Population

All FFS Medicare beneficiaries were required to have both Part A and Part B coverage. Those with CKD stages 3, 4, 5 (without routine dialysis), and ESKD were identified using *International Statistical Classification of Diseases, Tenth Revision* (*ICD-10*) codes. The *ICD-10* codes used to identify beneficiaries included N18.0, N18.1, N18.2, N18.3, N18.4, N18.5, N18.6, and N18.9.

Development of CKD Stage 3-Plus Cohort

Identification of disease progression. We identified beneficiaries who experienced progression from CKD stage 3 to later stages of kidney disease by identifying beneficiaries with a CKD stage 3 diagnosis between January 1, 2020, and December 31, 2020, who subsequently had a CKD stage 4 or 5 diagnosis without routine dialysis later within the study period. Beneficiaries who did not have a later diagnosis of CKD stage 4 or 5 during the study period were considered to have maintained a CKD stage 3 diagnosis throughout the study period.

Comorbidity selection. Comorbidities were identified using the Healthcare Cost and Utilization Project Elixhauser Comorbidity Software.[12] The prevalence rates of 32 comorbidities were compared in beneficiaries who had progressive disease during the study period vs those who had a continuous diagnosis of CKD stage 3 throughout the study period. Prevalence ratios were determined by dividing the prevalence of a comorbidity in beneficiaries who had disease progression by the prevalence of a comorbidity in all beneficiaries with CKD stage 3. Comorbidities with a prevalence rate greater than 20%, including diabetes and hypertension, and a prevalence ratio lower than 1.9 were excluded due to low average cost. Thus, a threshold of 1.9 and above was used to subsegment patients with CKD stage 3 for further analysis. Acute event-like conditions (eg, hemophilia, oncologic-related conditions) were also excluded. The 7 comorbidities selected were hypertensive encephalopathy, blood loss anemia, venous thromboembolism, hypertensive heart disease with heart failure, pulmonary circulation disorder, paralysis, and chronic peptic ulcer disease.

CKD stage 3-plus segmentation. Beneficiaries with CKD stage 3 were then subsegmented into beneficiaries with CKD stage 3 with selected comorbidities (CKD 3-plus) and those with CKD stage 3 without selected comorbidities.

Outcome Variables

Cost, utilization, and disease outcomes were compared by disease stage, including CKD stage 3-plus. Cost was estimated as total paid per member per month (PMPM) by type of service indicated in medical claims. Utilization was calculated as visits or admissions per thousand members per year (PTMPY) by type of service indicated in medical claims. The costs and utilization were captured based on the claims incurred during the time period from the index date to the end of the study period or the end of Part A and Part B coverage period, whichever came first. We then aggregated the claims at the beneficiary level and divided the aggregated cost and utilization by member months when beneficiaries had both Part A and Part B coverage.

To determine rate of disease progression, we compared the first identified date of ESKD or death vs the index date of an earlier disease stage. For CKD stage 3 (not 3-plus), CKD stage 4, and CKD stage 5, the index date was the first identified diagnosis of CKD stage 3 to 5, respectively. For CKD stage 3-plus, the index date was the later of (1) the first identified CKD stage 3 diagnosis or (2) the first selected comorbidity diagnosis.

Differences in paid claims PMPM and utilization PTMPY were determined with 2-sample *t* tests. Considering the large sample size in this study, our significance test was based on a *P* value

TABLE 1. Comparison of Comorbidity Prevalence Between Patients Experiencing Progression From CKD Stage 3 to CKD Stage 4 or 5 and Those Remaining in CKD Stage 3[a,b]

