

Risk Assessability and Recorded Organ-Protective Therapy Gaps in Type 2 Diabetes: A Five-Center Cross-Sectional Study

wenxuan li

Affiliated Hospital of Qingdao University

jinghan zheng

Affiliated Hospital of Qingdao University

wenshan lv

Affiliated Hospital of Qingdao University

lili xu

Affiliated Hospital of Qingdao University

ke si

Affiliated Hospital of Qingdao University

yuzhao liu

Affiliated Hospital of Qingdao University

shuhui hu

Affiliated Hospital of Qingdao University

shengli wu

Karamay People's Hospital

Yuancheng dai

Sheyang County Diabetes Specialist Hospital

qijuan dong

The Fifth Clinical Medical College, Henan University of Chinese Medicine

qidong zheng

Yuhuan Second People's Hospital

yangang wang

wangyg1966@126.com

Affiliated Hospital of Qingdao University

Article

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Abstract

Background

Cardio-kidney protection in type 2 diabetes requires more than recognizing risk; routine care must carry that risk into treatment. Most medication-use estimates cannot show whether risk and medication records were complete enough to support this judgment.

Methods

We analyzed one first eligible visit per adult with definite type 2 diabetes at five Chinese diabetes-management centers. Primary inference covered 2021–2025, comparing 2023–2025 with 2021–2022. Four care cascades paired a kidney-risk signal with an evidence-aligned sodium–glucose cotransporter 2 inhibitor (SGLT2i); recorded coronary heart disease or stroke with an evidence-aligned SGLT2i or glucagon-like peptide-1 receptor agonist; the same cardiovascular conditions with a statin; and albuminuria plus diagnosed hypertension with an angiotensin-converting enzyme inhibitor or angiotensin receptor blocker. Cascades separated risk and medication assessability from therapy recorded and recorded therapy gap. Modified Poisson models estimated prevalence ratios; logistic marginal standardization estimated adjusted probabilities and risk differences after multiple imputation.

Results

The analysis included 32,165 adults; medication status was assessable for 25,745/32,165 (80.0%). Risk assessability ranged from 62.3% to 82.8% across domains. Recorded gaps affected 3,338/5,734 (58.2%; 95% CI 56.9–59.5) in the kidney/SGLT2i domain, 1,772/2,884 (61.4%; 59.7–63.2) in the coronary heart disease or stroke/SGLT2i or GLP-1 receptor agonist domain, 1,061/2,884 (36.8%; 35.0–38.6) in the statin domain, and 1,462/2,948 (49.6%; 47.8–51.4) in the albuminuria-hypertension/ACE inhibitor or ARB domain. For 2023–2025 versus 2021–2022, adjusted prevalence ratios were 0.81, 0.95, 1.21, and 1.09, respectively.

Conclusions

Incomplete risk information and recorded therapy gaps formed one linked implementation problem. Completing cardio-kidney assessment, reconciling medications, and reviewing unresolved indications could turn guideline knowledge into more consistent organ protection. An absent record does not confirm clinical nonuse.

Research Insights

Item	Research insight
What is known?	Organ-protective therapies work, but routine uptake remains uneven.
What was asked?	Where does the path from assessable risk to recorded therapy break down?
What is new?	Four indication-specific gaps ranged from 36.8% to 61.4%.
Why it matters	Complete risk assessment, then reconcile therapy and review unresolved indications.

Background

Type 2 diabetes is not simply a disorder of glucose. It is a long course of overlapping vascular, kidney, and metabolic injury, often accompanied by hypertension, dyslipidemia, and obesity. The cardiovascular-kidney-metabolic framework gives that clinical reality a name, but the underlying message is older and more practical: durable benefit comes from protecting several organs and risk pathways at once, not from pursuing HbA1c in isolation [1–5, 20, 21, 41–44].

The therapeutic evidence has moved decisively in that direction. SGLT2 inhibitors reduce kidney disease progression and heart-failure events in defined kidney and cardiovascular settings; GLP-1 receptor agonists reduce major cardiovascular events in people with established or high cardiovascular risk. Statins remain a foundation of secondary prevention, while ACE inhibitors and ARBs retain a central role when diabetes, hypertension, and albuminuria converge [6–19, 22, 41–44]. These therapies are complementary rather than interchangeable. Their value depends on recognizing the right indication and carrying it into an individual treatment decision.

That translation remains uneven in routine care. Studies from the United Kingdom and Central and Eastern Europe found that established cardiovascular disease did not reliably lead to use of SGLT2 inhibitors or GLP-1 receptor agonists [26, 34]. Chinese prescription data show rapid growth in both classes, yet their overall share remained low and varied with insurance, hospital level, specialty, and geography [36]. Older therapies have not escaped the same problem. A Shanghai health-record study found that only about half of patients with cardiovascular disease received a statin for secondary prevention, and the national CCMR-3B study reported similarly incomplete ACE inhibitor or ARB use among people with diabetes, hypertension, and albuminuria [35, 37]. The long literature on clinical inertia makes the broader point: evidence can be settled while implementation stays slow [27–30].

There is an earlier break in the pathway that medication percentages often miss. A risk-directed treatment cannot be considered if the risk itself was never measured or was not available in the record. Albuminuria is a clear example. In the CCMR-3B study, only one-quarter of participants had an albumin-to-creatinine ratio measurement [37]. Large US health-system studies later found that albuminuria testing remained sparse, leaving much kidney risk undetected and weakening the link to kidney-protective treatment [45, 46]. Analyses that silently convert missing risk data to 'no risk,' or missing medication data to 'no treatment,' blur these two failures and can misstate the size of the treatment gap.

