

An umbrella analysis assessing the risk of acute kidney injury in COVID-19 patients

*Qinyan Gu^{1,A}, *Yongzhen Zhang^{2,B,C}, Xijun He^{3,D–F}

¹ Department of Emergency Medicine, The Second Affiliated Hospital of Soochow University, Suzhou, China

² Intensive Care Unit, The Second Affiliated Hospital of Soochow University, Suzhou, China

³ Department of Emergency Medicine, The Affiliated Jiangyin Hospital of Nantong University, China

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;

D – writing the article; E – critical revision of the article; F – final approval of the article

Advances in Clinical and Experimental Medicine, ISSN 1899–5276 (print), ISSN 2451–2680 (online)

Adv Clin Exp Med. 2025;34(5):831–845

Address for correspondence

Xijun He

E-mail: jzyxk173@sina.com

Funding sources

None declared

Conflict of interest

None declared

*Qinyan Gu and Yongzhen Zhang contributed equally to this work.

Received on February 23, 2024

Reviewed on April 2, 2024

Accepted on April 6, 2024

Published online on November 6, 2024

Abstract

A number of research studies have indicated a potential association between COVID-19 and acute kidney injury (AKI). However, the methodologies employed and the risk estimates derived from these studies vary. Therefore, an umbrella review of systematic reviews and meta-analyses was conducted to determine the incidence of AKI in COVID-19 patients and AKI-associated mortality. A complete literature search was undertaken in PubMed, Embase, Scopus, and the Cochrane Library. The methodological rigor of the included papers was evaluated using the Assessment of Multiple Systematic Reviews (AMSTAR-2) instrument. The pooled risk ratio (RR) and odds ratio (OR) of the included studies were calculated to establish the strength of the association between AKI cases and COVID-19 infections. This umbrella review included 20 studies. Two of the 20 studies assessed adult COVID-19 patient risk factors for AKI, 1 examined survival rates and 7 examined the incidence of AKI. The remaining 10 investigations revealed that patients with coronavirus were susceptible to AKI. The umbrella analysis comprised reviews that contained a range of 6 to 54 papers. The AMSTAR-2 ratings yielded a total of 14 studies deemed to be of high quality, with 6 studies classified as intermediate quality. Statistical analysis of included reviews revealed a 1.50 RR for AKI incidence in COVID-19 patients (95% confidence interval (95% CI): 1.40–1.60, I^2 69%, $p < 0.0001$) and a 2.02 RR (95% CI: 1.79–2.29, I^2 56%, $p < 0.0001$) for AKI-associated death. This umbrella review revealed that individuals infected with the novel coronavirus often develop AKI. SARS-CoV-2 infections were associated with AKI due to advanced age, male gender, coronary artery disease, diabetes, and hypertension. However, AKI and a renal replacement therapy (RRT) requirement independently predicted unfavorable COVID-19 results.

Key words: COVID-19, renal replacement therapy, chronic kidney disease, acute kidney injury, incidence of AKI

Cite as

Gu Q, Zhang Y, He X. An umbrella analysis assessing the risk of acute kidney injury in COVID-19 patients.

Adv Clin Exp Med. 2025;34(5):831–845.

doi:10.17219/acem/187998

DOI

10.17219/acem/187998

Copyright

Copyright by Author(s)

This is an article distributed under the terms of the Creative Commons Attribution 3.0 Unported (CC BY 3.0) (<https://creativecommons.org/licenses/by/3.0/>)

Introduction

The COVID-19 epidemic has developed into a disaster that affected healthcare systems all across the world. The SARS-CoV-2 virus, which causes COVID-19, was initially identified in Wuhan, China, in December 2019. Since then, it has rapidly spread across the world.^{1,2} The World Health Organization (WHO) decided to officially classify COVID-19 as a pandemic in March 2020.³ The clinical trajectory of SARS-CoV-2 infections is exceptionally erratic and diverse, encompassing subclinical infection, asymptomatic infection, productive cough, dyspnea, fatigue, and imaging indications of pneumonia, as well as multi-organ systemic failure and mortality.^{4,5} Several epidemiological studies have demonstrated that individuals with comorbidities such as diabetes, arterial hypertension, metabolic syndrome, and cardiovascular disease are more likely to manifest symptoms related to SARS-CoV-2 infections.^{6–9} This is especially true for older patients. In addition to this, the probability of these patients acquiring a severe condition is significantly higher than in most patients.¹⁰

COVID-19 is known to cause deterioration in kidney function, in addition to the negative effects it has on the respiratory system. There is a significant relationship between acute kidney injury (AKI) and coronavirus infections,¹¹ as seen in this correlation study. According to the findings of the research, AKI affects 5–15% of patients infected with SARS-CoV2 and is linked to a mortality rate of 70–90%.¹² Systemic inflammatory responses are triggered when viruses such as influenza, SARS CoV-2, etc., infect and replicate in cells that are the focus of their infection, which ultimately leads to malfunction in a number of organs.^{13,14}

Hypoxemia, dehydration, underlying conditions, and the deleterious effects of drugs supplied to these patients¹⁵ are the leading causes of AKI. Several studies have documented the occurrence of AKI and other serious renal complications in hospitalized individuals with COVID-19.^{16–20} However, the epidemiological burden of AKI in people who have been infected with COVID-19 and the involvement of the kidney are still unknown and require additional investigation.

Despite the fact that a significant number of research studies have been conducted to investigate the connection between COVID-19 and AKI, the designs of these studies are extremely diverse and the risk estimations produced by these studies are quite diverse. Therefore, it is problematic to focus on the highest quality of evidence, the multitude of published meta-analyses and systematic reviews, the duplication of patient data, and the variety of evidence sources, as this could impede the identification and implementation of evidence-based strategies in medical practice. Consequently, it is a significant challenge to concentrate on the highest quality evidence. Therefore, we conducted umbrella review of systematic reviews and meta-analyses to synthesize

findings from selected systematic reviews and meta-analyses^{21–40} concerning the effects of COVID-2019 on kidney health.

Objectives

The purpose of this umbrella analysis of systematic reviews and meta-analyses was to ascertain the frequency of AKI among COVID-19 patients and its correlation with disease severity and mortality.

Materials and methods

In accordance with the guidelines that were recently released,⁴¹ an umbrella review was carried out. We adhered to the Preferred Reporting Items for Overviews of Reviews (PRIOR) protocol⁴² when it came to the reporting process. Guidelines from the Assessing the Methodological Quality of Systematic Reviews (AMSTAR)⁴³ were utilized to conduct a quality evaluation of the studies.

Eligibility criteria

For studies to be considered, they had to meet all of the following criteria. The criteria used to assess the impact of COVID-19 on kidney health and the risk of AKI and AKI-related mortality in COVID-19 patients were: (1) systematic reviews that incorporated individual participant meta-analyses or meta-analyses of meta-analyses; (2) included individuals who had been diagnosed with COVID-19; (3) reported incidence of AKI in COVID-19 patients; (4) examined any of the outcomes listed below in COVID-19 patients: i) the incidence of AKI; ii) odds ratio (OR) of AKI; iii) AKI-associated mortality; and iv) risk ratio (RR) of AKI; and (5) risk factors associated with AKI in COVID-19 patients. Bibliographic references that were obsolete, anecdotal or solely relied on expert assessments were excluded from the selection process. Furthermore, studies that were dependent on animal experiments or trials were excluded, along with those in which the authors lacked access to primary data and critical information. Furthermore, non-research publications, qualitative studies, studies involving patients with HIV and other systemic diseases, and papers published in languages other than English were likewise omitted.

Information sources

A search of the literature was carried out in a number of different databases, such as PubMed, Embase, Scopus, Web of Science, and the Cochrane Library. In accordance with the PICOS methodology, the key words were identified and checked to ensure that they were consistent throughout both the MEDLINE and Embase databases.

Search strategy

The search covered the years 2020–2023 and utilized specific key words such as “acute kidney injury” OR “AKI” OR “COVID-19” OR “kidney injury” OR “incidence of AKI” OR “prevalence of AKI” OR “RRT” OR “SARS-CoV2” OR “kidney replacement therapy” OR “kidney disease” OR “kidney injury” OR “chronic kidney disease” OR “CKD” OR “mortality” OR “fatality” OR “disease severity” OR “recovery” OR “risk of AKI” OR “kidney failure” OR “meta-analysis” OR “systematic review and meta-analysis” OR “systematic review”. The key words were identified and verified for consistency in both the MEDLINE and Embase databases, in accordance with the PICOS framework (Table 1). The aforementioned key words were entered into the Title (ti)-Abstract (abs)-keyword (key) field in the Scopus search. Cochrane search terms included “AKI” and “COVID-19 patients”. The PICO structure was applied to establish specific criteria for selection. “P” in this context represented patients infected with COVID-19, “I” denoted the incidence of AKI, “C” represented a control, and “O” comprised the clinical outcomes, specifically the incidence of AKI in COVID-19 patients and mortality. The research design incorporated in this study was limited to the implementation of systematic reviews and meta-analyses. The identification of relevant studies was conducted through an unbiased and thorough examination of the related literature by 2 researchers (Q.G. and Y.Z.). Additional relevant papers were identified by carefully screening the references listed in the final research for analysis.

Selection process

A first screening of the titles and abstracts of the publications that were acquired was followed by an examination of the complete texts of references that had the potential to be eligible. The screening procedure was carried out by 2 researchers, and in case of any inconsistencies, the decision regarding whether or not to include the material under consideration was made through discussion.

