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# Acute kidney injury in hospitalized COVID-19 patients in Iran; a systematic review and meta-analysis

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## ABSTRACT

Acute kidney injury (AKI) is one of the complications in COVID-19 patients, which is reported with widely varied incidence rates in different studies and is known to have a major impact on prognosis and outcome of the disease. It is noticed that there are considerable differences in AKI rates between different countries. Rates in China are generally much lower than in Western Europe and the United States. One of the potential explanations is heterogeneity along racial and ethnic lines. This study aims to systematically investigate the scientific resources regarding AKI prevalence among hospitalized COVID-19 patients in Iran, and run a meta-analysis on currently published data. Web of Science, PubMed, Embase, Scopus, and Google Scholar databases were searched to identify the articles discussing the occurrence of AKI in hospitalized patients with COVID-19 in Iran. All observational and interventional studies with English full-text providing necessary data for analysis were included with no limitation in time of release or peer-review. Around, 4069 confirmed cases (age; 10-94) from 22 studies were included in the pooled outcome measurement. The proportion of hospitalized patients with COVID-19 in Iran who developed AKI was 24% (95% CI: 17-31%). To the best of our knowledge, this is the first systematic review and meta-analysis to measure the prevalence of AKI in hospitalized COVID-19 patients in Iran. The geographical dissimilarities in the proportion of AKI among COVID-19 patients suggest a role for ethnical and racial differences in the tendency to develop renal involvement.

### Implication for health policy/practice/research/medical education:

In this systematic review and meta-analysis, we showed that 24% of hospitalized COVID-19 patients in Iran developed acute kidney injury. The geographical dissimilarities in the proportion of acute kidney injury among COVID-19 patients suggest a role for ethnical and racial differences in the tendency to develop renal involvement.

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## Introduction

On 31 December 2019, 27 cases of pneumonia of unknown etiology were identified in Wuhan city, Hubei province in China. These patients most notably presented with clinical symptoms of dry cough, dyspnea, fever, and bilateral lung infiltrates on imaging. The causative agent was identified from throat swab samples conducted by the Chinese Centre for Disease Control and Prevention (CCDC) on January 7, 2020, and was subsequently named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The disease was named COVID-19 by the World Health Organization (WHO) (1). On March 11, 2020, the COVID-19 situation was characterized as a pandemic by WHO (2). Although the majority of patients presented

with mild symptoms so far, a substantial number of them experienced fatal complications like various end organ failures, septic shock, pulmonary edema, and acute respiratory distress syndrome (ARDS). Acute kidney injury (AKI) is one of the complications in COVID-19 patients, which is reported with widely varied incidence rates in different studies and is known to have a major impact on prognosis and outcome of the disease (3-10). In a study in Wuhan City, China, during the first few months of the outbreak, the incidence of AKI and aggravation of chronic kidney disease (CKD) among hospitalized COVID-19 patients was concluded to be uncommon. No patient in the study developed AKI based on the diagnostic criteria, reportedly (3). However, the results of