We designed this study to make both breaks visible. Across five Chinese diabetes-management centers, four indication-specific care cascades followed patients from risk assessability to risk positivity, medication assessability, therapy recorded, and recorded therapy gap. We aimed to show where routine care loses the

opportunity for organ protection, how that pattern differs across treatment domains and centers, and whether it changed between 2021–2022 and 2023–2025. The intended contribution is a usable quality framework: complete the risk picture, reconcile the medication record, and bring unresolved indications to clinical review.

Methods

Study design and data sources

This was a multicenter retrospective cross-sectional analysis with prespecified calendar-period comparisons. We used routinely collected records from hospital-affiliated or regional diabetes-management centers in Qingdao, Karamay, Sheyang, Yuhuan, and Zhengzhou, China. The harmonized data contained structured demographics, visits, laboratory results, diagnoses, and medication fields. Structured diagnoses and clinical values were entered or reviewed during routine clinical care before export and were treated as source-of-record inputs. We deduplicated identifiers within each center. Cross-center linkage was not possible because the centers did not share a reliable common identifier. Reporting follows STROBE and RECORD [39, 40].

Participants and index visit

Adults were eligible when they were at least 18 years old, had a valid visit date and recorded sex, and had either an explicit type 2 diabetes diagnosis in a structured disease field or a diabetes-type field coded as type 2. We retained the first visit meeting these criteria for each center-specific participant. The main analysis covered 2021–2025. We divided it a priori into 2021–2022 and 2023–2025, a pragmatic early-versus-later contemporary comparison that preserved adequate counts in all four domains. Records from 2017–2025 were used only to show historical uptake; incomplete 2026 data were excluded. Alternative earliest core-complete, highest-completeness, and first medication-assessable visits were examined in sensitivity analyses.

Care-cascade domains

Each cascade followed the same sequence: risk assessable, risk criterion met, treatment boundary met, medication status assessable, aligned therapy recorded, or recorded organ-protective therapy gap. Risk and medication states were coded as positive, negative, or unknown. Unknown states never entered a therapy-gap denominator.

The primary kidney-risk signal was one recorded $\text{eGFR} < 60 \text{ mL/min/1.73 m}^2$ or a unit-harmonized urinary albumin-to-creatinine ratio (UACR) $\geq 30 \text{ mg/g}$. SGLT2 inhibitor eligibility also required $\text{eGFR} \geq 20 \text{ mL/min/1.73 m}^2$. One abnormal result signals risk but does not establish chronic kidney disease, so CKD terminology was reserved for a sensitivity analysis requiring two abnormal kidney measurements 90–365 days apart [42, 43]. We calculated eGFR with the 2021 CKD-EPI creatinine equation [38].

Core atherosclerotic cardiovascular disease (ASCVD) comprised recorded coronary heart disease or stroke. We assessed two treatment pairings in this group: an evidence-aligned SGLT2 inhibitor or GLP-1 receptor agonist, and a statin. The fourth pairing linked albuminuria plus a recorded hypertension diagnosis to an ACE

inhibitor or ARB. Peripheral artery disease, heart failure, and revascularization fields were audited separately because structured capture was uneven across centers and were not used to define core ASCVD.

Medication and UACR harmonization

Medication text was normalized through ordered rules for generic names, active ingredients, fixed-dose combinations, brands, and spelling variants. Evidence-aligned definitions remained separate from broader class-wide definitions. The SGLT2 inhibitor evidence set contained dapagliflozin, empagliflozin, and canagliflozin; the ASCVD GLP-1 receptor agonist set contained liraglutide, semaglutide, and dulaglutide. The complete statin, ACE inhibitor, and ARB lists appear in Supplementary Table S2. Sacubitril/valsartan was treated as an angiotensin receptor-neprilysin inhibitor and did not satisfy the ACE inhibitor/ARB outcome. Review of all 1,978 center-specific raw medication names confirmed the prespecified mapping.

We harmonized UACR to mg/g with source-specific rules. Sheyang exports were interpreted as mg/g according to the center protocol. Unresolved units were coded as unknown. Technical review covered extreme values, uncertain units, inequalities, parsing failures, values around the 30 mg/g threshold, and center-stratified routine samples. The review confirmed the unit, parsing, and threshold classifications without changing the rules.

Outcome and interpretive boundary

The outcome in each domain was the absence of an aligned therapy record among participants whose risk, treatment eligibility, and medication status were all assessable. It is a documentation-based quality signal. It does not establish dispensing, adherence, an external prescription, contraindications, affordability, patient preference, or the clinical decision behind the record.

Statistical analysis

Continuous variables are summarized as median [interquartile range] with valid n ; categorical variables are shown as n/N (%). Modified Poisson generalized linear models with HC0 robust variance estimated prevalence ratios (PRs). Logistic marginal standardization produced bounded adjusted gap probabilities and risk differences (RDs). Models included center as a fixed effect, calendar period, age, sex, diabetes duration, HbA1c, systolic blood pressure, LDL cholesterol, and body mass index, together with domain-specific severity terms. The primary kidney comparison used a two-sided α of 0.05. Holm correction controlled multiplicity across the three key secondary outcomes. Global tests assessed center-by-period interaction, and sparse center-period estimates were suppressed when eligible n was < 30 or when events or non-events numbered < 5 .