Data items

The data extraction process was carried out by 1 author, and 2 other authors subsequently verified the extracted information. Disputes were resolved through deliberation. Information pertinent to our study was selectively gathered regarding the incidence of AKI and mortality associated with AKI in COVID-19 patients from publications that met the inclusion criteria and contained data on multiple disorders. Initially, we gathered pertinent details from the eligible reviews, such as author information, publication year, journal of publication, study type, number of included studies, study aim, age of participants, search engines used, quality assessment tools used, primary outcomes, and study conclusions. Furthermore, to encompass the full geographic range of evidence, we collected data regarding the specific locations of the individual studies that were included in the relevant reviews. This involved gathering information about the countries where the research was carried out.

Table 1. Database search strategy

Database	Search strategy
Scopus	#1 “acute kidney injury” OR “AKI”, OR “COVID-19” OR “kidney injury” OR “incidence of AKI” OR “prevalence of AKI” OR “renal replacement therapy” OR “SARS-CoV2” OR “kidney replacement therapy” OR “kidney disease” OR “kidney injury” OR “chronic kidney disease”. #2 “mortality” OR “fatality” OR “disease severity” OR “recovery” OR “risk of AKI” OR “kidney failure” OR “meta-analysis” OR “systematic review and meta-analysis”, OR “systematic review”. #3 #1 AND #2
PubMed	#1 “acute kidney injury” OR “AKI” OR “COVID-19” [MeSH Terms]* OR “kidney injury” OR “incidence of AKI” [All Fields] OR “prevalence of AKI” OR “renal replacement therapy” OR “SARS-CoV2” OR “kidney replacement therapy” [All Fields] OR “kidney disease” OR “kidney injury” [All Fields] OR “chronic kidney disease” [All Fields] #2 “mortality” OR “fatality” [MeSH Terms] OR “disease severity” OR “recovery” OR “risk of AKI” [All Fields] OR “kidney failure”, OR “meta-analysis”, OR “systematic review and meta-analysis” [All Fields], OR “systematic review” [All Fields]. #3 #1 AND #2
Embase	#1 “acute kidney injury”/exp ⁵ OR “AKI”/exp OR “COVID-19”/exp OR “kidney injury”/exp OR “incidence of AKI”/exp OR “prevalence of AKI”/exp OR “renal replacement therapy”/exp OR “SARS-CoV2”/OR “kidney replacement therapy”/exp OR “kidney disease”/exp OR “kidney injury”/exp OR “chronic kidney disease”/exp #2 “mortality”/exp OR “fatality”/exp OR “disease severity”/exp OR “recovery”/exp OR “risk of AKI”/exp OR “kidney failure”/exp OR “meta-analysis”/exp OR “systematic review and meta-analysis”/exp OR “systematic review”/exp #3 #1 AND #2
Cochrane Library	#1 (acute kidney injury): ti, ab, kw [@] OR (AKI): ti, ab, kw OR (COVID-19): ti, ab, kw OR (kidney injury): ti, ab, kw OR (incidence of AKI): ti, ab, kw OR (prevalence of AKI): ti, ab, kw OR (renal replacement therapy): ti, ab, kw OR (SARS-CoV2) OR (kidney replacement therapy): ti, ab, kw OR (kidney disease):OR (kidney injury):ti, ab, kw OR (chronic kidney disease): ti, ab, kw (word variations have been searched) #2 (mortality): ti, ab, kw OR (fatality): ti, ab, kw OR (disease severity): ti, ab, kw OR (recovery): ti, ab, kw OR (risk of AKI): ti, ab, kw OR (kidney failure): ti, ab, kw OR (meta-analysis): ti, ab, kw OR (systematic review and meta-analysis): ti, ab, kw OR (systematic review) (word variations have been searched) #3 #1 AND #2

* MeSH terms – Medical Subject Headings; ⁵ exp – explosion in Emtree – searching of selected subject terms and related subjects; [@] ti, ab, kw – either title or abstract or keyword fields.

Study risk of bias assessment

Regarding methodological rigor, we collected data on whether the authors assessed this aspect of the studies included in each systematic review using a pre-validated instrument or a supplemental set of extracted questions. We documented the specific tool that was used, and the primary findings of the evaluation were categorized into 3 broad groups: studies that exhibited weak methodological rigor, studies that demonstrated a high level of methodological rigor, or studies that displayed intermediate or mixed patterns from the 2 above groups. If the answer was affirmative, we documented the specific tool that was used. The methodological rigor of the included systematic reviews was evaluated by 2 reviewers using the AMSTAR-2 program. Any differences were resolved with the assistance of a 3rd reviewer. AMSTAR-2 utilizes a checklist consisting of 16 items or domains, of which 7 are deemed crucial for ensuring the overall validity of a review. The essential domains to be accounted for are as follows: (1) ensuring protocol registration prior to commencing the review; (2) conducting a thorough and comprehensive literature search; (3) providing a rationale for excluding specific studies; (4) assessing the risk of bias in the included studies; (5) employing suitable statistical techniques for conducting a meta-analysis; (6) considering the influence of bias when interpreting the findings; and (7) evaluating the existence and consequences of publication bias. Finally, utilizing abstracts and a full-text analysis, we retrieved pertinent information regarding the primary conclusions drawn from each of the reviews included. Moreover, if the review involved multiple disease areas, we only selected the primary outcomes from the individual studies concerning the incidence of AKI in COVID-19 patients.

Statistical analyses

A descriptive analysis was conducted due to the substantial variability observed in the study designs, research inquiries, findings, and metrics. The methodological assessment, summary estimates, 95% confidence intervals (95% CIs), and heterogeneity estimates, as well as the characteristic information, were compiled for each of the included studies. The elevated risk of AKI in COVID-19 patients was documented in every single study that was included. However, because the strategies used were so different, the overall OR and RR of the studies were also calculated to evaluate how strongly the incidence of AKI was linked to coronavirus infections. The subjects' health conditions (presence or absence of AKI) served as the basis for grouping the studies. An OR value higher than 1 was considered statistically significant and showed that COVID-19 patients were at high risk of AKI and AKI-associated mortality.

Results

Study selection

The process of selecting studies, in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines,⁴⁴ has been presented in Fig. 1. An electronic scanning technique was employed to perform an exhaustive search across multiple databases; this led to the identification of 315 articles that satisfied the inclusion criteria specified in the PICOS framework.⁴⁵ Prior to screening, 44 duplicate documents were eliminated, bringing the total number of papers screened to 271. One hundred and thirty-one papers were subsequently excluded for having invalid titles and abstracts, and 140 records were requested for retrieval. Twenty-five records were not retrieved in their entirety; the eligibility of the remaining 115 reports was evaluated. Upon implementation of the inclusion-exclusion criteria, 95 articles were determined to be ineligible and were consequently excluded. The principal determinants leading to the exclusion of research studies were their failure to provide essential outcome measures, no access to the complete texts, unsuitable study designs, and being published in a language other than English. Finally, 20 systematic reviews and meta-analyses that satisfied the predetermined inclusion criteria and spanned the time period from 2020 to 2023 were incorporated into this umbrella review.

Characteristics of included reviews

The included studies were published from 2020 to 2023. The articles included in the study were retrieved from Scopus (n = 68), PubMed (n = 135), Embase (n = 45), and the Cochrane Library (n = 67). Among the 20 reviews that were included, 2 studies, Cai et al.²² and Hidayat et al.,²⁶ investigated the risk factors associated with acute renal injury in adult patients with COVID-19, and 1 study, Ali et al.,²¹ discussed the survival rate in patients with AKI and COVID-19. The incidence of AKI in COVID-19 infections was reported in 7 additional studies.^{23,32–34,36,39,40} Individuals with coronavirus infections were found to have a higher risk of experiencing AKI, according to the remaining 10 investigations.^{24,25,27–31,35,37,38} All the reviews included in this analysis included articles without any geographical limitations. The evaluations included a range of study counts, varying from 6 to 54. Each of the 20 reviews involved data pooling, meta-analyses and qualitative analysis. Table 2 presents a comprehensive summary of the characteristics of the studies that were included in this umbrella review.

