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Relationship between sodium-glucose cotransporter 2 inhibitors and kidney neoplasm: systematic review and meta-analysis

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ABSTRACT

Introduction: Kidney cancer is a common tumor of the urinary system, and existing data on the relationship between sodium–glucose cotransporter 2 (SGLT2) inhibitors use and kidney cancer are inconsistent. Therefore, this study aimed to investigate the association between SGLT2 inhibitor use and the risk of developing kidney cancer.

Materials and Methods: This study was designed as a systematic review and meta-analysis following the PRISMA guidelines. Accordingly, a comprehensive search was conducted in the Cochrane, Scopus, Web of Science, Embase, and PubMed databases, as well as the Google Scholar search engine, up to January 5, 2026. Data analysis was performed using STATA version 14.

Results: The results showed that the association between the use of SGLT2 inhibitors (OR: 1.14, 95% CI: 0.86–1.52), dapagliflozin (OR: 1.67, 95% CI: 0.47–5.93), canagliflozin (OR: 1.59, 95% CI: 0.61–4.15), and empagliflozin (OR: 1.31, 95% CI: 0.52–3.27) with the risk of kidney cancer was not statistically significant. However, SGLT2 inhibitor use was associated with a reduced risk of renal cell carcinoma (RCC) (OR: 0.69, 95% CI: 0.63–0.76). In contrast, compared with dipeptidyl peptidase-4 (DPP-4) inhibitors, SGLT2 inhibitor use was linked to an increased risk of kidney cancer (OR: 1.64, 95% CI: 1.11–2.43).

Conclusion: In conclusion, the use of SGLT2 inhibitors did not affect the incidence of kidney cancer, but it was associated with a 31% reduction in the risk of RCC. In contrast, compared with DPP-4 inhibitors, SGLT2 inhibitor use increased the risk of kidney cancer by 64%.

Registration: This study has been compiled based on the PRISMA checklist, and its protocol was registered on the PROSPERO (ID: CRD420261293668) and Research Registry (UIN; reviewregistry2078) websites.

Implication for health policy/practice/research/medical education:
The results indicated that sodium–glucose cotransporter 2 (SGLT2) inhibitor therapy did not influence the overall occurrence of kidney cancer, yet it was linked to a 31% reduction in the risk of renal cell carcinoma (RCC). However, when compared with dipeptidyl peptidase-4 inhibitors (DPP-4), SGLT2 inhibitors were associated with a 64% higher likelihood of kidney cancer. Clinically, these findings underscore the importance of individualized drug selection in diabetes management, prompting clinicians to strike a balance between potential oncologic risks and benefits when choosing between glucose-lowering therapies.

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Meta-analysis

Introduction

Kidney cancer is a common and malignant tumor of the urinary system, and its global incidence and mortality rates continue to rise (1). In 2022, kidney cancer ranked as the fourteenth most common cancer worldwide, with approximately 434,419 new cases and 155,702 deaths (2). The incidence of kidney cancer varies across countries, with higher rates reported in developed nations compared with developing regions (3). Renal cell carcinoma (RCC) accounts for nearly 90% of all kidney cancer cases and is among the 10 most common neoplasms worldwide, carrying the highest mortality rate among urinary system cancers (4-6). RCC represents approximately 2% of all human malignancies, with a higher prevalence in men than in women (7). Moreover, the global incidence of RCC has risen over the past decade (8,9).

The SGLT2 inhibitors are used as glucose-lowering agents in patients with type 2 diabetes (10,11). These medications increase urinary glucose excretion and consequently reduce blood glucose levels (12). Beyond their established roles in diabetes, cardiology, and nephrology, the potential anticancer effects of SGLT2 inhibitors have emerged as another area of interest (13). Several studies have suggested that SGLT2 inhibitors may exhibit anticancer properties across various tumor types (14-17). However, the evidence regarding the relationship between SGLT2 inhibitor use and cancer remains inconsistent and warrants further investigation (18). It has been suggested that certain SGLT2 inhibitors may either increase or decrease the risk of specific cancers. For example, dapagliflozin has been reported to potentially raise the risk of bladder and breast cancer in patients with type 2 diabetes (19), whereas canagliflozin may reduce the risk of gastrointestinal cancers (20).