Missing model covariates were handled with 50 completed datasets from five independently seeded chained-equation runs. Each chain used 100 burn-in iterations and 20 updates between retained datasets. We did not impute outcomes, centers, periods, risk-defining variables, or medication assessability. Diagnostics covered trace behavior, observed-versus-imputed distributions, Monte Carlo error, fraction of missing information, and potential scale reduction; the largest retained potential scale reduction factor was 1.051.

Separate stabilized inverse-probability weights addressed risk assessability and medication assessability. Propensities were bounded at 0.02 and 0.98, and weights were truncated at the 1st and 99th percentiles. Balance, overlap, weight distributions, and effective sample size were inspected; the largest absolute weighted standardized difference was 0.501. Because residual imbalance remained, weighting was treated as a sensitivity analysis rather than a complete correction for assessability. Other analyses restricted center-years to domain assessability $\geq 70\%$, used 2022–2025 only, required strict kidney chronicity, stratified kidney severity, varied index selection and medication timing, compared complete-case and imputed estimates, and omitted one center at a time. Follow-up analyses were exploratory and used the terms first recorded appearance and persistent recorded gap.

Use of AI-assisted tools

Under study-team supervision, OpenAI Codex supported code review, language editing, reference organization, and document formatting. No identifiable patient-level data were sent to an external generative-AI service. The authors reviewed the analytical and written output and retain responsibility for the work.

Ethics

The protocol for this multicenter secondary analysis was approved by the Medical Ethics Committee of The Affiliated Hospital of Qingdao University (QYFY WZLL 5063), which waived the requirement for informed consent because the study used deidentified routine-care data. Secondary use of data at participating centers was covered by local ethics approvals from the Karamay People's Hospital Ethics Committee (ZXYJHKYEC-2019-001-01), the Ethics Committee for Human Research Projects of Sheyang County Diabetes Specialist Hospital [(Sheyang Diabetes) Ethics Approval No. 096], the Zhengzhou People's Hospital Scientific Research Ethics Committee (KY-2023-004-02), and the Ethics Committee of the Health Community Group of Yuhuan Second People's Hospital [(Yuhuan No. 2 Hospital) Ethics Approval No. 2264]. All methods were performed in accordance with the relevant institutional, national, and international guidelines and regulations, including the Declaration of Helsinki. All records were deidentified before cross-center harmonization and analysis.

Results

Study population and assessability

The source data contained 229,765 visits linked to 67,495 center-specific identifiers. The first-visit cohort included 47,085 adults with definite type 2 diabetes, of whom 46,728 had an index visit in 2017–2025 and 32,165 in the primary 2021–2025 window (Fig. 1). Medication status was assessable for 25,745/32,165 (80.0%). Risk status was assessable for 26,647/32,165 (82.8%) in the kidney domain, 25,912/32,165 (80.6%) in the ASCVD domains, and 20,050/32,165 (62.3%) in the albuminuria-hypertension domain (Table 1; Supplementary Figure S1).

Table 1
Participant characteristics and domain assessability, overall and by center

Characteristic	Overall	Qingdao	Karamay	Sheyang	Yuhuan	Zhengzhou
Participants, n	32165	1806	6296	7784	8513	7766
Age, years, median [IQR]	58.0 [50.0, 65.0] n = 32165	52.0 [42.0, 59.0] n = 1806	58.0 [51.0, 65.0] n = 6296	60.0 [54.0, 67.0] n = 7784	57.0 [48.0, 65.0] n = 8513	56.0 [46.0, 65.0] n = 7766
Diabetes duration, months, median [IQR]	56.0 [6.0, 132.0] n = 25679	40.0 [2.0, 120.0] n = 1752	69.0 [19.0, 143.0] n = 4545	97.0 [38.0, 164.0] n = 5383	24.0 [0.0, 92.8] n = 7570	59.0 [7.0, 128.0] n = 6429
Body mass index, kg/m ² , median [IQR]	25.8 [23.6, 28.5] n = 27521	26.3 [24.0, 29.3] n = 1757	26.3 [24.0, 29.1] n = 5349	26.4 [24.2, 28.9] n = 5390	25.4 [23.1, 27.8] n = 7902	25.4 [23.3, 28.0] n = 7123
HbA1c, %, median [IQR]	8.6 [7.0, 10.4] n = 26513	8.9 [7.3, 10.7] n = 1170	7.9 [6.6, 9.6] n = 5609	9.8 [8.3, 11.3] n = 4748	7.9 [6.7, 10.0] n = 7863	8.8 [7.3, 10.6] n = 7123
Systolic blood pressure, mmHg, median [IQR]	130.0 [120.0, 140.0] n = 28091	128.0 [117.0, 139.0] n = 1770	120.0 [120.0, 130.0] n = 5425	135.0 [124.0, 146.0] n = 5892	130.0 [119.0, 141.0] n = 7858	132.0 [123.0, 142.0] n = 7146
LDL cholesterol, mmol/L, median [IQR]	2.76 [2.10, 3.46] n = 25030	2.70 [2.12, 3.50] n = 139	2.81 [2.17, 3.47] n = 5233	2.74 [2.10, 3.43] n = 4739	2.93 [2.25, 3.63] n = 7883	2.56 [1.91, 3.21] n = 7036
eGFR, mL/min/1.73 m ² , median [IQR]	103.5 [93.7, 112.0] n = 25056	110.3 [103.0, 121.2] n = 138	99.7 [88.8, 106.8] n = 5216	103.2 [93.0, 111.0] n = 4743	104.6 [93.5, 113.4] n = 7929	106.1 [97.2, 115.0] n = 7030
UACR, mg/g, median [IQR]	12.1 [5.3, 33.6] n = 21186	10.5 [5.8, 32.3] n = 1111	13.3 [7.1, 31.8] n = 2701	3.2 [1.6, 9.9] n = 4473	23.0 [9.7, 67.2] n = 7687	11.2 [6.4, 26.2] n = 5214
Female sex, n/N (%)	13746/32165 (42.7%)	810/1806 (44.9%)	2361/6296 (37.5%)	3951/7784 (50.8%)	3650/8513 (42.9%)	2974/7766 (38.3%)
Values are median [interquartile range] with valid n, or n/N (%). The risk-domain rows show the number assessable among all participants and the number meeting the criterion among those assessable. The same ASCVD definition underlies both ASCVD treatment domains. Missing measurements were not coded as normal.						
Abbreviations: ASCVD, atherosclerotic cardiovascular disease; eGFR, estimated glomerular filtration rate; HbA1c, glycated hemoglobin; LDL, low-density lipoprotein; UACR, urinary albumin-to-creatinine ratio.						