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other studies support the probability of renal involvement in COVID-19. A study from China reported a 0.5% AKI incidence rate (5), while another study from New York City, the United States, calculated AKI development in hospitalized COVID-19 patients to be 36.6% (10). Understanding the pathophysiology of COVID-19 associated AKI is evolving, with no determined theory to date. It is suggested that the cause of kidney involvement might be multifactorial, with cardiovascular comorbidity and predisposing factors (e.g., sepsis, hypovolemia, and nephrotoxins) as important contributors (11). One study described the incidence of AKI as a feature of a thrombotic microangiopathy (TMA)-like phenomenon, secondary to SARS-CoV-2 infection (12). Moreover, virus particles were reported to be present in renal endothelial cells, indicating viremia as a possible cause of endothelial damage in the kidney and a probable contributor to AKI. Other possible mechanisms of injury are direct infection of the renal tubular epithelium and podocytes through an angiotensin-converting enzyme 2 (ACE2)-dependent pathway by SARS-CoV-2 which can cause mitochondrial dysfunction, acute tubular necrosis, the formation of protein reabsorption vacuoles, collapsing glomerulopathy, and protein leakage in Bowman's capsule (11). It is understood that complication of COVID-19 with AKI is associated with significantly higher in-hospital death rate (9), respiratory failure, and need for invasive mechanical ventilation (10); and thus is considered a marker of disease severity and a negative prognostic factor for survival (11). A hypothesis even suggests the possibility of CKD development in COVID-19 survivors complicated with AKI during the course of the disease (13). The difference in AKI prevalence between studies reporting hospitalized COVID-19 patients might partly be explained by different hospital admission policies applied to healthcare systems, and the quality of hospital care (14). However, that is unable to rationalize the substantial variation in AKI occurrence rate among COVID-19 patients ranging from 0% to 46% (3, 15). It is noticed that there are considerable differences in AKI rates between different countries. Rates in China are generally much lower than in Western Europe and United States (14,15). One of the potential explanations is heterogeneity along racial and ethnic lines (15). To the best of our knowledge, no publication discussed the issue independently to date, and hence, no validated analysis confirmed the role of ethnicity. This study aims to systematically investigate the scientific resources regarding AKI prevalence among hospitalized COVID-19 patients in Iran, and run a meta-analysis on currently published data. To date, this is the first meta-analysis study specifically concerned with the matter of race and hospital care by limiting the data inclusion to records from Iran. Results of this study can hint at the possible role of diversities in race and ethnicity and trigger further research in AKI predisposing factors, specifically in COVID-19 patients.

## Methods

### Search strategy

This analysis was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (16). Web of Science, PubMed, Embase, Scopus, and Google Scholar databases were searched to identify the articles discussing the occurrence of AKI in hospitalized patients with COVID-19 in Iran. The whole process of identification was conducted in December 2020. The search terms were selected through the MeSH terms evaluation by two authors independently. Boolean operators were used for an advanced search unless not applicable. The main search string was as follows with minor differences applied to each of the search engines: ("COVID-19" OR "SARS-CoV-2" OR "2019-nCoV" OR "coronavirus") AND ("acute kidney injury" OR "acute renal injury" OR "acute kidney failure" OR "acute renal failure" OR "Oliguria" OR "elevated creatinine" OR "elevated serum creatinine" OR "elevated BUN" OR "elevated serum BUN" OR "Reduced GFR" OR "Reduced glomerular filtration rate") AND ("Iran" OR "name of prominent Iranian provinces and cities"). Further details and exact search query for each database are provided in Supplementary file 1.

### Inclusion and exclusion criteria

All observational and interventional studies with English full-text providing necessary data for analysis were included with no limitation in time of release or peer-review. Exclusion of the articles based on each of the following criteria was conducted; review articles and other types of publications with no patient enrollment, case reports and case series with less than 10 patients, studies with data from outside Iran or out-patient population, studies limited to COVID-19 patients with renal presentation, articles which specifically focus on pediatric population, pregnant women, end-stage renal disease or chronic dialysis patients, and articles with insufficient data on AKI occurrence.

### Data extraction

Search results were evaluated by two independent authors (AS and HS) and study selection was performed assessing the title and the abstract. Among nominated publications, articles' full-texts were reviewed to judge the eligibility for inclusion. A third reviewer (MA) decided on to resolve the disagreements at any phase. The following information was extracted from the studies using an organized checklist: name of the first author, date of the publication, name of the journal, study location, study design, peer-review status, the definition of AKI, type of population (general or special), type of admission ward (general or intensive care), sample size, age range, gender ratio, and proportion of AKI occurrence. General information of the included articles came under scrutiny to prevent duplication and data overlap.

### Statistical analysis

We used the random-effects model for investigating pooled prevalence with their specific 95% confidence intervals (CIs). Study characteristics and estimated total proportion were graphically displayed by forest plots. To dissipate any heterogeneity, subgroup analyses with a random-effects model were carried out. Heterogeneity was measured using Cochran's Q test and  $I^2$  method. Publication bias was evaluated using funnel plot and Egger's test. The effect of each of the studies on the total proportion and confidence interval was assessed by cumulative graph. A meta-regression was performed to determine the impact of moderator variables on the percentage of AKI occurrence in hospitalized patients with COVID-19. Stata 16.0 (StataCorp, College Station, TX, USA) was used for statistical analysis.  $P < 0.05$  was considered statistically significant.