There are also inconsistencies regarding the association between SGLT2 inhibitor use and the risk of kidney cancer. Some studies (12,21) have reported that SGLT2 inhibitors reduce the risk of developing kidney cancer, whereas other studies (22,23) have suggested that their use may increase this risk. Therefore, the present study aimed to examine the relationship between SGLT2 inhibitor use and the risk of kidney cancer.

Materials and Methods

Study design

This article evaluated the association between SGLT2 inhibitor use and kidney cancer, and its review protocol, developed in accordance with the PRISMA guidelines (24), was registered on the PROSPERO (International Prospective Register of Systematic Reviews) and Research Registry websites.

Search strategy

A systematic literature search was performed in the Cochrane, Scopus, Web of Science, Embase, and PubMed databases, as well as through the Google Scholar search engine, up to January 5, 2026. No temporal or geographical restrictions were applied. The search strategy incorporated standardized keywords and Medical Subject Headings (MeSH), including 'SGLT-2 inhibitor', 'sodium-glucose cotransporter 2 inhibitors', 'gliflozins', 'kidney neoplasms', 'kidney neoplasm', and 'renal cancer'. Boolean operators (AND, OR) were used to combine terms and optimize search sensitivity and specificity. Additionally, the reference lists of all eligible studies were manually screened to identify any relevant publications not captured through electronic searching.

Inclusion and exclusion criteria

Studies were eligible for inclusion if they evaluated the association between the use of SGLT2 inhibitors and the risk of kidney cancer. Studies were excluded if they lacked the essential data required for quantitative analysis, assessed the effects of SGLT2 inhibitors on multiple cancer types rather than kidney cancer specifically, were published in low-credibility journals, examined the combined impact of SGLT2 inhibitors and another medication on kidney cancer risk, were duplicate publications, failed to meet predefined methodological quality standards, or did not provide full-text access despite attempts to contact the authors; review articles and meta-analyses were also excluded.

PICO framework

- Population: Studies that evaluated the association between the use of SGLT2 inhibitors and the risk of kidney cancer.
- Intervention: Exposure to SGLT2 inhibitors.
- Comparison: Non-use of SGLT2 inhibitors.
- Outcomes: Incidence or risk of kidney cancer.

Quality assessment

The methodological quality of the included studies was appraised independently by two reviewers using the Newcastle–Ottawa Scale (NOS), a nine-item, star-based evaluation tool (25). Studies that achieved a minimum score of six stars were considered to meet acceptable quality standards and were subsequently included in the meta-analysis.

Data extraction

Study characteristics were extracted independently by two reviewers using a structured data extraction form. The variables collected included the first author's name,

the specific type of kidney cancer assessed, the SGLT2 inhibitor evaluated, the study year and geographic location, reported risk estimates for kidney cancer associated with SGLT2 inhibitor use, the study design, participant age, and other relevant clinical or methodological details necessary for the analysis.

Statistical analysis

Log-transformed effect measures, including odds ratios (ORs), hazard ratios (HRs), and proportional reporting ratios (PRRs), were used to harmonize estimates across studies for quantitative synthesis. Heterogeneity was evaluated using the I^2 statistic, with fixed-effects models applied when heterogeneity was low and random-effects models used in the presence of moderate or substantial heterogeneity. All statistical analyses were conducted using STATA version 14, and a two-sided significance level of $P < 0.05$ was considered indicative of statistical significance.

Results

In the initial phase, the designated databases were searched, yielding 417 articles. The titles of these studies were screened, and 187 duplicates indexed across multiple databases were removed. In the next step, the abstracts of the remaining studies were reviewed, leading to the exclusion of 85 articles that lacked essential data required for quantitative analysis. Among the studies that proceeded to full-text assessment, 12 were excluded because their full texts were unavailable or inaccessible, and their abstracts did not provide sufficient information. Subsequently, an additional 125 articles were excluded based on other predefined exclusion criteria, and 8 articles were included in the final analysis (Figure 1).

The results encompassed seven cohort studies and one case/non-case investigation, all published between 2023 and 2025, reflecting a recent and methodologically consistent body of evidence concentrated within these three years (Table 1).