Characteristic	Overall	Qingdao	Karamay	Sheyang	Yuhuan	Zhengzhou
Medication status assessable, n/N (%)	25745/32165 (80.0%)	1182/1806 (65.4%)	4642/6296 (73.7%)	5394/7784 (69.3%)	7888/8513 (92.7%)	6639/7766 (85.5%)
Kidney-risk signal: assessable; criterion met	Assessable 26647/32165 (82.8%)	Assessable 1146/1806 (63.5%)	Assessable 5617/6296 (89.2%)	Assessable 4792/7784 (61.6%)	Assessable 7937/8513 (93.2%)	Assessable 7155/7766 (92.1%)
	Met 6546/26647 (24.6%)	Met 294/1146 (25.7%)	Met 930/5617 (16.6%)	Met 530/4792 (11.1%)	Met 3463/7937 (43.6%)	Met 1329/7155 (18.6%)
Recorded coronary heart disease or stroke: assessable; criterion met	Assessable 25912/32165 (80.6%)	Assessable 1752/1806 (97.0%)	Assessable 4628/6296 (73.5%)	Assessable 5384/7784 (69.2%)	Assessable 7668/8513 (90.1%)	Assessable 6480/7766 (83.4%)
	Met 2987/25912 (11.5%)	Met 252/1752 (14.4%)	Met 510/4628 (11.0%)	Met 203/5384 (3.8%)	Met 764/7668 (10.0%)	Met 1258/6480 (19.4%)
Albuminuria with diagnosed hypertension: assessable; criterion met	Assessable 20050/32165 (62.3%)	Assessable 1105/1806 (61.2%)	Assessable 2052/6296 (32.6%)	Assessable 4454/7784 (57.2%)	Assessable 7493/8513 (88.0%)	Assessable 4946/7766 (63.7%)
	Met 3038/20050 (15.2%)	Met 180/1105 (16.3%)	Met 266/2052 (13.0%)	Met 213/4454 (4.8%)	Met 1806/7493 (24.1%)	Met 573/4946 (11.6%)
Values are median [interquartile range] with valid n, or n/N (%). The risk-domain rows show the number assessable among all participants and the number meeting the criterion among those assessable. The same ASCVD definition underlies both ASCVD treatment domains. Missing measurements were not coded as normal.						
Abbreviations: ASCVD, atherosclerotic cardiovascular disease; eGFR, estimated glomerular filtration rate; HbA1c, glycated hemoglobin; LDL, low-density lipoprotein; UACR, urinary albumin-to-creatinine ratio.						

Care cascades and recorded therapy gaps

The kidney-risk criterion was met by 6,546 participants. Of these, 6,033 met the eGFR treatment boundary and 5,734 had assessable medication status. Recorded coronary heart disease or stroke was present in 2,987 participants, with medication status assessable in 2,884. Albuminuria with diagnosed hypertension was present in 3,038 participants, of whom 2,948 had assessable medication status (Fig. 1).

Recorded gaps were 3,338/5,734 (58.2%; 95% CI 56.9–59.5) for kidney risk/SGLT2 inhibitor, 1,772/2,884 (61.4%; 95% CI 59.7–63.2) for coronary heart disease or stroke/SGLT2 inhibitor or GLP-1 receptor agonist, 1,061/2,884 (36.8%; 95% CI 35.0–38.6) for coronary heart disease or stroke/statin, and 1,462/2,948 (49.6%; 95% CI 47.8–51.4) for albuminuria-hypertension/ACE inhibitor or ARB (Table 2; Fig. 2A).