### Results

A total of 948 articles were identified through the systematic search of the databases as previously explained. After removal of all duplications, 746 records remained and were carefully gone through, which returned 125 results. Evaluation of the full-texts to assess eligibility was done and 100 publications were excluded due to either not

fulfilling the inclusion criteria or being subject to any of the exclusion criteria. From 25 remained articles, 3 were excluded due to data overlap. Finally, 22 studies (17-38) were selected and included in the review and meta-analysis. The search process and results are outlined in Figure 1.

The summary of characteristics extracted from studies is presented in Table 1. From 22 included studies, 9 were cohort (17,19-21,23-25,33,36), 8 were cross-sectional (26,30-32,34,35,37,38), one was case-control (28), and 4 were trials (18,22,27,29). Nineteen studies had completed peer-review processes and were published from June to November 2020; while three studies (21,24,32) were not granted publication and peer-review at the time of inclusion. The pooled patient enrollment period was from 30/1/2020 to 30/6/2020. The studies provided a perfect geographical distribution. While 12 articles reported results from more than 7 hospitals located in various districts of Tehran, Iran's capital and the most populous city (17-20, 23,26,27,30,33,34,36,37), other studies were carried out in Zahedan (the Southeast) (21,35), Abadan (the Southwest) (22), Qom (the center) (24), Urmia and Tabriz (the northwest) (25,29,31), Mazandaran and Rasht (the north) (28,38), and Nahavand (the west) (32). Three studies were conducted in a multi-center fashion (21,25,30),

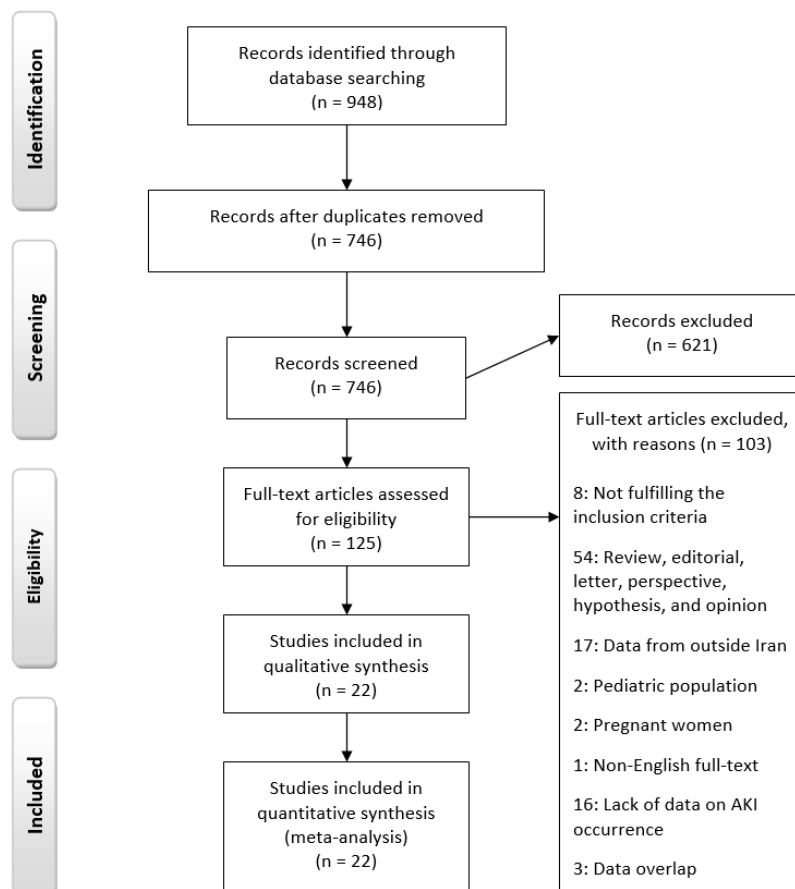


Figure 1. Flow diagram of studies.