Overall, the use of SGLT2 inhibitors, compared with non-use, did not increase the risk of kidney cancer (OR = 1.14; 95% CI: 0.86–1.52), and no statistically significant association was observed between SGLT2i exposure and incident kidney cancer. However, when compared with DPP-4 inhibitors, SGLT2i use was associated with a higher risk of kidney cancer (OR = 1.64; 95% CI: 1.11–2.43). In subtype-specific analyses, SGLT2 inhibitors were linked to a reduced risk of RCC (OR = 0.69; 95% CI: 0.63–0.76) (Figures 2-4).

Subgroup analysis further indicated that cohort studies showed no significant association between SGLT2

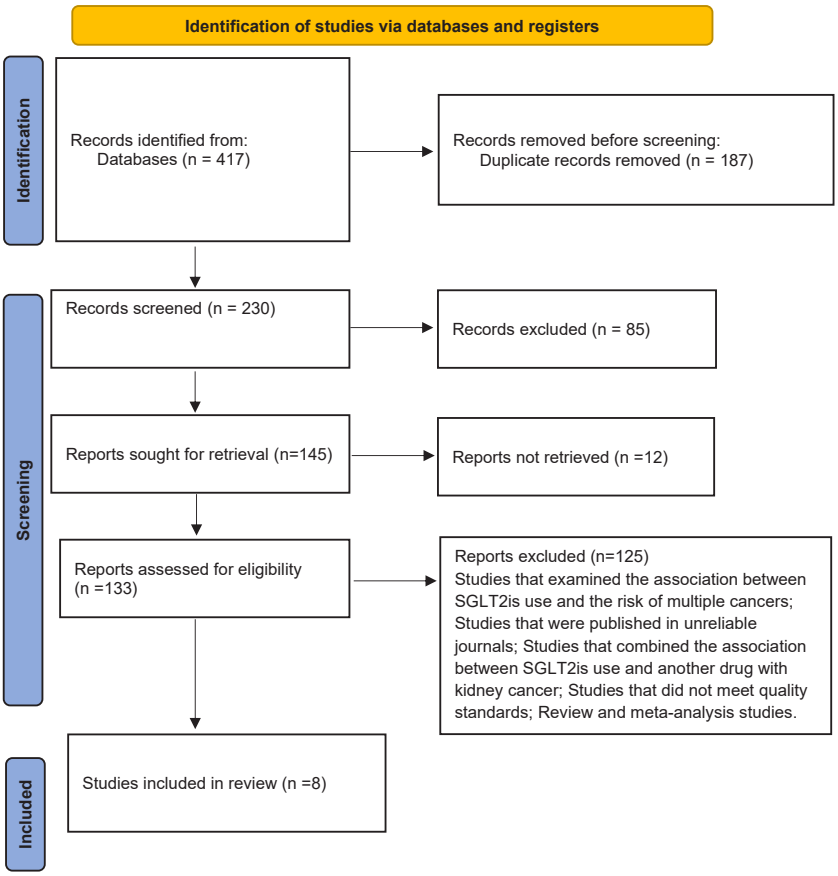

Figure 1. The PRISMA flowchart of study selection.

Table 1. Basic information about the articles reviewed

Author, year	Location	Type of study	Time	SGLT2i users		Comparison group		Compared with	Type of cancer	Relationship between SGLT2i use and kidney cancer		
				Sample size	Mean age (year)	Sample size	Mean age (year)			Risk	Low limit	Up limit
Chiu CH, 2024 (12)	Taiwan	Cohort	From 2004 to 2020	223848	>20	223848	>20	Non-SGLT2i	RCC	0.68	0.58	0.81
Lin TK, 2024 (21)	Taiwan	Cohort	From 2016 to 2021	237069	≥40	237069	≥40	Non-SGLT2i	RCC	0.72	0.60	0.86
Gautier P, 2025 (22)	WHO global database	Case/non-case	Between 2014 and 2023	644	66.5	NR	NR	DPP-4	Kidney cancer	1.84	1.25	2.69
Suzuki Y, 2024 (26)	Japan	Cohort	From April 2014 to November 2022	8941	66	17882	68	DPP-4	Kidney cancer	1.16	0.55	2.43
Lin L, 2024 (27)	UK Biobank	Cohort	NR	1114	NR	461896	NR	Non-SGLT2i	Kidney cancer	1	0.99	1
Xu B, 2024 (28)	US FDA database	Cohort	From 2014 to 2023	120687	38.7	NR	NR	Non-SGLT2i	Kidney cancer	3.38	2.68	4.25
Inose R, 2025 (23)	US FDA database	Cohort	Between 1997 and 2020	NR	NR	NR	NR	Non-SGLT2i	Kidney cancer	1.39	1.13	1.72
Jong GP, 2023 (29)	Taiwan	Cohort	2009-2019	241772	NR	483544	NR	Non-SGLT2i	RCC	0.68	0.58	0.81