Table 2
Main recorded organ-protective therapy gaps and adjusted calendar-period contrasts

Outcome hierarchy	Risk–therapy pairing	Eligible, n	Aligned therapy recorded, n/N (%)	Recorded therapy gap, n/N (%) [95% CI]	Adjusted PR, 2023–2025 vs 2021–2022 (95% CI)	Adjusted RD, percentage points, 2023–2025 minus 2021–2022 (95% CI)	P value
Primary	Kidney-risk signal: SGLT2 inhibitor	5734	2396/5734 (41.8%)	3338/5734 (58.2%) [56.9–59.5]	0.81 (0.78–0.85)	-11.5 (-14.0 to -8.9)	< 0.001
Key secondary 1	Coronary heart disease or stroke: SGLT2 inhibitor or GLP-1 receptor agonist	2884	1112/2884 (38.6%)	1772/2884 (61.4%) [59.7–63.2]	0.95 (0.89–1.00)	-2.8 (-6.3 to 0.6)	0.060
Key secondary 2	Coronary heart disease or stroke: statin	2884	1823/2884 (63.2%)	1061/2884 (36.8%) [35.0–38.6]	1.21 (1.09–1.33)	6.7 (3.2 to 10.1)	< 0.001
Key secondary 3	Albuminuria with diagnosed hypertension: ACE inhibitor or ARB	2948	1486/2948 (50.4%)	1462/2948 (49.6%) [47.8–51.4]	1.09 (1.01–1.19)	4.2 (0.4 to 8.0)	0.060
Denominators are specific to each risk–therapy pairing. PRs come from modified Poisson models with robust variance. Adjusted RDs come from logistic marginal standardization after 50 completed datasets from five independent chains. The reported P value is raw for the primary kidney outcome and Holm adjusted across the three key secondary outcomes. A recorded gap does not establish clinical nonuse.							
Abbreviations: ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; CI, confidence interval; GLP-1, glucagon-like peptide-1; PR, prevalence ratio; RD, risk difference; SGLT2, sodium–glucose cotransporter 2.							

Center and period patterns

Adjusted gap probabilities varied across the five centers: 46.9%–84.4% in the kidney domain, 42.5%–76.6% for ASCVD/newer agents, 25.0%–62.2% for ASCVD/statin, and 31.9%–71.0% for albuminuria–hypertension/ACE inhibitor or ARB. These estimates describe the participating centers; they are not rankings or national estimates (Supplementary Figure S2).

The period pattern was mixed. For 2023–2025 versus 2021–2022, the kidney gap was lower (PR 0.81 (95% CI 0.78–0.85); RD -11.5 percentage points (95% CI -14.0 to -8.9); $P < 0.001$). The ASCVD/newer-agent contrast was smaller (PR 0.95 (95% CI 0.89–1.00); RD -2.8 percentage points (95% CI -6.3 to 0.6); $P = 0.060$; did not

meet the multiplicity-adjusted threshold). The statin gap was higher (PR 1.21 (95% CI 1.09–1.33); RD 6.7 percentage points (95% CI 3.2 to 10.1); $P < 0.001$), as was the ACE inhibitor or ARB gap (PR 1.09 (95% CI 1.01–1.19); RD 4.2 percentage points (95% CI 0.4 to 8.0); $P = 0.060$; did not meet the multiplicity-adjusted threshold) (Fig. 2B). Global center-by-period interaction tests were significant in all four domains (all $P \leq 0.008$), showing that the period pattern was not uniform across centers (Supplementary Figure S3).

Sensitivity and exploratory follow-up analyses

Joint weighting for risk and medication assessability gave gap estimates of 58.6%, 61.7%, 36.8%, and 51.5%. Restricting the data to center-years with assessability $\geq 70\%$ produced 57.0%, 61.0%, 34.6%, and 46.8%, respectively. The strict kidney chronicity cohort included 3,939 eligible participants; 2,568/3,939 (65.2%) had no aligned SGLT2 inhibitor record. Other robustness analyses are reported in the Supplementary Appendix and machine-readable files.

Among participants with an index-visit gap and assessable follow-up medication fields, the first recorded appearance of aligned therapy occurred in 108/1,924 (5.6%), 54/1,102 (4.9%), 27/608 (4.4%), and 31/863 (3.6%) across the four domains. Follow-up timing was not protocolized, and a later record may represent reconciliation or delayed documentation rather than treatment initiation.

Discussion

This study identifies a continuous implementation problem with two distinct breaks. Risk information was incomplete for a meaningful share of patients, especially in the albuminuria-hypertension domain. Even after both risk and medication status could be assessed, the record lacked the aligned therapy in 36.8%–61.4% of eligible participants. The result is more than a set of prescribing percentages. It shows exactly where the pathway from a documented risk signal to organ protection becomes uncertain, and it gives diabetes services a way to measure that loss.

The upstream loss of risk information deserves attention in its own right. Early diabetic kidney disease is often clinically quiet; eGFR and UACR provide different information, and relying on serum creatinine alone misses patients with albuminuria and preserved filtration [31–33, 42, 45, 46]. In a large US electronic-health-record cohort, an estimated two-thirds of patients with albuminuria went undetected because urine albumin was not tested; testing was also strongly associated with subsequent use of ACE inhibitors or ARBs and SGLT2 inhibitors [45]. A separate 20-system study found that fewer than one-quarter of adults with type 2 diabetes received both recommended kidney screening measures [46]. Chinese data point in the same direction: CCMR-3B had ACR measurements for only 25.1% of participants [37]. Our albuminuria-hypertension risk status was assessable for 62.3% of the cohort, better than those earlier reports but still too incomplete for a condition that helps determine several disease-modifying therapies. Missing UACR is therefore not a neutral blank. It can close the door to risk recognition before a treatment decision is reached.