Clinical condition	CKD stage 3 → CKD stage 4/5	CKD stage 3	CKD stage 3 → CKD stage 4/5	CKD stage 3	Prevalence ratio
Total beneficiaries	515,449	3,624,622	100.0%	100.0%	
Hypertensive encephalopathy	51,309	129,465	10.0%	3.6%	2.8
Blood loss anemia	66,116	180,009	12.8%	5.0%	2.6
Coagulation deficiency	113,331	362,461	22.0%	10.0%	2.2
Venous thromboembolism	62,834	204,500	12.2%	5.6%	2.2
Congestive heart failure	291,908	950,204	56.6%	26.2%	2.2
Chronic peptic ulcer disease	33,669	110,924	6.5%	3.1%	2.1
Fluid and electrolyte disorders	365,568	1,234,891	70.9%	34.1%	2.1
Hypertensive heart disease with heart failure	144,194	499,013	28.0%	13.8%	2.0
Deficiency anemias	414,958	1,480,786	80.5%	40.9%	2.0
Pulmonary circulation disorder	43,692	157,605	8.5%	4.3%	1.9
Paralysis	49,311	179,657	9.6%	5.0%	1.9
Lymphoma	21,296	79,645	4.1%	2.2%	1.9
Diabetes with chronic complications	327,637	1,335,686	63.6%	36.9%	1.7
Valvular disease	246,750	1,006,775	47.9%	27.8%	1.7
Cardiac arrhythmia	164,232	671,400	31.9%	18.5%	1.7
Other neurological disorders	222,670	955,358	43.2%	26.4%	1.6
Thrombocytosis	8387	36,106	1.6%	1.0%	1.6
Metastatic cancer	31,590	136,621	6.1%	3.8%	1.6
Diabetes without chronic complications	312,930	1,353,544	60.7%	37.3%	1.6
Coronary artery disease	324,969	1,410,056	63.0%	38.9%	1.6
Peripheral vascular disease	266,981	1,160,777	51.8%	32.0%	1.6
Liver disease	89,094	391,236	17.3%	10.8%	1.6
Hypothyroidism	70,936	320,893	13.8%	8.9%	1.6
Chronic pulmonary disease	223,242	1,027,789	43.3%	28.4%	1.5
Drug abuse	24,869	117,565	4.8%	3.2%	1.5
Depression	178,952	886,209	34.7%	24.4%	1.4
Obesity	236,875	1,174,676	46.0%	32.4%	1.4
Tumor	120,784	627,826	23.4%	17.3%	1.4
Secondary hypertension, unspecified	196,367	1,045,566	38.1%	28.8%	1.3
Psychoses	56,742	307,184	11.0%	8.5%	1.3
Connective tissue	76,068	416,933	14.8%	11.5%	1.3
Preexisting hypertension complicating the puerperium	499,756	2,839,788	97.0%	78.3%	1.2

CKD, chronic kidney disease; *ICD-10-CM*, *International Classification of Diseases, Tenth Revision, Clinical Modification*.

[a]Clinical conditions are derived from Elixhauser Comorbidity Software Refined for *ICD-10-CM*.[12]

[b]Comorbidities with a prevalence ratio greater than 1.9 were selected to subsegment patients with CKD stage 3 for further analysis. Acute event-like conditions (eg, hemophilia, oncologic-related conditions) and conditions that had a prevalence greater than 20% among all beneficiaries with a CKD stage 3 diagnosis were excluded.

of .01. All data management and analyses were conducted using SAS Enterprise Guide 7.1 (SAS Institute Inc).

RESULTS

Development of CKD Stage 3 Cohort

There were 3,624,622 beneficiaries identified with CKD stage 3, who represented 73.4% of all beneficiaries with CKD stages 3, 4, or 5 or ESKD (N = 4,940,937) from January 1, 2020, through December 31, 2021. Among beneficiaries who had CKD stage 3, 515,449 had progressive disease (14.2%) during the study period. Beneficiaries who had progressive disease had a higher prevalence of all 32 comorbidities analyzed. After excluding acute event-like conditions and comorbidities with greater than 20% prevalence among all beneficiaries with CKD stage 3, 7 comorbidities (hypertensive encephalopathy, blood loss anemia, venous thromboembolism, hypertensive heart disease with heart failure, pulmonary circulation disorder, paralysis, and chronic peptic ulcer disease) had a prevalence ratio of 1.9 or greater (**Table 1**).