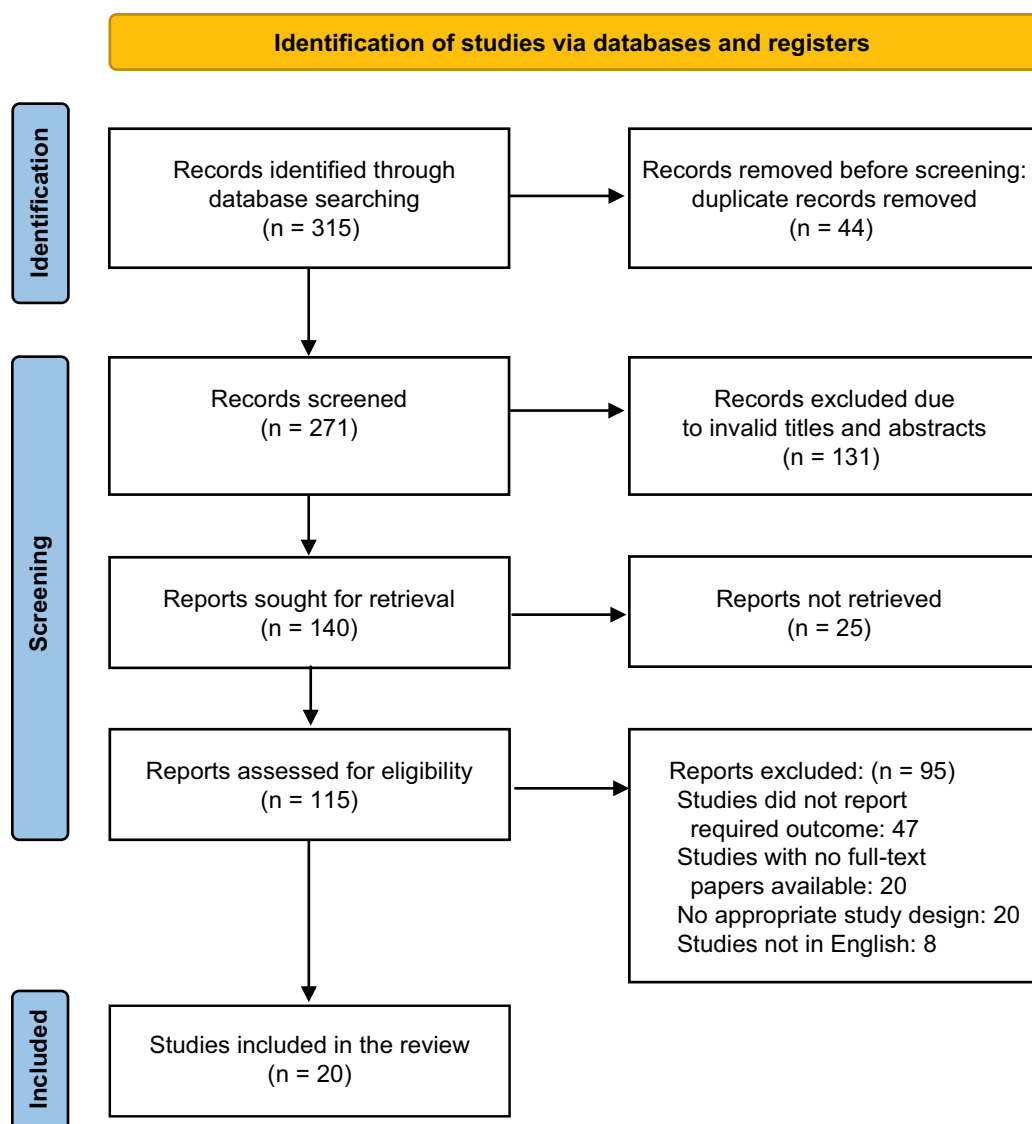


Fig. 1. Flowchart of the study selection

Methodological quality

Figure 2 provides a summary of the frequency of each AMSTAR2 rating for each domain across all of the evaluations. Table 3 shows the domain-specific methodological quality evaluations for the individual study. These evaluations are provided for each review. Twenty of the included studies^{21–40} addressed the review questions using the PICO elements, provided an explanation of their study design selection, compiled a list of excluded studies, evaluated their conclusions, employed appropriate statistical methods, assessed the possible impact of bias risk in the individual studies, and conducted a quantitative synthesis. Sixteen reviews^{21,24–29,31–37,39–40} stated that the review methods were established prior to use and provided justification for substantial deviations from the protocol, while articles by Cai et al.²² and Chen et al.²³ partially met this criterion, and papers by Lim et al.³⁰ and Wang et al.³⁸ failed to do so. Each of the studies included in the review provided a comprehensive account of the rationale behind the selection

of study designs for inclusion. With the exception of Ali et al.,²¹ which could benefit from a more exhaustive search strategy, every article employed a comprehensive literature search approach. Six studies^{21,24,29,30,33,37,38} did not disclose their funding sources. All studies used appropriate methods for the statistical combination of the results. With the exception of Chen et al.,²³ Hidayat et al.²⁶ and Saghafi et al.,³⁴ all other studies employed duplicate study selection; nevertheless, the methodology of Lim et al.³⁰ and Wang et al.³⁸ was also ambiguous, thus they received a partial yes. Likewise, with the exception of studies Ali et al.,²¹ Menon et al.³² and Zhou et al.,⁴⁰ all remaining studies extracted data in duplicate; however, Saghafi et al.³⁴ was also assessed as a partial affirmation. The research included in this study provides adequate summaries of the studies included and utilizes satisfactory techniques to evaluate the potential for bias. All studies, except Menon et al.,³² accounted for the possibility of bias in the individual studies when interpreting or analyzing the results, and provided a satisfactory explanation for and discussion

Table 2. Characteristics of the included studies (all of them were systematic reviews and meta-analyses)

Study ID	Year of publication	Journal of publication	Country of study	Number of included studies	Aim of study	Age of participants	Search engines used	Quality assessment tool	Primary outcome	Conclusions
Ali et al. ²¹	2020	<i>Renal Failure</i>	UK	6	Survival rate in acute kidney injury superimposed COVID-19 patients	> 18 years	PubMed, MEDLINE, Embase, and Cochrane databases	NOS	mortality	Severe AKI in patients with COVID-19 is an ominous clinical predictor and is associated with high mortality.
Cai et al. ²²	2021	<i>Frontiers in Medicine</i>	China	38	Risk factors for acute kidney injury in adult patients with COVID-19	> 16 years	PubMed, Embase, Web of Science, the Cochrane Library, CNKI, VIP, and Wan Fang Data	NOS	prevalence of AKI	AKI is a common and serious complication of COVID-19.
Chen et al. ²³	2020	<i>Critical Care</i>	Taiwan	20	Incidence of acute kidney injury in COVID-19 infection	45–70 years	PubMed and Embase	–	incidence of AKI	COVID patients are at high risk of AKI.
Cheruiyot et al. ²⁴	2020	<i>Acta Biomedica</i>	Kenya	15	Acute kidney injury is associated with worse prognosis in COVID-19 patients	40–78 years	PubMed and CNKI	Methodological index for non-randomized studies (MINORS) tool	mortality, prevalence of AKI	AKI is a relatively frequent manifestation in COVID-19 patients.
Fabrizi et al. ²⁵	2020	<i>Pathogens</i>	Italy	39	Acute kidney injury in COVID-19 patients	35–70 years	MEDLINE and manual searches	–	incidence of AKI (%), all-cause mortality	AKI is a common complication in hospitalized COVID-19-positive patients.
Hidayat et al. ²⁶	2023	<i>Pathophysiology</i>	Indonesia	30	Risk factors and clinical characteristics of acute kidney injury in patients with COVID-19	35–90 years	PubMed and DOAJ databases	NIH quality assessment tools	AKI prevalence, mortality rate	AKI carries high morbidity and mortality in COVID-19.
Hsiao et al. ²⁷	2023	<i>Frontiers in Medicine</i>	USA	12	Acute kidney injury in patients with COVID-19	> 18 years	PubMed, Embase and Cochrane databases	NOS	mortality, incidence of AKI	COVID-19 patients had higher risk of developing AKI.
Juarez et al. ²⁸	2020	<i>Kidney International Reports</i>	USA	20	Outcomes for patients with COVID-19 and acute kidney injury	45–71 years	MEDLINE, Embase, Scopus, and MedRxiv databases	Study Quality Assessment Tool for Case Series Studies	mortality, incidence of AKI	Kidney dysfunction is common among patients with COVID-19.
Lee et al. ²⁹	2021	<i>Nature Scientific Reports</i>	South Korea	16	Increased risk of acute kidney injury in coronavirus disease patients	35–90 years	PubMed, Embase, Scopus, and Cochrane databases	NOS	mortality, incidence of AKI	Coronavirus disease patients have high risk of AKI.
Lim et al. ³⁰	2020	<i>Canadian Journal of Kidney Health and Disease</i>	Indonesia	15	Acute kidney injury and severity of COVID-19	40–60 years	PubMed, Scopus, Europe PMC, and the Cochrane Central Database	NOS	mortality, incidence of AKI	High risk of AKI was associated with COVID-19 patients.
Liu et al. ³¹	2021	<i>PLoS One</i>	China	36	The chronic kidney disease and acute kidney injury involvement in COVID-19 pandemic	30–90 years	PubMed, CNKI and WanFang databases	NOS	mortality, incidence of AKI	CKD and AKI are susceptible to occur in patients with severe COVID-19.