The 58.2% kidney/SGLT2 inhibitor gap sits against a mature evidence base. Cardiovascular outcome trials first signaled the kidney benefit of SGLT2 inhibitors, and dedicated kidney trials then showed slower disease progression across a broad range of CKD [6–12]. Multinational routine-care cohorts have reported kidney and cardiovascular benefits outside trial settings as well [23–25]. Yet uptake has lagged behind evidence. In a

contemporary US cohort restricted to people with type 2 diabetes, CKD, and albuminuria, only 4.6% had an SGLT2 inhibitor prescription during 2019–2020 [46]. The CORDIALLY study likewise documented limited use of newer glucose-lowering agents among patients with cardiovascular or kidney disease in Central and Eastern Europe [34]. Chinese prescription volumes rose sharply from 2018 to 2021, but the proportion remained low and access differed by socioeconomic and care-setting factors [36]. Against that background, the lower kidney gap in 2023–2025 is encouraging. It suggests that kidney-protective evidence is entering practice, but the remaining gap is still large enough to matter.

The cardiovascular newer-agent gap was similarly substantial at 61.4%. Trials of empagliflozin, canagliflozin, liraglutide, semaglutide, and dulaglutide established cardiovascular benefit in relevant populations, and current guidance places these therapies within cardiovascular risk reduction rather than treating them only as glucose-lowering options [6, 8, 11–17, 41, 43, 44]. Real-world prescribing has not fully caught up. UK CPRD data showed that a history of cardiovascular disease did not consistently translate into use of these classes, while CORDIALLY found a comparable disconnect across several health systems [26, 34]. Our pairing deliberately allowed either an evidence-aligned SGLT2 inhibitor or GLP-1 receptor agonist. The gap therefore does not arise from demanding one particular drug; it reflects the absence of both evidence-supported options in the structured medication record.

The older treatment domains sharpen the message. A 36.8% statin gap among participants with recorded coronary heart disease or stroke is lower than the roughly 48% gap implied by the Shanghai study's 51.6% secondary-prevention statin use, but it remains clinically consequential for a low-cost, long-established therapy [19, 35]. The 49.6% ACE inhibitor or ARB gap in albuminuria with diagnosed hypertension is strikingly close to CCMR-3B, where only 48.3% of patients with the same broad clinical profile used either class [18, 22, 37]. More than a decade separates that survey from much of our contemporary window. The persistence of a similar shortfall suggests that the implementation problem is not confined to expensive or recently introduced drugs. Familiar therapies can also fall out of the care pathway when risk assessment, medication reconciliation, and ownership of multisystem care are fragmented.

Calendar time offered no single upward curve. The kidney/SGLT2 inhibitor gap declined, but the statin and ACE inhibitor or ARB gaps were higher in 2023–2025; the ASCVD/newer-agent contrast did not meet the multiplicity-adjusted threshold. National prescription counts can rise rapidly while indication-specific coverage moves differently [36]. Case mix, formulary access, guideline diffusion, competing treatment priorities, and changes in structured documentation may all be involved. Because each participant contributed one index visit, these are period contrasts rather than within-person changes. Even so, the mixed pattern carries a practical warning: tracking one rapidly adopted drug class can create a false sense of progress while established prevention domains drift in the other direction.

Variation among centers adds another layer. The adjusted probabilities moved over a wide range, and the center-by-period interaction was significant in every domain. Some of that variation may reflect local prescribing and access; some clearly reflects how consistently laboratories, diagnoses, and medications enter the structured record. These five sites cannot support a national ranking, and the estimates should not be used that way. They do show that implementation is local. The literature on clinical inertia has traditionally focused on delayed glucose-lowering intensification [27–30]. Our findings extend that idea to organ

protection, where the action may involve several specialties and where a missing test can be as limiting as a missing prescription.

There is evidence that this gap is modifiable. In the COORDINATE-Diabetes cluster-randomized trial, a clinic-level intervention that combined local barrier assessment, interdisciplinary pathways, clinician education, audit and feedback, and patient tools increased use of high-intensity statins, ACE inhibitors or ARBs, and SGLT2 inhibitors or GLP-1 receptor agonists in people with type 2 diabetes and ASCVD [47]. Our care cascade could support a similar approach in diabetes-management centers. It can identify whether the next task is to obtain eGFR or UACR, clarify a cardiovascular diagnosis, reconcile outside and current medications, or ask a clinician to review an unresolved indication. That order matters. An alert that skips reconciliation risks noise; a cascade that locates the missing step is more likely to prompt useful action.

The exploratory later-visit findings reinforce, without proving, this interpretation. First recorded appearance of aligned therapy was uncommon among those with an index-visit gap. Because follow-up was not protocolized, a later entry could represent initiation, reconciliation, or delayed documentation, and patients who returned were a selected group. Still, the pattern does not suggest that routine follow-up reliably closes these gaps on its own. A deliberate workflow is likely to be needed.

The analysis has several strengths. It uses indication-specific denominators rather than a single broad high-risk category, preserves unknown states, and separates risk assessability from medication assessability. Evidence-aligned drug sets and a contemporary study window make the pairings clinically interpretable. Relative estimates are accompanied by absolute marginal probabilities and risk differences. Multiple imputation, separate assessability weights, sparse-cell rules, kidney chronicity analyses, and a wide sensitivity set make the study's numerical boundaries visible rather than burying them in assumptions.