NR: Not reported, UK: United Kingdom, FDA: Food and Drug Administration, US: United States, DPP-4: Dipeptidyl peptidase-4, SGLT2i: Sodium-Glucose cotransporter-2 Inhibitors, RCC: Renal cell carcinoma.

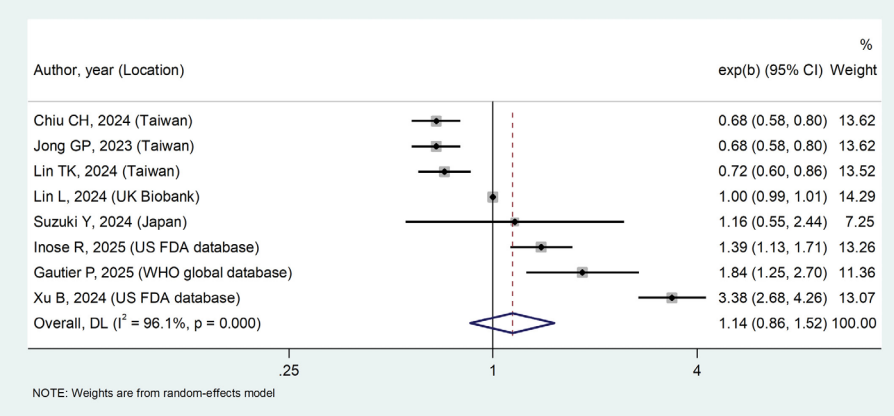

Figure 2. Forest plot showing the association between SGLT2is use and kidney neoplasm.

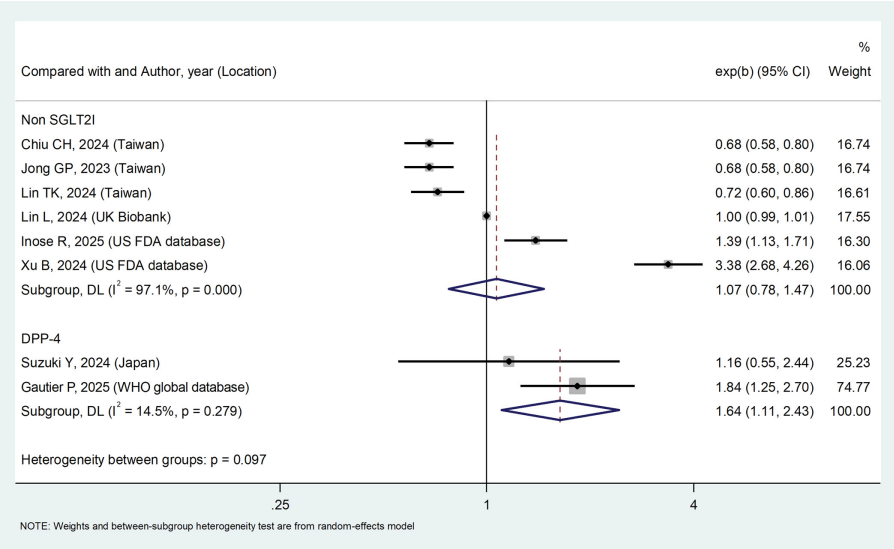

Figure 3. Forest plot comparing SGLT2is and DPP-4 inhibitors in the incidence of kidney neoplasms.