Table 2. Characteristics of the included studies – cont

Study ID	Year of publication	Journal of publication	Country of study	Number of included studies	Aim of study	Age of participants	Search engines used	Quality assessment tool	Primary outcome	Conclusions
Menon et al. ³²	2021	<i>The Cureus Journal of Medical Science</i>	USA	20	The association of acute kidney injury with disease severity and mortality in COVID-19	43–72 years	PubMed, Embase, Google Scholar, and clinicaltrial.gov	NOS	mortality, incidence of AKI	AKI develops in a considerable number of COVID-19 patients, and the condition is significantly associated with adverse outcomes in patients with COVID-19.
Passoni et al. ³³	2022	<i>Nefrologia</i>	Brazil	28	Occurrence of acute kidney injury in adult patients hospitalized with COVID-19	>18 years	PubMed, Embase, Web of Science, Scopus, and Lilacs	Joanna Briggs Institute's critical appraisal tool	mortality, incidence of AKI	The occurrence of AKI is frequent among adult patients hospitalized with COVID-19.
Saghafi et al. ³⁴	2021	<i>Journal of Renal Injury Prevention</i>	Iran	22	Acute kidney injury in hospitalized COVID-19 patients	10–94 years	Web of Science, PubMed, Embase, Scopus, and Google Scholar databases	–	mortality, incidence of AKI	AKI is prevalent in hospitalized COVID-19 patients.
Shao et al. ³⁵	2020	<i>Pharmacological Research</i>	China	40	Acute kidney injury in patients with COVID-19	23–80 years	PubMed, Web of Science, ScienceDirect, MedRxiv and COVID-19, academic research communication platforms	–	fatality, incidence of AKI	AKI is a crucial complication in patients with COVID-19.
Silver et al. ³⁶	2020	<i>Kidney Medicine</i>	China	54	The prevalence of acute kidney injury in patients hospitalized with COVID-19 infection	45–70 years	MEDLINE, Embase, Cochrane Library, and a registry of preprinted studies	NIH Quality Assessment Tool for Case Series Studies	prevalence, mortality of AKI	Risk of AKI was higher in critically ill COVID-19 patients.
Singh et al. ³⁷	2021	<i>Clinical and Experimental Medicine</i>	Switzerland	29	Kidney disease and COVID-19 disease severity	40–80 years	PubMed, Web of Science, Scopus, and MedRxiv	NOS	prevalence, mortality of AKI	COVID-19 patients are at high risk of AKI.
Wang et al. ³⁸	2021	<i>Kidney and Blood Pressure Research</i>	China	42	The involvement of acute kidney injury in disease severity and mortality in patients with COVID-19	40–70 years	PubMed, Embase, Cochrane Library, medRxiv, Social Science Research Network, and Research Square databases	NOS	mortality and prevalence of AKI	AKI was associated with higher risks of severity and mortality in COVID-19 patients.
Yang et al. ³⁹	2021	<i>International Immunopharmacology</i>	China	58	Acute kidney injury and renal replacement therapy in COVID-19 patients	40–75 years	PubMed, Embase, Web of Science, medRxiv, and bioRxiv databases	NOS	mortality and prevalence of AKI	AKI and RRT use among COVID-19 patients represent a major public health concern.
Zhou et al. ⁴⁰	2021	<i>Frontiers in Medicine</i>	China	37	Chronic kidney diseases and acute kidney injury in patients with COVID-19	>18 years	PubMed, Embase, bioRxiv, and medRxiv	NOS	prevalence, mortality of AKI	AKI is associated with COVID-19 prognosis.

DOAJ – Directory of Open Access Journals; CNKI – China National Knowledge Infrastructure; NOS – Newcastle–Ottawa Scale; AKI – acute kidney injury; NIH – National Institutes of Health; CKD – chronic kidney injury; RRT – renal replacement therapy.

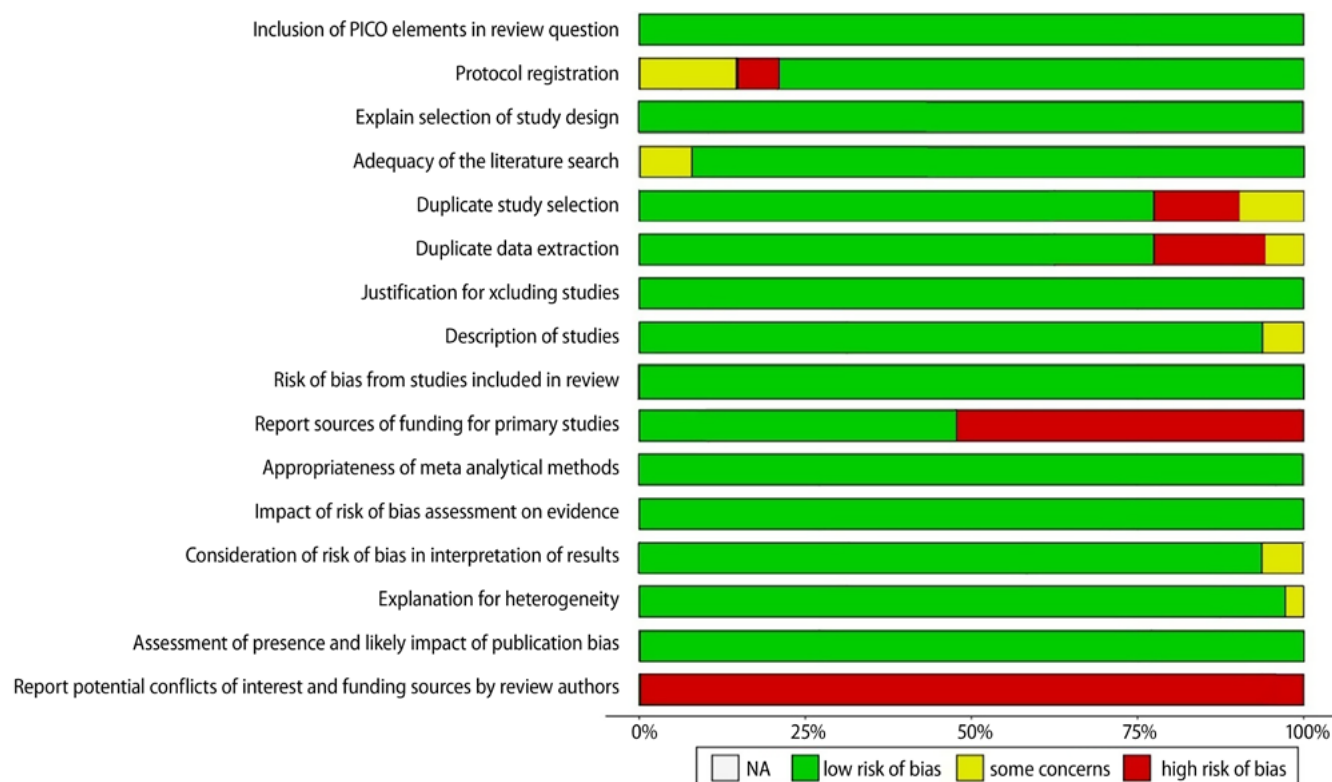


Fig. 2. Frequency of the risk of bias for Assessment of Multiple Systematic Reviews (AMSTAR-2) parameters

of any heterogeneity seen in the results of the review, with the exception of Saghafi et al.,³⁴ which partially satisfied this requirement. Based on the aforementioned evaluations, 14 of 20 studies^{22,24,25,27–29,31–33,35–39} received a high overall assessment, whereas the remaining 6^{21,23,26,30,34,40} were deemed to be of moderate quality.

Characteristics of the patients included in the umbrella review

The present umbrella analysis analyzed a total of 20 selected systematic reviews and meta-analyses, encompassing an overall cohort of 3 and 17,538 COVID-19 patients, to assess the risk of AKI in these individuals. The COVID-19-infected participants analyzed in these studies had a high frequency of AKI (about 60%) and a high mortality rate (around 72%). The populations that were taken from the included studies came from a variety of nations, with the bulk of the research being conducted in countries with high or moderate incomes, including the UK, China, Taiwan, Kenya, Italy, Indonesia, the USA, South Korea, Brazil, Iran, and Switzerland. For the reviews that were included, the summary estimates of the occurrences of AKI in COVID-19 patients are presented in Table 4.

Statistical analysis of extracted data

Using the results extracted on the incidence of AKI in COVID-19 patients and associated mortality, the overall

OR of the included studies was calculated to assess how strongly the incidence of AKI was linked with COVID-19. Figure 3 displays the forest plot for the RR of the incidence of AKI in COVID-19 patients. The pooled RR was 1.50 (95% CI: 1.40–1.60, $I^2 = 69\%$, $p < 0.0001$) with a heterogeneity of $\text{Tau}^2 0.07$, $\chi^2 60.60$, degrees of freedom (df) = 19 and $Z = 4.35$. Figure 4 shows the pooled OR for AKI-associated mortality of COVID-19 patients with an OR of 2.02 (95% CI: 1.79–2.29, $I^2 = 56\%$, $p < 0.0001$) with a heterogeneity of $\text{Tau}^2 0.11$, $\chi^2 43.44$, DF: 19, and $Z = 4.89$. The pooled RR and OR values were greater than 1, indicating a strong correlation between the incidence of AKI and COVID-19. This suggests that patients infected with COVID are at high risk of AKI and associated mortality.

Discussion

COVID-19, a coronavirus disease that predominantly impacts the respiratory system, has evolved into a global pandemic and is now widespread.⁴⁶ Acute kidney injury, which carries an increased risk of mortality, has been documented as a severe complication of COVID-19. Kidney impairment can manifest in a wide range of ways, including a gradual deterioration of renal function or complete cessation of kidney activity. The term 'AKI' denotes the sudden cessation of renal function.^{47,48} The RIFLE classification is the optimal framework for defining AKI. The 3 progressive stages of AKI, as outlined in this system, are risk (class R), injury (class I) and

Table 3. Methodological assessment of the studies was conducted using the Assessment of Multiple Systematic Reviews (AMSTAR-2) evaluation

Study ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Overall assessment
Ali et al. [2020] ²¹	Y	Y	Y	PY	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	N	moderate
Cai et al. [2021] ²²	Y	PY	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	high
Chen et al. [2020] ²³	Y	PY	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	high
Cheruiyot et al. [2020] ²⁴	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	high
Fabrizi et al. [2020] ²⁵	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	high
Hidayat et al. [2023] ²⁶	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	high
Hsiao et al. [2023] ²⁷	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	high
Juarez et al. [2020] ²⁸	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	high
Lee et al. [2021] ²⁹	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	high
Lim et al. [2020] ³⁰	Y	N	Y	Y	PY	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	moderate
Liu et al. [2021] ³¹	Y	Y	Y	Y	Y	Y	Y	PY	Y	Y	Y	Y	Y	Y	Y	N	high
Menon et al. [2021] ³²	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	PY	Y	Y	N	moderate
Passoni et al. [2022] ³³	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	high
Saghafi et al. [2021] ³⁴	Y	Y	Y	Y	N	PY	Y	Y	Y	Y	Y	Y	Y	PY	Y	N	moderate
Shao et al. [2020] ³⁵	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	high
Silver et al. [2020] ³⁶	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	high
Singh et al. [2021] ³⁷	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	high
Wang et al. [2021] ³⁸	Y	N	Y	Y	PY	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	moderate
Yang et al. [2021] ³⁹	Y	Y	Y	Y	Y	Y	Y	PY	Y	Y	Y	Y	Y	Y	Y	N	high
Zhou et al. [2020] ⁴⁰	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	PY	Y	Y	N	moderate

AMSTAR-2 overall assessment rating

1. High – the review accurately and comprehensively summarizes the studies on the topic.
2. Moderate – the review has multiple problems but no major ones. It may accurately summarize study outcomes.
3. Low – the review has a critical flaw and may not provide an accurate and comprehensive summary of the studies that address the question of interest.
4. Critically low – the review has multiple critical flaws and should not be relied on.