The limitations set clear limits on interpretation. These records cannot fully capture outside prescriptions, dispensing, adherence, contraindications, affordability, or patient preference. For that reason, a recorded gap is a signal for review, not proof of clinical nonuse or inappropriate care. Data capture differed across centers, and the assessability weights showed limited overlap and residual imbalance; weighting cannot repair structural differences or unmeasured factors. Cross-center linkage was unavailable, so one person could in principle appear at more than one site. The centers are not a national sample, and no adjudicated cardiovascular or kidney outcomes were available. One abnormal kidney value signals risk but does not establish chronicity, although the strict chronicity analysis gave a consistent picture. The main analysis used one visit per participant, and irregular follow-up supports description rather than causal inference.

The clinical opportunity is concrete. Diabetes-management systems should look beyond HbA1c and make eGFR, UACR, established cardiovascular disease, and current medication status visible in the same workflow. They should then reconcile the medication list and bring unresolved risk–therapy pairings to clinician and patient review. This is not automatic prescribing, and it does not replace judgment. It turns organ protection from a guideline paragraph into a measurable care process, one that can be audited, discussed, and improved.

Conclusions

Across five Chinese diabetes-management centers, incomplete risk information and absent records of aligned therapy formed a continuous implementation problem. Four indication-specific care cascades exposed sizeable gaps that differed by treatment domain, center, and calendar period. Routine care can act on both parts of that pathway: complete cardio-kidney risk assessment, reconcile the medication record, and bring unresolved indications to clinical review. Used this way, the cascade can make organ protection a visible and improvable part of diabetes care without mistaking a missing record for confirmed nonuse.

Abbreviations

ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; ARNI, angiotensin receptor-neprilysin inhibitor; ASCVD, atherosclerotic cardiovascular disease; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; GLP-1, glucagon-like peptide-1; IPW, inverse-probability weighting; LDL, low-density lipoprotein; PR, prevalence ratio; RD, risk difference; SGLT2, sodium–glucose cotransporter 2; T2DM, type 2 diabetes mellitus; UACR, urinary albumin-to-creatinine ratio.

Declarations

Ethics approval and consent to participate: The protocol for this multicenter secondary analysis was approved by the Medical Ethics Committee of The Affiliated Hospital of Qingdao University (QYFY WZLL 5063), which waived the requirement for informed consent because the study used deidentified routine-care data. Secondary use of data at participating centers was covered by local ethics approvals from the Karamay People's Hospital Ethics Committee (ZXYJHKYEC-2019-001-01), the Ethics Committee for Human Research Projects of Sheyang County Diabetes Specialist Hospital [(Sheyang Diabetes) Ethics Approval No. 096], the Zhengzhou People's Hospital Scientific Research Ethics Committee (KY-2023-004-02), and the Ethics Committee of the Health Community Group of Yuhuan Second People's Hospital [(Yuhuan No. 2 Hospital) Ethics Approval No. 2264]. All records were deidentified before cross-center harmonization and analysis.

Consent for publication: Not applicable.

Availability of data and materials: De-identified patient-level data are governed by participating-center agreements and are not included in the public submission package. Aggregated numerators, denominators, model estimates, and diagnostic summaries are supplied as Additional Files 2–4. Requests for further access will be considered by the corresponding author and participating institutions, subject to ethics and data-governance approval.

Code availability: A code workflow and analysis specification are documented in the internal reproducibility archive. Shareable analysis code will be released with the accepted article where institutional data-governance rules permit; source-data paths and secure patient locators will not be shared.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: WXL and JHZ conceived and designed the study, curated and analyzed the data, and drafted the manuscript. WXL led the statistical analysis and visualization. WSL, LLX, KS, YZL, SHH, SLW, YCD, QJD, and QDZ coordinated local data acquisition and validation and critically revised the manuscript. YGW conceived and supervised the project, interpreted the findings, and critically revised the manuscript. WXL and JHZ contributed equally. QDZ and YGW are co-corresponding authors. All authors read and approved the final manuscript.

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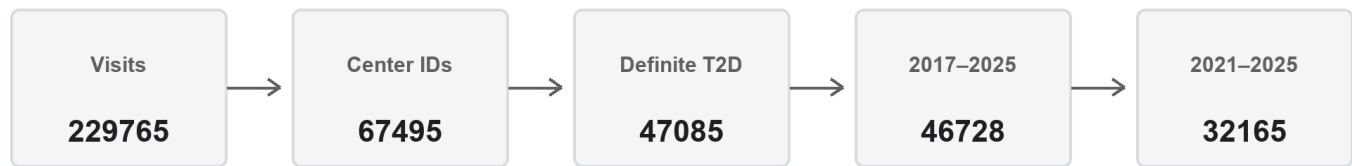
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Figures