Table 1. Summary of study characteristics

First Author	Publication date	Journal	Hospital City or province Study Date	Study design	P-R	Aki Definition	Population	Sample Size	Age (y)	Sex (female/ male)	AKI
Aghaaliakbari F	Nov 2020	Iran J Kidney Dis	Firoozgar Tehran, 1/3 to 30/6	Retrospective Cohort	Y	KDIGO	General	617	18-94 (58.49 ±15.8)	255/362	55/617 (8.9%)
							DM	153	(64.4 ± 11.7)	62/91	19/153 (12.4%)
							Non-DM	464	(56.5 ± 16.5)	193/271	36/464 (7.8%)
Rahmani H	Nov 2020	Int Immunopharmacol	Imam Khomeini, Tehran, 20/4 to 20/5	RCT	Y		General	66	47-73 (60)	27/39	7/66 (10.6%)
Alamdari NM	Oct 2020	Diabetes Metab Syndr	Shahid Modarres, Tehran, 1/4 to 3/5	Retrospective Cohort	Y	Serum Cr	ICU	157	63-72 (67.58)	19/138	72/157 (45.9%)
Soleimani A	Sep 2020	Am J Hypertens	Sina, Tehran, 20/2 to 29/5	Retrospective Cohort	Y	KDIGO	General	636	(57.2 ± 16.3)	239/397	74/636 (11.6%)
							HT	254	(66.4 ± 12.9)	105/149	49/254 (19.3%)
							Non-HT	382	(51.2 ± 15.5)	134/248	25/382 (6.5%)
Hashemi-Shahri SM			MC ZAUMS, Zahedan 29/2 to 31/4	Retrospective Cohort	N		General	413	10-92 (45.05 ± 17.38)	184/229	20/413 (4.9%)
Eslami G	Aug 2020	J Antimicrob Chemother	Taleghani, Abadan 18/3 to 16/4	Open-label trial	Y		General	62	(62.5 {46-71})	31/31	8/62 (12.9%)
Rahmani H	Aug 2020	Daru	Imam Khomeini, Tehran 20/2 to 29/3	Prospective Cohort	Y	KDIGO	General	213	(60 ± 14)	100/113	33/213 (15.5%)
Hormati A			Shahid Beheshti, Qom 25/2 to 20/3	Retrospective Cohort	N	KDIGO	General	200	(62.63 ± 14.9)	88/112	67/200 (33.5%)
							Dead	100	(66.4 ± 14.8)	43/57	57/100 (57%)
							Dis	100	(58.9 ± 14.1)	45/55	10/100 (10%)
Mirza-Aghazadeh-Attari M	Aug 2020	Emerg Radiol	MC, Urmia and/or Tabriz 25/2 to 15/4	Retrospective Cohort	Y		General	50	(65.4 ± 16.77)	23/27	6/50 (12%)
							Dead	23	(70.65 ± 16.51)	8/15	6/23 (26.1%)
							Dis	27	(60.93 ± 15.94)	15/12	0/27 (0%)
Alamdari NM	Sep 2020	Tohoku J Exp Med	Shahid Modarres Tehran 30/1 to 5/4	Cross-sectional	Y		General	459	(61.79 ± 11.89)	139/320	128/459 (27.9%)
							Dead	63	(70.58 ± 10.66)	14/49	50/63 (79.4%)
							Dis	396	(60.39 ± 11.47)	125/271	78/396 (19.7%)
Davoudi-Monfared E	Aug 2020	Antimicrob Agents Chemother	Imam Khomeini Tehran 29/2 to 3/4	RCT	Y	KDIGO	General	81	(57 ± 15)	37/44	23/81 (28.4%)
Taghiloo S	Sep 2020	J Med Virol	Imam Khomeini Mazandaran 3 to 4	Case-control	Y		General	61	(62 {50-72})	24/37	6/61 (9.8%)
Valizadeh H	Oct 2020	Int Immunopharmacol	Imam Reza Tabriz	RCT	Y	Serum Cr > 1.5	General	39 (40)	19-69 (52.35 ± 8.15)	9/31	6/28 (21.4%)