Questions:

N – no; PY – partial yes, Y – yes.

Q1: Did the research questions and inclusion criteria for the review include the components of PICO?

Q2: Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?

Q3: Did the review authors explain their selection of the study designs for inclusion in the review?

Q4: Did the review authors use a comprehensive literature search strategy?

Q5: Did the review authors perform study selection in duplicate?

Q6: Did the review authors perform data extraction in duplicate?

Q7: Did the review authors provide a list of excluded studies and justify the exclusions?

Q8: Did the review authors describe the included studies in adequate detail?

Q9: Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?

Q10: Did the review authors report on the sources of funding for the studies included in the review?

Q11: If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?

Q12: If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?

Q13: Did the review authors account for RoB in individual studies when interpreting/discussing the results of the review?

Q14: Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?

Q15: If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?

Q16: Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?

failure (class F).⁴⁹ An increasing body of data indicates that AKI, even when moderate and transitory, is linked to the onset of chronic renal illness and a higher likelihood of long-term death in COVID-19 patients.^{50–52} Moreover, acute renal damage imposes substantial economic burdens in addition to its detrimental health consequences, prolonged hospital stays, admission to an intensive care unit (ICU), and the necessity for renal replacement therapy (RRT).^{53–55}

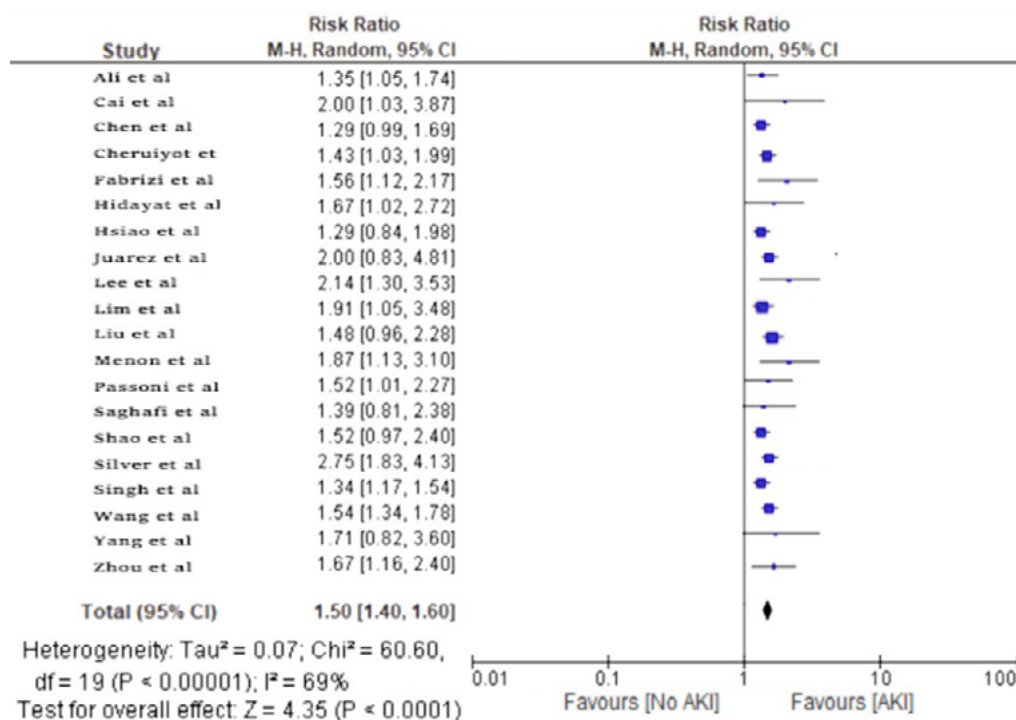
The present study identified a strong correlation between AKI and mortality in patients diagnosed with COVID-19. Additionally, the study identified key risk factors for AKI development in these patients.

The survival rate of patients with AKI and COVID-19 was determined by Ali et al.,²¹ who performed a comprehensive review and meta-analysis of 6 trials. No evidence of publication bias was found (Egger's test: $p < 0.05$).

Table 4. Summary estimates of the included studies

Study ID	Outcome	Number of studies	OR (95% CI)	I ² [%]	p-heterogeneity
Ali et al. ²¹	RR	6	3.08 (1.54–6.19)	90	<0.001
Cai et al. ²²	OR	38	1.37 (1.25–1.49)	40	<0.001
Chen et al. ²³	I (%)	20	8.9 (4.6–14.5)	97.8	<0.001
Cheruiyot et al. ²⁴	OR	15	23.9 (18.84–30.31)	0	0.47
Fabrizi et al. ²⁵	OR	39	15.4 (11.4–20.99)	97.26	<0.001
Hidayat et al. ²⁶	OR	30	3.24 (2.20–4.79)	74	<0.001
Hsiao et al. ²⁷	OR	12	1.67 (1.56–1.80)	92.42	<0.01
Juarez et al. ²⁸	OR	20	15.27 (4.82–48.36)	97.9	<0.001
Lee et al. ²⁹	OR	16	1.68 (1.19–2.36)	79.65	<0.01
Lim et al. ³⁰	RR	15	13.38 (8.15, 21.95)	24	<0.001
Liu et al. ³¹	OR	36	13.29 (4.69–41.26)	0	<0.001
Menon et al. ³²	I (%)	20	11 (0.07–0.15)	98	<0.01
Passoni et al. ³³	I (%)	28	50.4 (17.0–83.9)	98.9	<0.005
Saghafi et al. ³⁴	I (%)	22	24 (17–31%)	97	<0.01
Shao et al. ³⁵	OR	40	14.63 (9.94–21.51)	55	<0.00001
Silver et al. ³⁶	I (%)	54	28 (22–34)	99	<0.001
Singh et al. ³⁷	OR	29	8.28 (4.42–15.52)	73	<0.00001
Wang et al. ³⁸	OR	42	30.46 (18.33–50.59)	98.3	<0.001
Yang et al. ³⁹	I (%)	58	12.3 (9.5–15.6)	97	<0.001
Zhou et al. ⁴⁰	I (%)	37	11.43 (6.93–16.94)	95	<0.001

RR – relative risk of AKI; OR – odds ratio of AKI; I² [%] – percentage of incidence of AKI; AKI – acute kidney injury; 95% CI – 95% confidence interval.

**Fig. 3.** Forest plot for relative risk (RR) of acute kidney injury (AKI) in COVID-19 patients

Severe AKI was associated with a higher risk of mortality (95% CI: 3.08; 1.54–6.19). Cai et al.²² conducted a comprehensive review and meta-analysis of 38 studies involving 42,779 participants to assess the parameters linked to AKI in adult COVID-19 patients. The scientists discovered

several important risk factors for AKI. These risk factors included advanced age (mean difference = 5.63), male gender (OR = 1.37), smoking (OR = 1.23), obesity (OR = 1.12), hypertension (OR = 1.85), diabetes (OR = 1.71), pneumopathy (OR = 1.36), cardiovascular disease (OR = 1.98), cancer

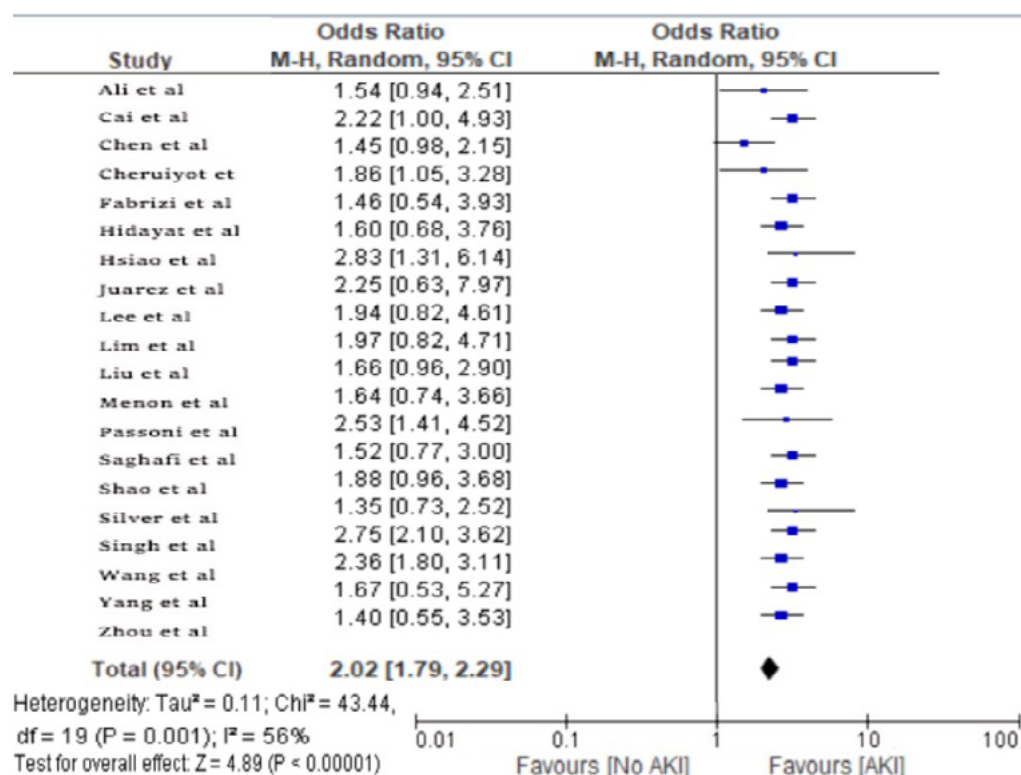


Fig. 4. Forest plot for odds ratio (OR) of mortality due to acute kidney injury (AKI) in COVID-19 patients