Outcome Variables

A total of 4,940,937 beneficiaries were included in the analysis. Of these, 2,340,465 (47.4%) had CKD stage 3 without selected comorbidities; 1,284,157 (26.0%) had CKD stage 3 with selected comorbidities (CKD stage 3-plus); 806,414 had CKD stage 4 or 5 (16.3%); and 509,901 had ESKD (10.3%) (**Table 2**).

The CKD stage 3-plus cohort had significantly higher medical costs compared with beneficiaries with CKD stage 3 without comorbidities ($3877 PMPM vs $1145 PMPM, respectively; $P < .01$). The cohort with CKD stage 4 or 5 had overall medical spend ($3956 PMPM) comparable to that of those with CKD stage 3-plus (**Figure 1**).

The CKD stage 3-plus cohort had 5 times the amount of acute inpatient medical costs compared with those with CKD stage 3 without comorbidities ($1639 PMPM vs $315 PMPM, respectively; $P < .01$). The CKD stage 3-plus cohort also had 5 times the number of inpatient admissions compared with those with CKD stage 3 without comorbidities (1267 PTMPY vs 264 PTMPY, respectively; $P < .01$).

Beneficiaries with CKD stage 3-plus had a higher proportion of patients experiencing

progression to advanced stages than those with CKD stage 3 without comorbidities. During the study period, 9.1% of beneficiaries with CKD stage 3 without comorbidities experienced progression to ESKD or death. In comparison, 40.4% of the CKD stage 3-plus cohort experienced progression to ESKD or death during the study period, with median progression time of 9 months (**Figure 2**).

DISCUSSION

Overall, we found that a subset of beneficiaries with CKD stage 3 with selected comorbidities had outcomes more similar to beneficiaries with CKD stage 4 or 5 than to beneficiaries with CKD stage 3 without the selected comorbidities. This cohort (CKD stage 3-plus) was more likely to experience progression to ESKD or death compared with beneficiaries with CKD stage 3 without the selected comorbidities and had higher costs and utilization. Cost and utilization patterns of CKD stage 3-plus were similar to those of beneficiaries with CKD stage 4 or 5.

Previous investigators have demonstrated that there is heterogeneity in disease progression for patients with CKD stage 3.[5,10] The current study builds on prior work by demonstrating that there is a distinct subset of patients with CKD stage 3 who not only have a higher likelihood of disease progression and higher comorbidity burden but also have higher costs and utilization.

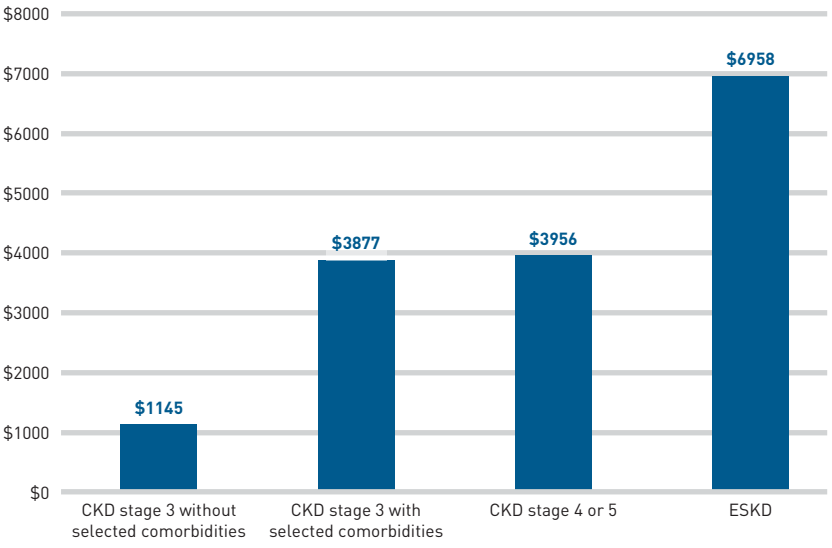
In the biologic context, this elevated progression risk comes as no surprise. The comorbidities we included in CKD stage 3-plus largely match the clinical risk factors for CKD progression identified in the Chronic Renal Insufficiency Cohort Study.[13] Other studies have associated CKD progression risk with specific comorbidities in our list.[14-19] As just 1 example, anemia's relevance as a prognostic factor in CKD stage 3 was evaluated in a longitudinal study that included more than 400 patients. Those who developed anemia in the cohort had significantly increased risk of hospital admission, cardiovascular events, increased proteinuria, rapid decrease in eGFR, and mortality compared with nonanemic patients with CKD stage 3.[14] By gathering these comorbidities into a distinct cohort and validating their association with progression risk, we concur with these biologic hypotheses while focusing on their clinical implications for managed care.