Table 1. Continued

First Author	Publication date	Journal	Hospital City or province Study Date	Study design	P-R	Aki Definition	Population	Sample Size	Age (y)	Sex (female/male)	AKI
Jamaati H	Aug 2020	Biomedical and Biotechnology Research J	MC SBMU, Tehran 3 to 5	Cross-sectional	Y	Serum Cr > 1.2	ICU	36	26-86 (57.9 ± 16.8)	8/28	6/36(16.6%)
Mahmoodpoor A	Jun 2020	Anesth Pain Med	Imam Reza, Tabriz 20/2 to 20/4	Cross-sectional	Y		ICU	200			50/200 (25%)
Mahmoudi H			Alimoradiyan, Nahavand 17/2 to 11/4	Cross-sectional	N	Elevation in Serum Cr and Urea	General	100	20-82 (51)	31/69	35/100 (35%)
Mansour A	Nov 2020	EXCLI J	Shariati Tehran 25/2 to 21/4	Retrospective Cohort	Y	Serum Cr > 1.5	General	339 (353)	18-97 (61.67 ± 16.38)	150/203	66/339 (19.5%)
							DM	101 (111)	(63.66 ± 13.32)	49/62	25/101 (24.8%)
							Non-DM	238 (242)	(60.76 ± 17.56)	101/141	41/238 (17.2%)
Besharat S	Sep 2020	Open Access Maced J Med Sci	Modarres Tehran 1/4 to 30/4	Cross-sectional	Y		Dead	62	28-95 (67.62 ± 15.07)	18/44	18/62 (29%)
Rokni M	Nov 2020	BMC Infect Dis	Buali Zahedan 29/2 to 24/5	Cross-sectional	Y	Serum Cr > 1.4	General	212 (233)	(49.8)	84/149	47/212 (22.2%)
							Dead	23 (28)	(65.3)	8/20	15/23 (65.2%)
							Dis	189 (205)	(47.6)	76/129	32/189 (16.9%)
Barkhordari K	Aug 2020	J Card Surg	THC Tehran 29/2 to 10/4	Retrospective Cohort	Y	KDIGO	Concurrent Cardiac Surgery	25	(57.33 ± 15.13)	7/18	10/25 (40%)
Ghaffari Rahbar M	Jul 2020	Transpl Infect Dis	Labbafinejad Tehran 20/2 to 15/4	Cross-sectional	Y	> 30% decrease in eGFR (MDRD)	Kidney Transplant	19	29-66 (47.6 ± 12.4)	6/13	14/19 (73.7%)
							Dead	9	(51.2 ± 12.8)	1/8	7/9 (77.8%)
							Dis	10	(44.3 ± 11.8)	5/5	7/10 (70%)
Monfared A	Jul 2020	Transpl Infect Dis	Razi Rasht 20/2 to 19/4	Cross-sectional	Y	KDIGO	Kidney Transplant	22	(52 {40.75-62.75})	7/15	12/22 (54.5%)
							Dead	6			6/6 (100%)
							Dis	16			6/16 (37.5%)

P-R: Peer-review, Y: Yes, N: No, MC: Multi-center, RCT: Randomized Clinical Trial, Cr: Creatinine, DM: Diabetes, HT: Hypertension, Dead: Deceased, Dis: Discharged.

Note: Empty cells show absence of data, NLM Title Abbreviation used in Journal column when applicable, Age column is filled with either age range (Mean ± SD) or (Median {IQR-IQR}) upon data availability, some records of Sample size column are in a No.1 (No.2) fashion. No.2 shows the real sample size, while no.1 shows how many had normal baseline Cr. Patients with high baseline Cr were put aside in order not to be mistaken with AKI when required

while the rest were single-center studies. 7 articles defined AKI according to KDIGO criteria (17,20, 23, 24, 27, 36, 38) which is an increase in serum creatinine by 0.3 mg/dL within 48 hours or a 50% increase in serum creatinine from baseline within 7 days (39). One study outlined AKI as >30% decrease in eGFR estimated by MDRD equation (37), while AKI was defined roughly by serum creatinine cut-off if specified in other studies. In three studies, patients were specifically from intensive care unit (ICU) (19,30,31). Two studies enrolled a population of kidney transplant recipients (37,38), one only deceased patients (34), and one patients who underwent concurrent cardiac surgery (36). The funnel plot to evaluate publication bias is demonstrated in Figure 2.