(OR = 1.26), chronic kidney disease (CKD) (OR = 4.56), mechanical ventilation (OR = 8.61), and the use of vaso-pressors (OR = 8.33).

In a comprehensive review and meta-analysis of 20 articles involving 6,945 patients, Chen et al.²³ examined the occurrence of AKI in individuals with COVID-19 infections. The occurrence of AKI in patients with COVID-19 was 8.9%, with a 95% CI of 4.6–14.5. The statistical heterogeneity of the studies was demonstrated by the fact that the I^2 value was 97.8% and the p -value was less than 0.001. Acute kidney injury was claimed to have occurred in approx. 9/100 COVID-19 individuals, according to the analysis of Chen et al.²³

In a comprehensive review and meta-analysis of 15 studies involving 5,832 patients, Cheruiyot et al.²⁴ did a thorough review and meta-analysis of 15 studies with 5,832 patients to explore the association between AKI and adverse outcomes in COVID-19 patients. Acute kidney injury was found to be substantially linked with increased odds of COVID-19 severity (OR = 18.5; 95% CI: 8.99–38.08) and death (OR = 23.9; 95% CI: 18.84–30.31). With Cochran's $Q = 4.56$, $p = 0.47$ and $I^2 = 0\%$, and Cochran's $Q = 6.21$, $p = 0.52$ and $I^2 = 0\%$, respectively, for the 2 outcomes, it was concluded that AKI was associated with a poorer outcome in COVID-19 individuals.

Fabrizi et al.²⁵ carried out a comprehensive review and meta-analysis of 39 clinical investigations, which included a total of 25,566 patients. There was a significant amount of variability ($p = 0.0001$) in the aggregated incidence of AKI across all of the trials, which was 0.154 (95% CI: 0.107; 0.201; $p < 0.0001$). This study did not find any

instances of publication bias, as determined with Egger's test ($p = 0.11$). The prevalence of COVID-19-positive individuals undergoing RRT was 0.043 (95% CI: 0.031–0.055; $p < 0.0001$). Acute kidney injury occurrence was significantly associated with age ($p < 0.007$) and arterial hypertension ($p < 0.001$) in hospitalized patients diagnosed with COVID-19.

Hidayat et al.²⁶ conducted a meta-analysis of 30 studies involving 22,385 confirmed COVID-19 patients to examine the risk factors and clinical characteristics of AKI in COVID-19 patients. Patients diagnosed with AKI exhibited proteinuria (OR = 3.31; 2.59; 4.33) and hematuria (OR = 3.25; 2.59; 4.08), as well as the need for invasive mechanical ventilation (OR = 13.88; 8.23; 23.40). Diabetes, hypertension, ischemic cardiac disease, heart failure, CKD, chronic obstructive pulmonary disease (COPD), peripheral vascular disease, and a history of using nonsteroidal anti-inflammatory drugs (NSAIDs) are all factors that enhance the risk of AKI in male COVID-19 patients.

Hsiao et al.²⁷ conducted a comprehensive study of 12 retrospective cohort studies, including 17,618 hospitalized patients with influenza and COVID-19. This study aimed to investigate the parallels and distinctions in acute renal impairment across patients with influenza and COVID-19. Patients with COVID-19 had a greater incidence of AKI compared to influenza patients with AKI (29.37% vs 20.98%, OR = 1.67, 95% CI: 1.56–1.80, $p < 0.01$, $I^2 = 92.42\%$), as well as a higher in-hospital mortality rate (30.95% vs 5.51%, OR: 8.16, 95% CI: 6.17–10.80, $p < 0.01$, $I^2 = 84.92\%$). Juarez et al.²⁸ investigated 20 cohorts that included a total of 13,137 individuals. The majority

of these patients were hospitalized and diagnosed with COVID-19. It was established that 17% of patients with AKI had developed severe COVID-19 infections, and 52% of those patients died. The prevalence of AKI was found to be 17%. Despite the fact that there was a significant amount of variation between studies and locales, AKI was found to be related to an elevated risk of mortality among COVID-19 patients (pooled OR = 15.27; 95% CI: 4.82–48.36). Their findings indicated that RRT was necessary for approx. 5% of all patients.

In a comprehensive study and meta-analysis, Lee et al.²⁹ examined the increased risk of AKI in patients with coronavirus infection who were using renin–angiotensin–aldosterone pathway (RAAS) blockers. According to their analysis of 14 studies that included 17,876 patients, the utilization of RAAS blockers was substantially linked with an increased risk of AKI in hospitalized COVID-19 patients (OR = 1.68; 95% CI: 1.19–2.36). Regarding multi-organ failure, more notably AKI and the severity of COVID-19, Lim et al.³⁰ carried out a comprehensive study that included 3,615 patients who were the participants of 15 different investigations. It was documented by the researchers that AKI was associated with a higher composite outcome (RR [7.68, 14.50], $p < 0.001$; I^2 : 0%), an increased mortality rate (RR: 13.38 [8.15, 21.95], $p < 0.001$; I^2 : 24%), severe COVID-19 (RR: 8.12 [4.43, 14.86], $p < 0.001$; I^2 : 0%), and the need for ICU treatment (RR: 5.90 [1.32, 26.35], $p = 0.02$; I^2 : 0%).

An investigation of the role that acute renal damage and CKD in the COVID-19 pandemic was the focus of a comprehensive review and meta-analysis that was carried out by Liu et al.³¹ The research project included a total of 36 trials and included 6,395 patients who were diagnosed with COVID-19. The severity group had significantly higher odds of having preexisting CKD (OR = 3.28), complications of AKI (OR = 11.02), abnormal serum creatinine (OR = 4.86), blood urea nitrogen (BUN; standard mead difference (SMD) = 1.95), and continuous RRT (OR = 23.63) compared to the non-severe group, according to the findings of their overall analysis.

Menon et al.³² conducted a study in which they investigated the relationship between AKI, the severity of the disease and mortality from COVID-19. A total of 14,415 patients participated in the trial, and they were divided into 20 different groups. There were 3,820 patients from the total who experienced AKI. This is equivalent to a pooled prevalence of 11% (95% CI: 0.07–0.15; $p = 0.01$; $I^2 = 98\%$). A pooled OR of 8.45 (95% CI: 5.56–12.56; $p < 0.00001$; $I^2 = 0\%$) suggested that there was a significant link between AKI and severe COVID-19 disease. Such a correlation was detected. Patients diagnosed with COVID-19 and experiencing AKI had a significantly elevated risk of mortality, as evidenced by an OR of 13.52 (95% CI: 5.43–33.67; $p < 0.00001$; $I^2 = 88\%$).

The incidence of AKI in adult patients who were hospitalized with COVID-19 was the focus of a comprehensive

review and meta-analysis that was conducted by Passoni et al.³³ Researchers examined information obtained from 28 studies that included a total of 18,043 adult patients diagnosed with COVID-19. According to their report, the overall incidence estimates for AKI were 9.2% (4.6–13.9), while the critical care unit incidence estimates were 32.6% (8.5–56.6). The estimated death rate from AKI was 50.4% (17–83.9), whereas the estimated incidence of patients requiring RRT was 3.2% (range: 1.1–5.4). Saghaei et al.³⁴ focused on AKI in COVID-19 patients hospitalized in Iran. They performed a systematic review and meta-analysis of 4,069 verified cases, with ages ranging from 10 to 94, extracted from 22 distinct investigations. Acute kidney injury was shown to occur in 24% (95% CI: 17–31%) of hospitalized patients in Iran who were infected with COVID-19. Shao et al.³⁵ conducted a study that established a correlation between severe infections, mortality and AKI in patients infected with COVID-19. The conclusions drawn were derived from the results of 40 studies comprising a total of 24,527 patients. They discovered that the frequency of AKI in individuals infected with COVID-19 was 10% (95% CI: 8–13%). Patients who were infected with COVID-19 had considerably greater rates of severe illness and mortality compared to those who were not infected with the virus (55.6% vs 17.7% and 63.1% vs 12.9%, respectively, all $p < 0.01$). In patients diagnosed with COVID-19, AKI was found to be a significant predictor of both death (OR = 14.63, 95% CI: 9.94–21.51, p -value < 0.00001) and severe infections (OR = 8.11, 95% CI: 5.01–13.13, p -value < 0.00001).