TABLE 2. Cost and Utilization Profile of CKD Stage 3, CKD Stage 4 or 5, and ESKD Populations

	All CKD stage 3	CKD stage 3 without selected comorbidity	CKD stage 3-plus	CKD stage 4 or 5	ESKD
Member count	3,624,622	2,340,465	1,284,157	806,414	509,901
Member months	40,906,194	26,849,782	14,056,412	8,682,923	5,099,647
Risk score	1.8	1.39	2.59	2.26	1.95
Age	77.8	77.33	78.53	76.51	66.07
Female	53.30%	53.60%	52.70%	52.10%	43.20%
Paid claims PMPM					
Acute inpatient	$770	$315	$1639	$1586	$2656
Other inpatient	$92	$29	$211	$173	$307
Outpatient facility	$324	$238	$489	$770	$2131
SNF	$191	$79	$406	$328	$377
Home health	$113	$54	$225	$185	$183
Hospice	$57	$36	$96	$89	$59
Professional + DME	$537	$394	$811	$824	$1244
Medical total	$2084	$1145	$3877	$3956	$6958
Utilization PTMPY					
IP admit	609	264	1267	1156	1550
SNF admit	45	17	99	76	111
Home health visit	8060	6497	11,045	12,184	18,135
Hospice visit	126	49	273	222	247
DME utilization	6352	2982	12,789	10,332	9695
OP facility visit	59	31	112	110	102
Professional visit	79,540	60,118	116,376	115,862	146,962

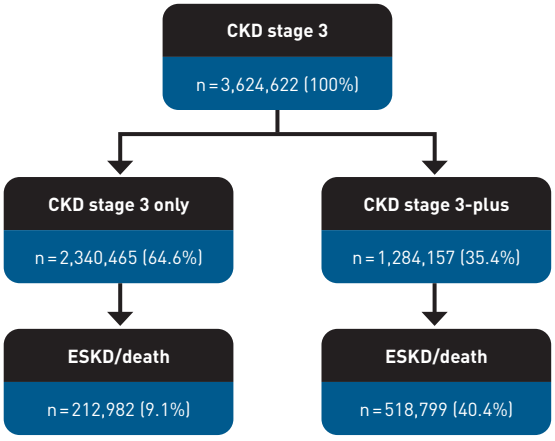
CKD, chronic kidney disease; DME, durable medical equipment; ESKD, end-stage kidney disease; IP, inpatient; OP, outpatient; PMPM, per member per month; PTMPY; per thousand members per year; SNF, skilled nursing facility.

FIGURE 1. Comparison of Medical Costs Paid PMPM by CKD Stage



CKD, chronic kidney disease; ESKD, end-stage kidney disease; PMPM, per member per month.

FIGURE 2. Cohort Progression[a]



CKD, chronic kidney disease; ESKD, end-stage kidney disease.
[a]The denominator of each percentage is based on the preceding cell.

KDIGO clinical practice guidelines currently recommend that primary care physicians refer patients to nephrologists when patients develop CKD stage 4.[8] Population health programs (such as the Center for Medicare and Medicaid Innovation CKCC VBP models) parallel these recommendations by attributing patients to nephrologists beginning at CKD stage 4. Such an approach appears practical considering that there are 15 times as many individuals with CKD stage 3 compared with CKD stage 4,[3] there is variability in disease progression,[5,10] and some study findings have pointed to a supply shortage of nephrologists.[20] However, considering the results of this study, earlier referral of patients with CKD stage 3-plus may improve both health care outcomes and costs at the population level.