Around 4069 confirmed cases (age; 10-94) were included in the pooled outcome measurement. The proportion of hospitalized patients with COVID-19 in Iran who developed AKI was 24% (95% CI: 17-31%). Figure 3 shows the forest plot of AKI in COVID-19 hospitalized patients. The effect of each of the studies on the total proportion and confidence interval is displayed by cumulative graph (Figure 4). Subgroup analyses revealed AKI development to be higher in ICU than general ward (30%, 95% CI: 13-47%, versus 23%, 95% CI: 16-31%). Studies which defined AKI according to either KDIGO or decline in GFR showed higher AKI occurrence than ones with serum Cr as an indicator (32%, 95% CI: 16-47%, versus 21%, 95% CI: 15-27%). Observational studies returned higher AKI percentage than trials (26%, 95% CI: 17-34%, versus 17%, 95% CI: 10-25%). None of the subgroup analysis results were, however, statistically significant ( $P=0.52$ ,  $P=0.20$  and  $P=0.15$  respectively). There was no difference between peer-reviewed and not-peer-reviewed articles in terms of AKI proportion (24%, 95% CI: 17-32%, versus 24%, 95% CI: 5-43%). Figure 5 summarizes the outcomes of subgroup analysis.

Pooled data from deceased patients showed a significantly higher proportion of AKI compared with the patients who were discharged from hospital (62%, 95% CI:

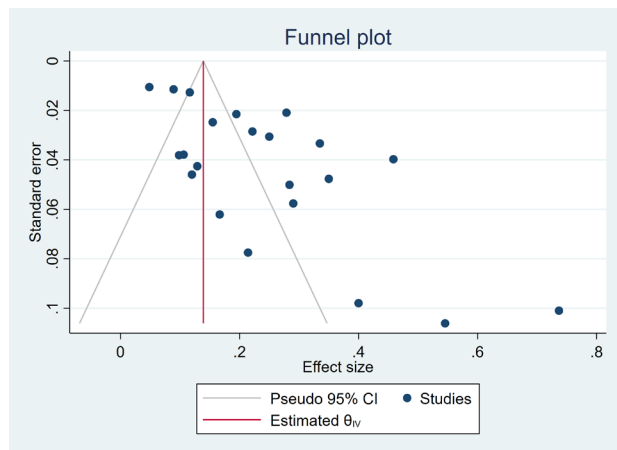


Figure 2. Funnel plot based on total studies.

42-82%, versus 28%, 95% CI: 7-49%,  $P=0.02$ ) (Figure 6 and Figure 7). It should be taken into consideration that the majority of included studies did not report segregated data regarding survival. Hence, these percentages do not represent the whole proportion. AKI was found in 64% (95% CI: 46-83%) of kidney transplant patients, data from two independent studies indicated (Figure 8).

Evaluating the variables in terms of their impact on AKI occurrence, it turned out that kidney transplantation and death outcome are the two predictors. Details are summarized in Table 2.

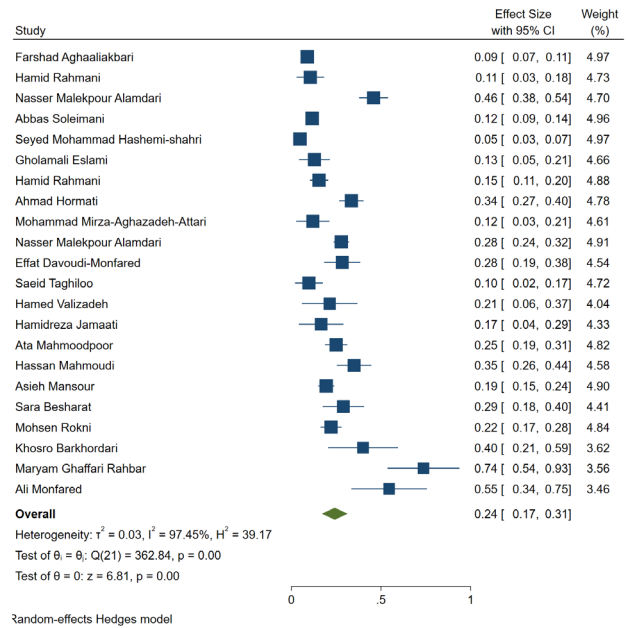


Figure 3. Forest plot for proportions of AKI. Note: Weights are from random-effects analysis.