Silver et al.³⁴ conducted a study comprised of 30,639 participants sourced from 54 distinct studies. The purpose of their investigation was to ascertain the incidence of AKI across hospitalized patients infected with COVID-19. The pooled prevalence of RRT was 9% (95% CI: 7–11%; $I^2 = 97\%$), and AKI occurred at a rate of 28% (95% CI: 22–34%; $I^2 = 99\%$).

Singh et al.³⁷ conducted a study of the pertinent literature concerning the association between AKI and the severity of COVID-19 disease. These analyses encompassed a cohort of 39 investigations, which comprised 15,017 positive COVID-19 patients. The total prevalence of AKI was 11.6% (430/3693), concomitant CKD was 9.7% (1,342/13,728), and the utilization of RRT was 2.58% (102/3,946). Drawing from the aforementioned results, it was determined that the severity of COVID-19 disease was significantly related to concurrent CKD, AKI and RRT use.

A meta-analysis was undertaken by Wang et al.³⁸ regarding the correlation between AKI and CKD and the sternness of illness and fatality among COVID-19 patients. The meta-analysis encompassed 42 studies comprising a total of 8,932 participants. In patients infected with COVID, AKI was linked to a significantly elevated probability of progression to severe disease (OR = 11.88, 95% CI: 9.29–15.19) or death (OR = 30.46, 95% CI: 18.33–50.59).

To examine the association between RRT and AKI in patients inflicted with COVID-19, Yang et al.³⁹ conducted a meta-analysis involving 21,531 patients. Acute kidney injury was observed in 12.3% (95% CI: 9.5–15.6%) of the total study population. Among the 1,745 patients who had passed away, the incidence was 42.0% (95% CI: 30.3–54.9%), while it was 38.9% (95% CI: 27.3–51.9%) among 290 kidney transplant patients and 39.0% (95% CI: 23.2–57.6%) among 565 ICU patients.

Chronic kidney disease and AKI in COVID-19 patients were the subject of the analysis conducted by Zhou et al.⁴⁰ including 52 studies and a total of 31,164 individuals. It was established that the composite values for the prevalence of AKI were 11.46% (95% CI: 6.93–16.94%). Both the risk of mortality (45.79, 36.88–56.85; $I^2 = 17\%$) and the incidence of severe cases were substantially greater among patients with AKI (OR = 6.97; 95% CI: 3.53–13.75; interaction coefficient = 0%).

The statistical analysis of the current umbrella review demonstrates that patients infected with COVID-19 have an increased likelihood of developing AKI. The pooled RR of AKI incidence in COVID-19 patients is greater than 1, with an observed RR of 1.50 (95% CI: 1.40–1.60). Likewise, the probability of mortality associated with AKI is significantly increased in patients inflicted with COVID-19, as indicated by an OR value of 2.02 (95% CI: 1.79–2.29). Furthermore, the study revealed a correlation between AKI and an increased prevalence of CKD and mortality. Nevertheless, the majority of information was obtained from heterogeneous research of moderate quality. Therefore, it is imperative to conduct well-executed research endeavors covering a wider geographical area and conduct thorough systematic reviews accompanied by rigorous meta-analyses to obtain vital insights in this field.

Limitations

The present investigation is not without inherent limitations. It is crucial to acknowledge that while we adhered to recent guidelines concerning the optimal databases for umbrella reviews encompassing AKI, CKD, prognosis, aggravating variables, incidence/prevalence of AKI, and kidney transplant recipients infected with COVID-19, we might have overlooked other noteworthy considerations. These include the potential for CKD progression and non-recovery of AKI during post-acute COVID-19. Moreover, this umbrella review is primarily comprised of systematic reviews that include research articles exhibiting a moderate-to-high degree of bias. In addition, retrospective observational, cross-sectional and case-series research designs, which are all susceptible to residual confounding and influence temporal associations, provided the majority of the conclusions in these reviews. Furthermore, evaluations of the risk of bias indicated substantial variation in the quality of the studies, with specific interventions exhibiting particularly pronounced

disparities in quality. Additionally, probability estimates could be affected by selection biases. Moreover, it is critical to acknowledge the potential existence of selection bias in this study, given that a substantial proportion of papers were excluded. Therapeutic possibilities for COVID-19 patients who suffered from kidney impairments were subsequently not examined, as this topic was outside the purview of the current umbrella review. To gain an improved comprehension of the overall incidence and possibility of AKI in COVID-19-infected patients, further research is required.

Conclusions

It is evident from the available evidence that AKI is a prevalent complication among individuals infected with COVID-19. Substantial risk factors associated with AKI in SARS-CoV-2-infected individuals included progressive age, male gender, coronary artery disease, hypertension, and diabetes. Acute kidney injury and the requirement for RRT were both autonomous predictors of adverse COVID-19 outcomes. It is critical to conduct additional research to ascertain the specific effects of different SARS-CoV-2 variants on the kidneys and the long-term prognosis of these individuals. As a result, future high-quality research studies must incorporate meticulous meta-analyses and systematic reviews to acquire insightful information in this area.

ORCID iDs

Qinyan Gu  <https://orcid.org/0009-0001-8126-8011>

Yongzhen Zhang  <https://orcid.org/0009-0002-9066-9965>

Xijun He  <https://orcid.org/0009-0006-0849-9944>

References

1. Velavan TP, Meyer CG. The COVID-19 epidemic. *Trop Med Int Health*. 2020;25(3):278–280. doi:10.1111/tmi.13383
2. Baloch S, Baloch MA, Zheng T, Pei X. The coronavirus disease 2019 (COVID-19) pandemic. *Tohoku J Exp Med*. 2020;250(4):271–278. doi:10.1620/tjem.250.271
3. Cucinotta D, Vanelli M. WHO declares COVID-19 a pandemic. *Acta Biomed*. 2020;91(1):157–160. doi:10.23750/abm.v91i1.9397
4. Da Rosa Mesquita R, Francelino Silva Junior LC, Santos Santana FM, et al. Clinical manifestations of COVID-19 in the general population: Systematic review. *Wien Klin Wochenschr*. 2021;133(7–8):377–382. doi:10.1007/s00508-020-01760-4
5. Healey Q, Sheikh A, Daines L, Vasileiou E. Symptoms and signs of long COVID: A rapid review and meta-analysis. *J Glob Health*. 2022;12:05014. doi:10.7189/jogh.12.05014
6. Sanyaolu A, Okorie C, Marinkovic A, et al. Comorbidity and its impact on patients with COVID-19. *SN Compr Clin Med*. 2020;2(8):1069–1076. doi:10.1007/s42399-020-00363-4
7. Gęca T, Wojtowicz K, Guzik P, Góra T. Increased risk of COVID-19 in patients with diabetes mellitus: Current challenges in pathophysiology, treatment and prevention. *Int J Environ Res Public Health*. 2022;19(11):6555. doi:10.3390/ijerph19116555
8. Bigdelou B, Sepand MR, Najafikhoshnoo S, et al. COVID-19 and pre-existing comorbidities: Risks, synergies, and clinical outcomes. *Front Immunol*. 2022;13:890517. doi:10.3389/fimmu.2022.890517
9. Fitero A, Bungau SG, Tit DM, et al. Comorbidities, associated diseases, and risk assessment in COVID-19: A systematic review. *Int J Clin Pract*. 2022;2022:1571826. doi:10.1155/2022/1571826