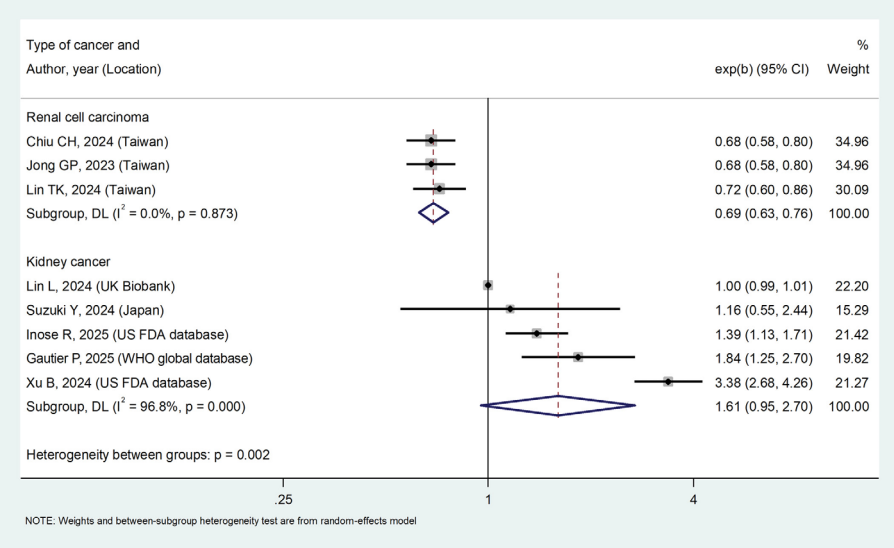

Figure 4. Forest plot showing the association between the SGLT2is use and kidney neoplasms by cancer type.

inhibitor use and the risk of kidney cancer (OR = 1.07; 95% CI: 0.79–1.45), whereas the case/non-case study demonstrated an elevated risk of kidney cancer among SGLT2i users (OR = 1.84; 95% CI: 1.25–2.70) (Figure 5).

Among the included studies, three directly compared different SGLT2 inhibitors, and the pooled analysis showed no statistically significant association between the use of dapagliflozin (OR = 1.67; 95% CI: 0.47–5.93), canagliflozin (OR = 1.59; 95% CI: 0.61–4.15), or empagliflozin (OR = 1.31; 95% CI: 0.52–3.27) and the risk of kidney cancer, as illustrated in Figures 6–8.

Meta-regression analysis showed that the association between SGLT2 inhibitor use and the risk of kidney cancer was not statistically influenced by the year of publication (P = 0.257) or by study sample size (P = 0.243; Figures 9 and 10).

The assessment of publication bias was not statistically

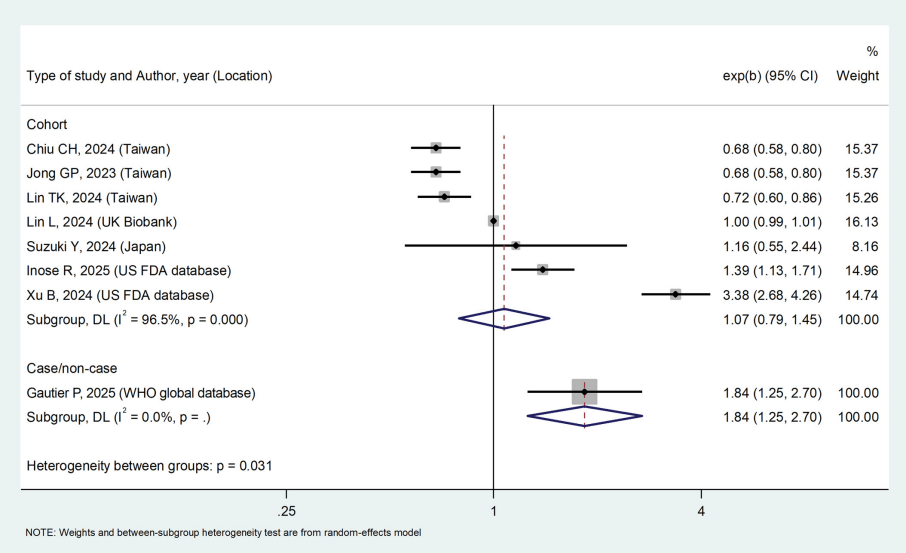

Figure 5. Forest plot showing the association between the SGLT2is use and kidney neoplasms by study design