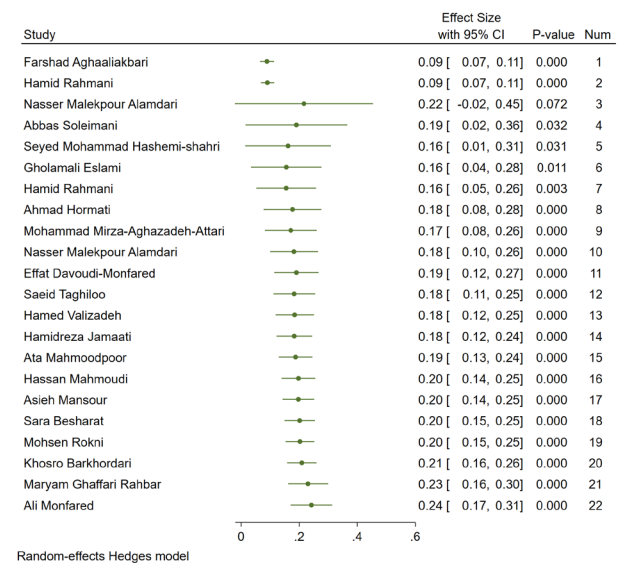


Figure 4. Cumulative graph for showing the effect of each study on the total proportion.

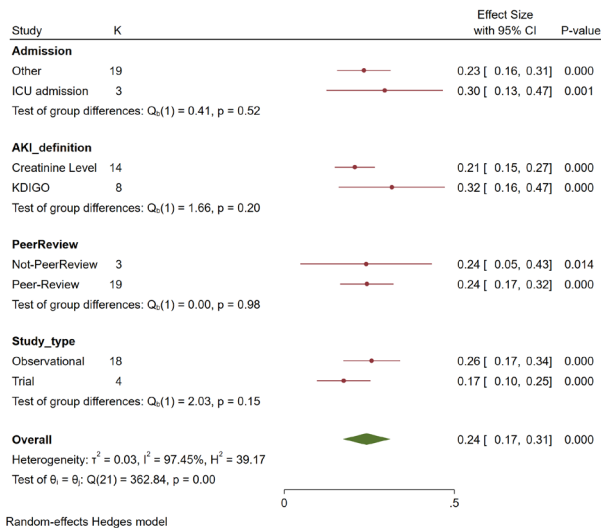


Figure 5. Summary of outcomes of subgroup analyses.

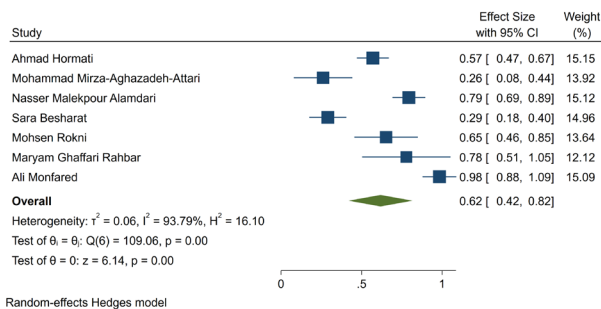


Figure 6. Forest plot for proportions of AKI in deceased patients.

### Discussion

Since December 2019, when COVID-19 emerged in Wuhan city and rapidly spread throughout China, to date, when it still is the most prominent health issue throughout the world, the data on the disease's presentation, clinical course, and outcome was rapidly growing (5). Because of the novelty of the disease, our knowledge about it is subject to evolution, and the combination of reports yields a more comprehensive understanding as time goes by. We conducted a systematic review and meta-analysis on the studies which reported the occurrence of AKI in hospitalized COVID-19 patients in Iran. We found out that 24% of patients developed AKI, which

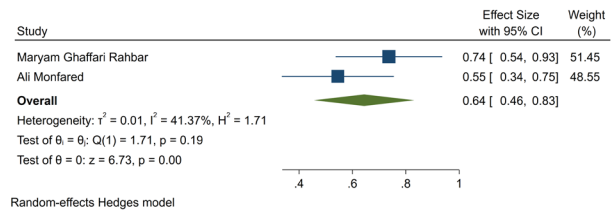


Figure 8. Forest plot for proportions of AKI in kidney transplant patients.