10. Gupta A, Marzook H, Ahmad F. Comorbidities and clinical complications associated with SARS-CoV-2 infection: An overview. *Clin Exp Med*. 2022;23(2):313–331. doi:10.1007/s10238-022-00821-4
11. Bansode J, Sayed S, Ahmad S, Sinha S, Swami R, Mehta K. Acute kidney injury in COVID-19: Clinical profile and outcome. *Indian J Nephrol*. 2022;32(4):291. doi:10.4103/ijn.IJN_21_21
12. Aroca-Martínez G, Musso CG, Avendaño-Echavez L, et al. Differences between COVID-19-induced acute kidney injury and chronic kidney disease patients. *Braz J Nephrol*. 2022;44(2):155–163. doi:10.1590/2175-8239-jbn-2021-0161
13. Faist A, Janowski J, Kumar S, et al. Virus infection and systemic inflammation: Lessons learnt from COVID-19 and beyond. *Cells*. 2022; 11(14):2198. doi:10.3390/cells11142198
14. Hall MW, Joshi I, Leal L, Ooi EE. Immune immunomodulation in coronavirus disease 2019 (COVID-19): Strategic considerations for personalized therapeutic intervention. *Clin Infect Dis*. 2022;74(1):144–148. doi:10.1093/cid/ciaa904
15. Basile DP, Anderson MD, Sutton TA. Pathophysiology of acute kidney injury. *Compr Physiol*. 2012;2(2):1303–1353. doi:10.1002/cphy.c110041
16. Hirsch JS, Ng JH, Ross DW, et al. Acute kidney injury in patients hospitalized with COVID-19. *Kidney Int*. 2020;98(1):209–218. doi:10.1016/j.kint.2020.05.006
17. Al Abri SY, Burad J, Al Wahaibi MM. The incidence of acute kidney injury (AKI) in critically ill COVID-19 patients: A single-center retrospective cohort study at a tertiary level hospital in Oman. *Cureus*. 2023;15(6):e40340. doi:10.7759/cureus.40340
18. Kolhe NV, Fluck RJ, Selby NM, Taal MW. Acute kidney injury associated with COVID-19: A retrospective cohort study. *PLoS Med*. 2020; 17(10):e1003406. doi:10.1371/journal.pmed.1003406
19. Procaccini FL, Alcázar Arroyo R, Albalade Ramón M, et al. Acute kidney injury in 3182 patients admitted with COVID-19: A single-center, retrospective, case-control study. *Clin Kidney J*. 2021;14(6):1557–1569. doi:10.1093/ckj/sfab021
20. Wan YI, Bien Z, Apea VJ, et al. Acute kidney injury in COVID-19: Multi-centre prospective analysis of registry data. *Clin Kidney J*. 2021;14(11): 2356–2364. doi:10.1093/ckj/sfab071
21. Ali H, Daoud A, Mohamed MM, et al. Survival rate in acute kidney injury superimposed COVID-19 patients: A systematic review and meta-analysis. *Ren Fail*. 2020;42(1):393–397. doi:10.1080/0886022X.2020.1756323
22. Cai X, Wu G, Zhang J, Yang L. Risk factors for acute kidney injury in adult patients with COVID-19: A systematic review and meta-analysis. *Front Med (Lausanne)*. 2021;8:719472. doi:10.3389/fmed.2021.719472
23. Chen YT, Shao SC, Hsu CK, Wu IW, Hung MJ, Chen YC. Incidence of acute kidney injury in COVID-19 infection: A systematic review and meta-analysis. *Crit Care*. 2020;24(1):346. doi:10.1186/s13054-020-03009-y
24. Cheruiyot I, Henry B, Lippi G, et al. Acute kidney injury is associated with worse prognosis in COVID-19 patients: A systematic review and meta-analysis. *Acta Biomed*. 2020;91(3):e2020029. doi:10.23750/abm.v91i3.10222
25. Fabrizi F, Alfieri CM, Cerutti R, Lunghi G, Messa P. COVID-19 and acute kidney injury: A systematic review and meta-analysis. *Pathogens*. 2020;9(12):1052. doi:10.3390/pathogens9121052
26. Hidayat AA, Gunawan VA, Iragama FR, et al. Risk factors and clinical characteristics of acute kidney injury in patients with COVID-19: A systematic review and meta-analysis. *Pathophysiology*. 2023;30(2): 233–247. doi:10.3390/pathophysiology30020020
27. Hsiao CY, Pan HC, Wu VC, et al. Acute kidney injury in patients with COVID-19 compared to those with influenza: A systematic review and meta-analysis. *Front Med (Lausanne)*. 2023;10:1252990. doi:10.3389/fmed.2023.1252990
28. Robbins-Juarez SY, Qian L, King KL, et al. Outcomes for patients with COVID-19 and acute kidney injury: A systematic review and meta-analysis. *Kidney Int Rep*. 2020;5(8):1149–1160. doi:10.1016/j.ekir.2020.06.013
29. Lee SA, Park R, Yang JH, et al. Increased risk of acute kidney injury in coronavirus disease patients with renin-angiotensin-aldosterone-system blockade use: A systematic review and meta-analysis. *Sci Rep*. 2021;11(1):13588. doi:10.1038/s41598-021-92323-8
30. Lim MA, Pranata R, Huang I, Yonas E, Soeroto AY, Supriyadi R. Multiorgan failure with emphasis on acute kidney injury and severity of COVID-19: Systematic review and meta-analysis. *Can J Kidney Health Dis*. 2020;7:205435812093857. doi:10.1177/2054358120938573
31. Liu YF, Zhang Z, Pan XL, et al. The chronic kidney disease and acute kidney injury involvement in COVID-19 pandemic: A systematic review and meta-analysis. *PLoS One*. 2021;16(1):e0244779. doi:10.1371/journal.pone.0244779
32. Menon T, Sharma R, Kataria S, et al. The association of acute kidney injury with disease severity and mortality in COVID-19: A systematic review and meta-analysis. *Cureus*. 2021;13(3):e13894. doi:10.7759/cureus.13894
33. Passoni R, Lordani TVA, Peres LAB, Carvalho ARDS. Occurrence of acute kidney injury in adult patients hospitalized with COVID-19: A systematic review and meta-analysis. *Nefrologia (Engl Ed)*. 2022; 42(4):404–414. doi:10.1016/j.nefro.2022.11.005
34. Saghafi A, Aghaali M, Saghafi H. Acute kidney injury in hospitalized COVID-19 patients in Iran: A systematic review and meta-analysis. *J Renal Inj Prev*. 2021;10(2):e09. doi:10.34172/jrip.2021.09
35. Shao M, Li X, Liu F, Tian T, Luo J, Yang Y. Acute kidney injury is associated with severe infection and fatality in patients with COVID-19: A systematic review and meta-analysis of 40 studies and 24,527 patients. *Pharmacol Res*. 2020;161:105107. doi:10.1016/j.phrs.2020.105107
36. Singh J, Malik P, Patel N, et al. Kidney disease and COVID-19 disease severity: Systematic review and meta-analysis. *Clin Exp Med*. 2022; 22(1):125–135. doi:10.1007/s10238-021-00715-x
37. Silver SA, Beaubien-Souligny W, Shah PS, et al. The prevalence of acute kidney injury in patients hospitalized with COVID-19 infection: A systematic review and meta-analysis. *Kidney Med*. 2021;3(1):83–98.e1. doi:10.1016/j.xkme.2020.11.008
38. Wang B, Luo Q, Zhang W, et al. The involvement of chronic kidney disease and acute kidney injury in disease severity and mortality in patients with COVID-19: A meta-analysis. *Kidney Blood Press Res*. 2021;46(1):17–30. doi:10.1159/000512211
39. Yang X, Tian S, Guo H. Acute kidney injury and renal replacement therapy in COVID-19 patients: A systematic review and meta-analysis. *Int Immunopharmacol*. 2021;90:107159. doi:10.1016/j.intimp.2020.107159
40. Zhou Y, Ren Q, Chen G, et al. Chronic kidney diseases and acute kidney injury in patients with COVID-19: Evidence from a meta-analysis. *Front Med (Lausanne)*. 2020;7:588301. doi:10.3389/fmed.2020.588301
41. Belbasis L, Bellou V, Ioannidis JPA. Conducting umbrella reviews. *BMJ Med*. 2022;1(1):e000071. doi:10.1136/bmjmed-2021-000071
42. Pollock M, Fernandes RM, Pieper D, et al. Preferred Reporting Items for Overviews of Reviews (PRIOR): A protocol for development of a reporting guideline for overviews of reviews of healthcare interventions. *Syst Rev*. 2019;8(1):335. doi:10.1186/s13643-019-1252-9
43. Shea BJ, Reeves BC, Wells G, et al. AMSTAR 2: A critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ*. 2017;358:j4008. doi:10.1136/bmj.j4008
44. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. *BMJ*. 2009;339:b2700. doi:10.1136/bmj.b2700
45. Schardt C, Adams MB, Owens T, Keitz S, Fontelo P. Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Med Inform Decis Mak*. 2007;7(1):16. doi:10.1186/1472-6947-7-16
46. Van Damme W, Dahake R, Delamou A, et al. The COVID-19 pandemic: Diverse contexts, different epidemics. How and why? *BMJ Glob Health*. 2020;5(7):e003098. doi:10.1136/bmjgh-2020-003098
47. Turgut F, Awad A, Abdel-Rahman E. Acute kidney injury: Medical causes and pathogenesis. *J Clin Med*. 2023;12(1):375. doi:10.3390/jcm12010375
48. Mercado MG, Smith DK, Guard EL. Acute kidney injury: Diagnosis and management. *Am Fam Physician*. 2019;100(11):687–694. PMID:31790176.
49. Venkataraman R, Kellum JA. Defining acute renal failure: The RIFLE criteria. *J Intensive Care Med*. 2007;22(4):187–193. doi:10.1177/0885066607299510

50. Schiffli H, Lang SM. Long-term interplay between COVID-19 and chronic kidney disease. *Int Urol Nephrol*. 2023;55(8):1977–1984. doi:10.1007/s11255-023-03528-x
51. Chung EYM, Palmer SC, Natale P, et al. Incidence and outcomes of COVID-19 in people with CKD: A systematic review and meta-analysis. *Am J Kidney Dis*. 2021;78(6):804–815. doi:10.1053/j.ajkd.2021.07.003
52. Khoshdel-Rad N, Zahmatkesh E, Shpichka A, Timashev P, Vosough M. Outbreak of chronic renal failure: Will this be a delayed heritage of COVID-19? *J Nephrol*. 2021;34(1):3–5. doi:10.1007/s40620-020-00851-9
53. Ostermann M, Cerdá J. The burden of acute kidney injury and related financial issues. In: Ding X, Rosner MH, Ronco C, eds. *Acute Kidney Injury: Basic Research and Clinical Practice*. Vol. 193. Contributions to Nephrology. Berlin, Germany: Karger; 2018:100–112. doi:10.1159/000484967
54. Dasta JF, Kane-Gill S. Review of the literature on the costs associated with acute kidney injury. *J Pharm Pract*. 2019;32(3):292–302. doi:10.1177/0897190019852556
55. Altawalbeh SM, Wali LM, Alshogran OY, Hammad EA, Tahaine L. Incidence, predictors, clinical outcomes, and economic burden of recurrent acute kidney injury: A retrospective cohort study. *Curr Med Res Opin*. 2023;39(3):399–407. doi:10.1080/03007995.2023.2175997