One objection to this proposal could focus on the comorbidities that define CKD stage 3-plus. Might this subcohort's higher utilization and costs be driven more by the comorbidities than by kidney disease? And if so, would not the appropriate protocol simply be referral to the corresponding specialty (eg, endocrinology)? We take as given that all appropriate specialties should be involved in a patient's care. What calls for nephrology referral here is progression risk. It may or may not be the case that kidney disease uniquely drives utilization and cost for this subcohort today. However, the elevated progression risk we observe in this subcohort augurs a significant increase on the horizon that will unquestionably be driven by kidney disease. Further, if CKD stage 3-plus were to qualify patients for nephrology-focused VBP models, overall utilization and costs could decline through patients' access to more comprehensive, coordinated services.

Limitations

Our study has several limitations. First, claims data lack laboratory results and can suffer from misclassification of individuals. However, the reasonable accuracy of *ICD-10* diagnosis code–based CKD stage identification is reported with positive predictive value greater than 80%.[21] Second, our study is also subject to the potential overrepresentation of individuals matching the CKD stage 3-plus criteria among the general CKD stage 3 population, given that CKD is generally underdiagnosed in the population and that individuals with more symptomatic disease may be more likely to engage routinely with the health care system. Further research that incorporates laboratory data could validate and refine cohort size and progression risk. Additionally, measurement of disease progression was limited to the relatively short study period (2.5 years). A longer study period may provide a more accurate view into the natural course of the CKD stage 3-plus cohort. Lastly, our findings might not extend to patients with other forms of health insurance outside of FFS Medicare (eg, Medicaid, no insurance).

CONCLUSIONS

We found that Medicare beneficiaries with CKD stage 3 and at least 1 of 7 selected comorbidities have similar disease progression, costs, and utilization to beneficiaries with CKD stage 4 or 5. Our findings demonstrate the use of a claims-based algorithm to identify patients with CKD stage 3 who are at higher risk. Following the same logic that generally calls for nephrology intervention at CKD stage 4, this subset may be more likely to benefit from early nephrology intervention to improve health care costs and outcomes, such as greater readiness for dialysis transition and potential eligibility for VBP models providing access to more comprehensive, coordinated care. ■

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REFERENCES

1. Vart P, Powe NR, McCulloch CE, et al; Centers for Disease Control and Prevention Chronic Kidney Disease Surveillance Team. National trends in the prevalence of chronic kidney disease among racial/ethnic and socioeconomic status groups, 1988-2016. *JAMA Netw Open*. 2020;3(7):e207932. doi:10.1001/jamanetworkopen.2020.7932
2. Levey AS, Eckardt KU, Tsukamoto Y, et al. Definition and classification of chronic kidney disease: a position statement from Kidney Disease: Improving Global Outcomes (KDIGO). *Kidney Int*. 2005;67(6):2089-2100. doi:10.1111/j.1523-1755.2005.00365.x
3. United States Renal Data System. *2022 USRDS Annual Data Report: Epidemiology of Kidney Disease in the United States*. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; 2022. Accessed March 16, 2023. https://usrds-adr.niddk.nih.gov/2022