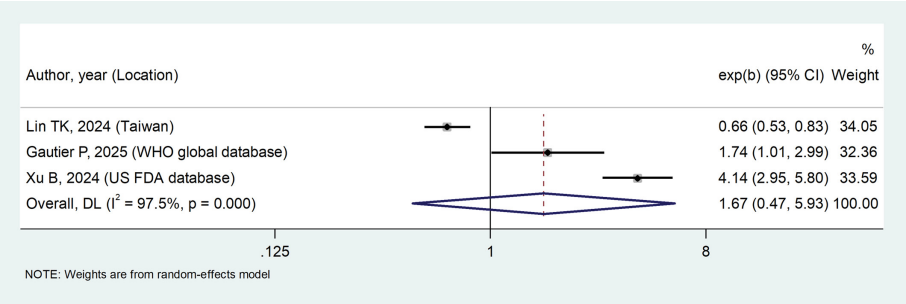

Figure 6. Forest plot showing the association between dapagliflozin use and kidney neoplasm.

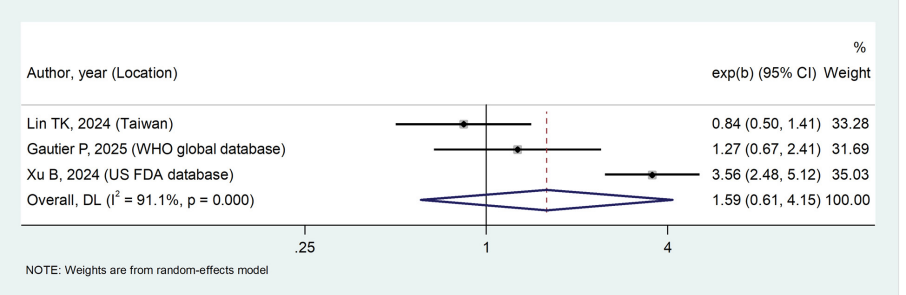

Figure 7. Forest plot showing the association between canagliflozin use and kidney neoplasm.

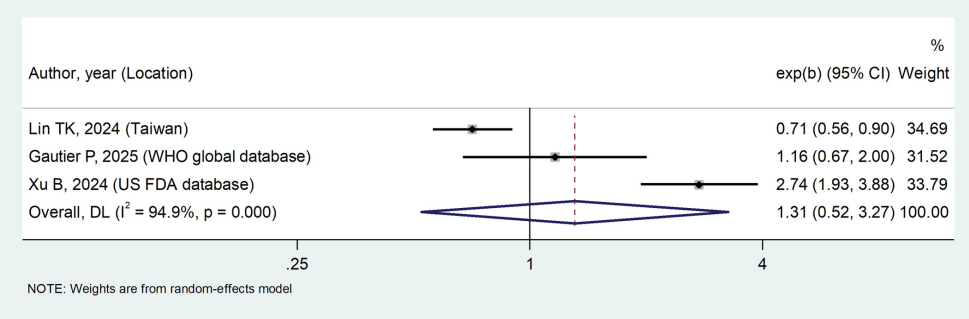

Figure 8. Forest plot showing the association between empagliflozin use and kidney neoplasm.

significant (P = 0.768), indicating that studies reporting a significant association between SGLT2 inhibitor use and kidney cancer, as well as those reporting no significant association, were all similarly likely to be published, suggesting no evidence of publication bias in this body of literature (Figure 11).

Discussion

The overall analysis indicated no statistically significant association between the use of all SGLT2 inhibitors, including dapagliflozin, canagliflozin, and empagliflozin, and the risk of developing kidney cancer. However, SGLT2 inhibitor use was associated with a 31% reduction in the risk of RCC. In contrast, when compared with DPP-4 inhibitors, SGLT2 inhibitors were linked to a 64% higher risk of kidney cancer.