A Cohort construction



B Domain-specific care cascades

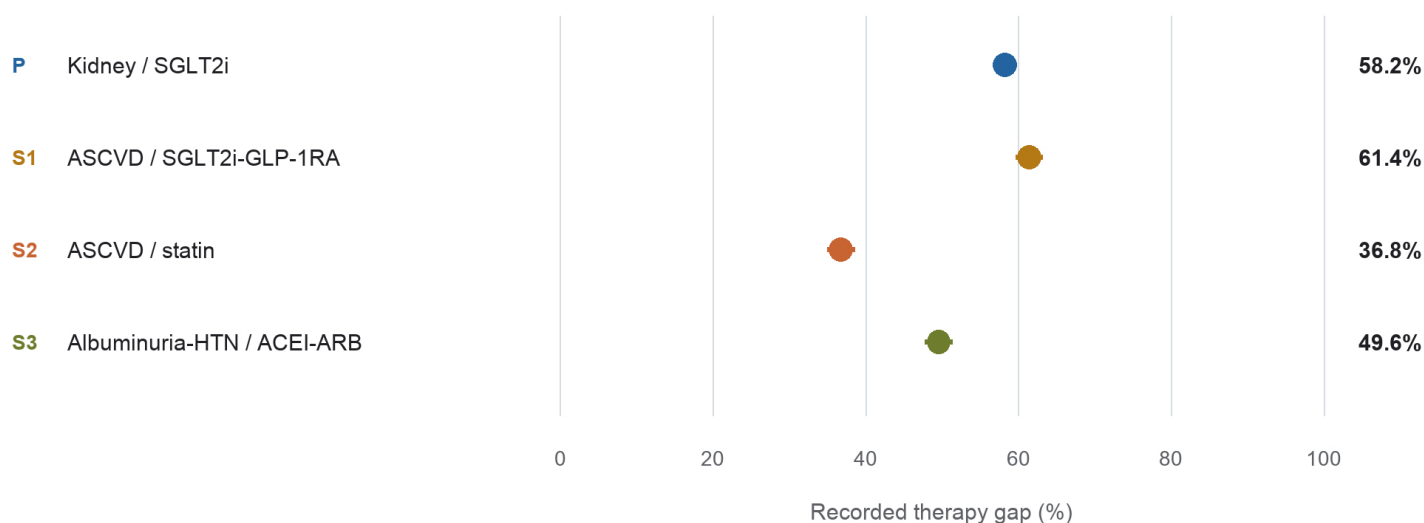


Percentages use the preceding cascade stage. Denominators differ by domain.

Figure 1

Cohort construction and four-domain care cascade. Panel A shows the source visits, center-specific identifiers, definite type 2 diabetes cohort, historical window, and primary window. Panel B separates risk assessability, criterion met, treatment eligibility, medication assessability, aligned therapy recorded, and recorded gap. Grey boxes show unknown risk or medication states. Percentages use the preceding cascade stage; denominators differ by domain.

A Overall recorded therapy gap



B Marginally standardized probability by period

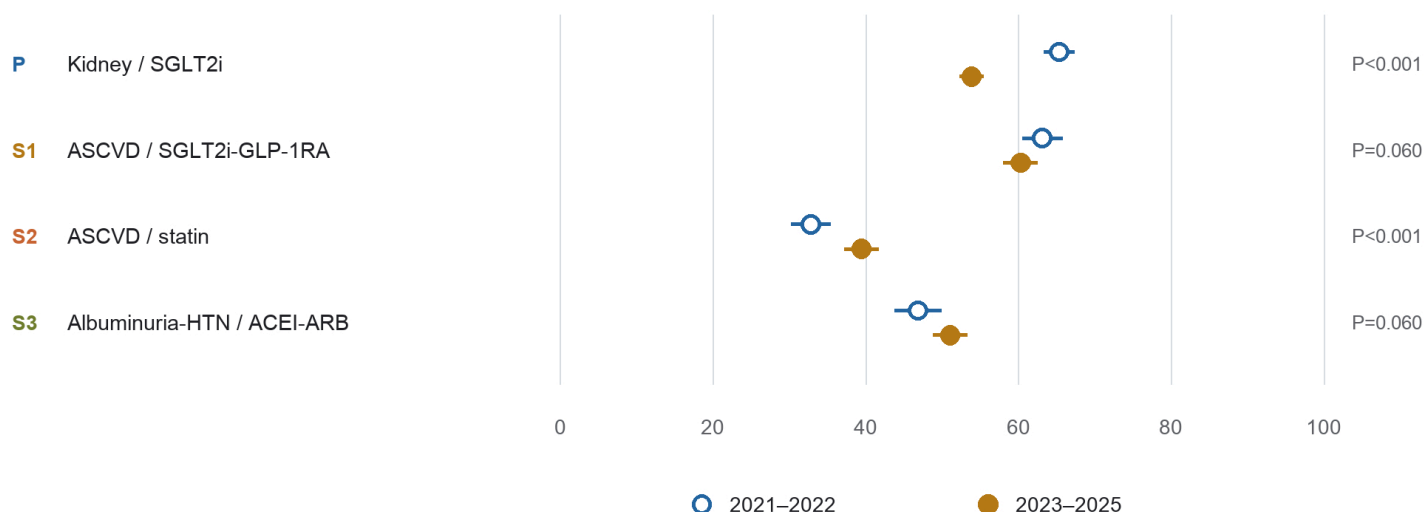


Figure 2

Recorded therapy gaps overall and by calendar period. Panel A shows crude gap proportions with Wilson 95% confidence intervals. Panel B shows marginally standardized probabilities for 2021–2022 and 2023–2025. P denotes the primary kidney outcome; S1–S3 denote the three key secondary outcomes. The primary outcome uses its raw P value, while secondary P values are Holm adjusted.

Supplementary Files

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- [SupplementaryFigureS3Centerperiodrecordedtherapygapsv5.5.jpg](#)
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