4. Molnar AO, Hiremath S, Brown PA, Akbari A. Risk factors for unplanned and crash dialysis starts: a protocol for a systematic review and meta-analysis. *Syst Rev*. 2016;5(1):117. doi:10.1186/s13643-016-0297-2
5. Saggi SJ, Allon M, Bernardini J, Kalantar-Zadeh K, Shaffer R, Mehrotra R; Dialysis Advisory Group of the American Society of Nephrology. Considerations in the optimal preparation of patients for dialysis. *Nat Rev Nephrol*. 2012;8(7):381-389. doi:10.1038/nrneph.2012.66
6. Kurella Tamura M, Li S, Chen SC, et al. Educational programs improve the preparation for dialysis and survival of patients with chronic kidney disease. *Kidney Int*. 2014;85(3):686-692. doi:10.1038/ki.2013.369
7. Gillespie BW, Morgenstern H, Hedgeman E, et al. Nephrology care prior to end-stage renal disease and outcomes among new ESRD patients in the USA. *Clin Kidney J*. 2015;8(6):772-780. doi:10.1093/ckj/sfv103
8. Stevens PE, Levin A; Kidney Disease: Improving Global Outcomes Chronic Kidney Disease Guideline Development Work Group Members. Evaluation and management of chronic kidney disease: synopsis of the Kidney Disease: Improving Global Outcomes 2012 clinical practice guideline. *Ann Intern Med*. 2013;158(11):825-830. doi:10.7326/0003-4819-158-11-201306040-00007
9. Jalal K, Anand EJ, Venuto R, Eberle J, Arora P. Can billing codes accurately identify rapidly progressing stage 3 and stage 4 chronic kidney disease patients: a diagnostic test study. *BMC Nephrol*. 2019;20(1):260. doi:10.1186/s12882-019-1429-4
10. Tangri N, Stevens LA, Griffith J, et al. A predictive model for progression of chronic kidney disease to kidney failure. *JAMA*. 2011;305(15):1553-1559. doi:10.1001/jama.2011.451
11. Baek SD, Baek CH, Kim JS, Kim SM, Kim JH, Kim SB. Does stage III chronic kidney disease always progress to end-stage renal disease? a ten-year follow-up study. *Scand J Urol Nephrol*. 2012;46(3):232-238. doi:10.3109/00365599.2011.649045
12. Elixhauser Comorbidity Software Refined for ICD-10-CM. Agency for Healthcare Research and Quality. Accessed March 16, 2023. https://hcup-us.ahrq.gov/toolssoftware/comorbidityicd10/comorbidity_icd10.jsp
13. Hannan M, Ansari S, Meza N, et al; Chronic Renal Insufficiency Cohort (CRIC) Study Investigators. Risk factors for CKD progression: overview of findings from the CRIC Study. *Clin J Am Soc Nephrol*. 2021;16(4):648-659. doi:10.2215/CJN.07830520
14. Portolés J, Gorriz JL, Rubio E, et al; NADIR-3 Study Group. The development of anemia is associated to poor prognosis in NKF/KDOQI stage 3 chronic kidney disease. *BMC Nephrol*. 2013;14:2. doi:10.1186/1471-2369-14-2
15. Bidani AK, Griffin KA. Pathophysiology of hypertensive renal damage: implications for therapy. *Hypertension*. 2004;44(5):595-601. doi:10.1161/01.HYP.0000145180.38707.84
16. Amraoui F, Bos S, Vogt L, van den Born BJ. Long-term renal outcome in patients with malignant hypertension: a retrospective cohort study. *BMC Nephrol*. 2012;13:71. doi:10.1186/1471-2369-13-71
17. House AA, Wanner C, Sarnak MJ, et al; Conference Participants. Heart failure in chronic kidney disease: conclusions from a Kidney Disease: Improving Global Outcomes (KDIGO) Controversies Conference. *Kidney Int*. 2019;95(6):1304-1317. doi:10.1016/j.kint.2019.02.022
18. Giusti S, Lin Y, Sogbetun F, et al. The effect of proton pump inhibitor use on the course of kidney function in patients with chronic kidney disease stages G3a to G4. *Am J Med Sci*. 2021;362(5):453-461. doi:10.1016/j.amjms.2021.05.017
19. Navaneethan SD, Walther CP, Gregg LP, et al. Mortality, kidney failure, and hospitalization among Medicare beneficiaries with CKD and pulmonary hypertension. *Am J Kidney Dis*. 2021;78(5):700-708.e1. doi:10.1053/j.ajkd.2021.02.336
20. Sozio SM, Pivert KA, Caskey FJ, Levin A. The state of the global nephrology workforce: a joint ASN-ERA-EDTA-ISN investigation. *Kidney Int*. 2021;100(5):995-1000. doi:10.1016/j.kint.2021.07.029
21. Paik JM, Patorno E, Zhuo M, et al. Accuracy of identifying diagnosis of moderate to severe chronic kidney disease in administrative claims data. *Pharmacoepidemiol Drug Saf*. 2022;31(4):467-475. doi:10.1002/pds.5398