In line with our findings, the meta-analysis conducted by Xu et al reported that SGLT2 inhibitors, compared with similar antidiabetic agents, did not affect overall cancer risk. Their site-specific analyses likewise showed no significant association between SGLT2i use and the risk of kidney, breast, gastrointestinal, prostate, or respiratory cancers (30). Similarly, the meta-analysis by Wang et al found no meaningful relationship between SGLT2 inhibitor exposure and overall cancer incidence (31). Another meta-analysis by Xu and colleagues comparing SGLT2 inhibitors with placebo demonstrated no effect on total cancer occurrence (32). In a further analysis focused on genitourinary malignancies, Xu et al showed that SGLT2 inhibitors did not significantly alter the risk of genitourinary cancers relative to placebo (33). Collectively, these converging lines of evidence reinforce the conclusions of the present study, demonstrating that SGLT2 inhibitor therapy does not exert a measurable impact on the overall risk of kidney cancer across diverse

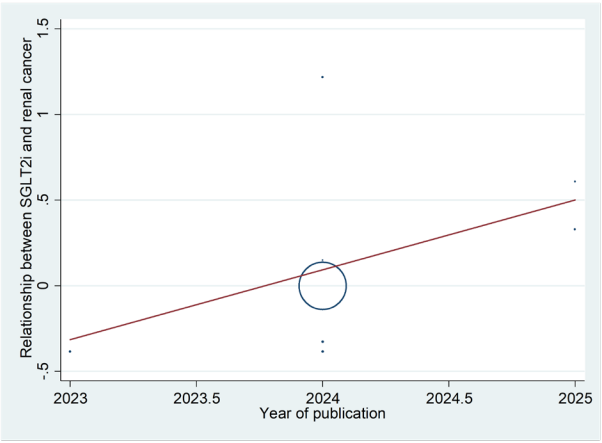

Figure 9. Meta-regression plot of the association between SGLT2is use and kidney neoplasm with year of publication

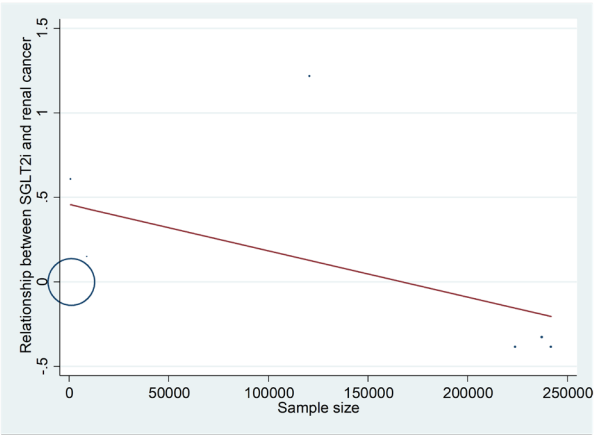

Figure 10. Meta-regression plot of the association between SGLT2is use and kidney neoplasm with sample size.

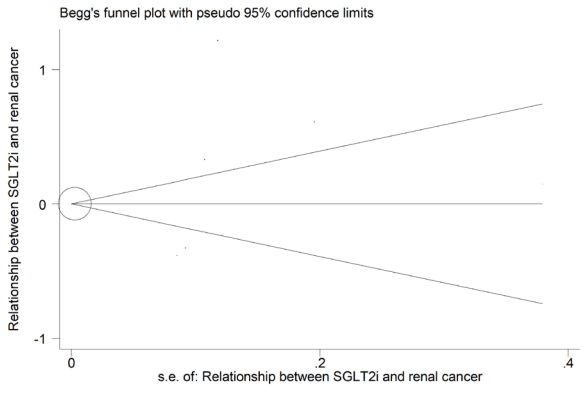

Figure 11. Plot of publication bias.

study designs, populations, and analytical approaches.

Based on the meta-analysis conducted by Kenawy et al, SGLT2 inhibitors were associated with a significantly lower risk of cancer when compared with sulfonylureas (OR = 0.54; 95% CI: 0.40–0.74), glucagon-like peptide-1 (GLP-1) receptor agonists (OR = 0.70; 95% CI: 0.53–0.92), and DPP-4 inhibitors (OR = 0.72; 95% CI: 0.57–0.92) (34). These findings were not fully aligned with the results of the present study, in which SGLT2 inhibitor use, when compared specifically with DPP-4 inhibitors, was associated with an increased risk of kidney cancer. It is important to note, however, that the cancer type under investigation and the sample sizes differed substantially between our analysis and that of Kenawy et al, which may account for the observed discrepancies in effect estimates.