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CKD3

Analysis Variable : t2outcome								
index_cat	index_year	N Obs	N	Mean	Median	Minimum	Maximum	Std Dev
CKD3	2018	315488	315488	558.3692312	461.0000000	-27.0000000	1773.00	472.3839980
	2019	251771	251771	434.6384810	359.0000000	-27.0000000	1415.00	369.8705744
	2020	164143	164143	277.8876833	194.0000000	-24.0000000	1051.00	265.6579823
	2021	108665	108665	163.4637096	111.0000000	-927.0000000	682.0000000	160.5983492
Other	2018	49959	49959	503.2784483	377.0000000	-23.0000000	1764.00	461.2999130
	2019	79605	79605	410.3241505	319.0000000	-6.0000000	1410.00	367.3629093
	2020	68738	68738	265.7123716	173.0000000	-16.0000000	1044.00	262.8058654
	2021	55598	55598	151.2217886	93.0000000	-21.0000000	680.0000000	156.5545622

Index Year	Days to ESRD/Death	
2018	503	16.5
2019	410	13.4
2020	266	8.7

index_cat	index_year	esrd_death	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CKD3	2018	0	555067	14.91	555067	14.91
CKD3	2018	1	315488	8.47	870555	23.38
CKD3	2019	0	577659	15.51	1448214	38.89
CKD3	2019	1	251771	6.76	1699985	45.65
CKD3	2020	0	515723	13.85	2215708	59.50
CKD3	2020	1	164143	4.41	2379851	63.91
CKD3	2021	0	607571	16.32	2987422	80.22
CKD3	2021	1	108665	2.92	3096087	83.14
Other	2018	0	40246	1.08	3136333	84.22
Other	2018	1	49959	1.34	3186292	85.56
Other	2019	0	90136	2.42	3276428	87.98
Other	2019	1	79605	2.14	3356033	90.12
Other	2020	0	105056	2.82	3461089	92.94
Other	2020	1	68738	1.85	3529827	94.79
Other	2021	0	138570	3.72	3668397	98.51
Other	2021	1	55598	1.49	3723995	100.00

CKD4,5 to composite outcome

Analysis Variable : t2outcome							
index_year	N Obs	N	Mean	Median	Minimum	Maximum	Std Dev
2018	256065	162428	599.6654579	523.0000000	-8.0000000	1778.00	479.2573603
2019	219983	132907	449.4879878	380.0000000	-666.0000000	1416.00	373.2314714
2020	166938	92094	286.4751775	214.0000000	-994.0000000	1047.00	269.1126811
2021	141775	64285	165.8305359	126.0000000	-1357.00	680.0000000	182.3044051

index_cat	index_year	esrd_death	Frequency	Percent	Cumulative Frequency	Cumulative Percent
CKD45	2018	0	15453	1.66	15453	1.66
CKD45	2018	1	256065	27.45	271518	29.11
CKD45	2019	0	31491	3.38	303009	32.49
CKD45	2019	1	219983	23.58	522992	56.07
CKD45	2020	0	41385	4.44	564377	60.51
CKD45	2020	1	166938	17.90	731315	78.41
CKD45	2021	0	59638	6.39	790953	84.80
CKD45	2021	1	141775	15.20	932728	100.00

41385			
166938	208323	0.801342	
59638			
141775	201413	0.703902	

diagnosis	code_description
N183	Chronic kidney disease, stage 3 (moderate)
N1830	Chronic kidney disease, stage 3 unspecified
N1831	Chronic kidney disease, stage 3a
N1832	Chronic kidney disease, stage 3b
N189	Chronic kidney disease, unspecified
N184	Chronic kidney disease, stage 4 (severe)
N185	Chronic kidney disease, stage 5
N186	End stage renal disease