According to the findings of the cohort study by Chiu et al in patients with type 2 diabetes, SGLT2 inhibitor use was associated with a significantly lower risk of RCC (12). A similar protective association was reported in another cohort study by Lin et al, in which SGLT2 inhibitor therapy was linked to a reduced risk of RCC (21). These observations are consistent with the results of the current meta-analysis, which likewise demonstrated that SGLT2 inhibitor use, compared with non-use, was associated with a decreased risk of RCC. Collectively, these findings suggest that although SGLT2 inhibitors do not appear to influence the overall incidence of kidney cancer, they may confer a protective effect specifically against RCC.

Meta-analysis by Xu et al demonstrated that SGLT2 inhibitor use, compared with placebo, was associated with an increased risk of kidney cancer (32). Similarly, in the study by Gautier et al, conducted to evaluate the relationship between SGLT2 inhibitors and cancer risk, SGLT2i exposure was linked to a higher risk of bladder cancer and kidney cancer (22). In another investigation by Inose et al assessing the association between SGLT2 inhibitors and malignancies, SGLT2i use was significantly associated with kidney cancer (23). These findings contrast with the results of the current meta-analysis, which showed no significant effect of SGLT2 inhibitor use on the overall risk of kidney cancer.

Conclusion

The findings of this study indicate that SGLT2 inhibitor use does not influence the overall incidence of kidney cancer; however, it appears to confer a protective effect against the development of RCC. In our analysis, SGLT2 inhibitor users experienced a substantially lower risk of RCC compared with non-users, suggesting a potentially meaningful preventive benefit for this specific histological subtype. In contrast, when SGLT2 inhibitors were compared with DPP-4 inhibitors, their use was associated with an increased risk of kidney cancer, highlighting that the choice of comparator drug may significantly influence observed risk estimates. Given the limited number of available studies and the variability in study design, populations, and reporting quality, these findings should be interpreted with caution. Additional high-quality, large-scale investigations are recommended to confirm these associations and to clarify the underlying mechanisms that may differentiate overall kidney cancer risk from RCC-specific outcomes.

Limitations of the study

The present review is subject to several limitations. Subgroup analyses based on patient age and gender were not feasible because most included studies did not report detailed demographic characteristics. Only three of the eight eligible studies provided drug-specific estimates, limiting the ability to evaluate the differential effects of individual SGLT2 inhibitors on kidney cancer risk. The studies were conducted across diverse geographical regions, yet the available data did not allow for stratification by study location or patient nationality. Additionally, only three studies specified the histological subtype of kidney cancer, which restricted the depth of analyses related to cancer classification.

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Authors' contribution

Conceptualization: Mohammadreza Nowroozi and Seyed Amir Banikarim.
Data curation: Mohammadreza Nowroozi and Naeem Nikpour.
Formal analysis: Houshang Sanadgol and Ali Khalilzadeh.
Investigation: Houshang Sanadgol and Rasoul Jafari Arismani.
Methodology: Ali Khalilzadeh and Zahed Karimi.
Project administration: Mohammadreza Nowroozi, Naeem Nikpour.
Supervision: All authors.
Validation: Seyed Amir Banikarim and Peyman Khajehnabi.
Visualization: Ahmadreza Maghsoudi and Zahed Karimi.
Writing–original draft: All authors.
Writing–review and editing: All authors.

Conflicts of interest

The authors declare that they have no competing interests.

Ethical issues

This study has been compiled based on the PRISMA checklist, and its protocol was registered on the PROSPERO website (ID: CRD420261293668) and the Research Registry website with (Unique Identifying Number [UIN]: reviewregistry2078). Besides, ethical issues (including plagiarism, data fabrication, and double publication) have been completely observed by the authors.

Funding/support

None.

Declaration of generative artificial intelligence (AI) and AI-assisted technologies in the writing process

During the preparation of this work, the authors utilized AI tools (Copilot and Grammarly) to refine grammatical points and language style in their writing. Subsequently, the authors thoroughly reviewed and edited the content as necessary, assuming full responsibility for the accuracy and content of the publication.

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