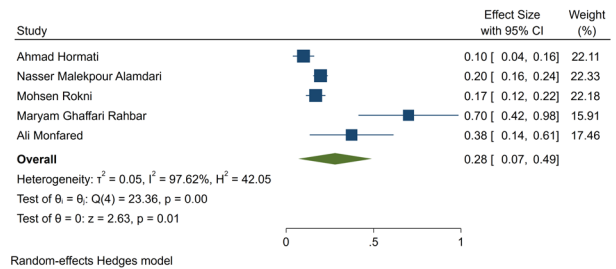


Figure 7. Forest plot for proportions of AKI in discharged patients.

indicated kidney damage to be a common complication of the disease. Compared to previous reports, our study returned a higher percentage of AKI. Two previously published meta-analyses, calculated the prevalence of AKI 4.5% (40), and 17% (41). The noteworthy point is that in those meta-analyses, the majority of data came from China, which had published most of the cited documents due to the precedence of disease emergence there. A primary report from china had even concluded that AKI is not a complication of COVID-19 (3), although the following information modified the presumption (14). However, several researchers noticed lower rates of AKI in reports from China than elsewhere (10, 15). It means that the conclusion of previous meta-analysis might have been affected by the Chinese reports, while to date, only about 0.1% of COVID-19 cases were from China (42). Hirsch et al conducted a retrospective cohort study on admitted COVID-19 patients in the New York metropolitan area, which showed 36.6% AKI occurrence (10). Another multi-center observational study from New York reported AKI development in up to 46% of admitted COVID-19 patients (43). Although few European data are currently available on this topic, published data presented generally higher rates than Chinese studies (15). These

Table 2. Meta-regression details and results

Variable	Coefficient	Std. Error	t	P value	95% CI	
Kidney transplantation	0.3677449	0.0911501	4.03	0.000	0.1807203	0.5547696
Death outcome	0.3465766	0.0640734	5.41	0.000	0.2151088	0.4780444
_cons	0.1807131	0.0277139	6.52	0.000	0.1238489	0.2375774
REML estimate of between-study variance:	tau2 = .01418					
% Residual variation due to heterogeneity:	I-squared_res = 91.34%					
Proportion of between-study variance explained:	Adj R-squared = 74.30%					
With Knapp-Hartung modification:	Prob > F = 0.0000					

geographical differences can potentially be explained by the differences in admission criteria, hospital care, and ethnic predisposition to kidney involvement. Our study indicated the development of AKI in about a quarter of patients admitted in more than 18 hospitals in various regions of Iran, remarkably higher than most of the Chinese reports and close to reports from Western Europe and United States (14,15).

In our study, ICU admitted patients had a higher rate of AKI development than general ward admissions (30% versus 23%). However, the difference was not statistically significant. Moreover, general AKI prevalence in ICU patients was close and even sometimes higher in previous reports from Iran (44-46). An explanation might be that although AKI is a common complication, it is not a key contributor to disease severity in COVID-19 patients.

In another subgroup study, we analyzed the data from studies which defined AKI either in line with KDIGO criteria (39) or GFR estimation and studies that either did not specify or used serum creatinine to assess AKI. The proportion was higher in the first group (32% versus 21%), although not statistically significant. It is possible that applying a more precise definition to AKI diagnosis leads to a higher occurrence rate.

We conducted an analysis to determine if there is a difference in AKI percentage in deceased compared to discharged patients. Seven articles had reported the necessary data, and analysis revealed that the prevalence of AKI was significantly higher in patients who did not survive than the ones who discharged (62% versus 28%,  $P=0.02$ ). Richardson et al performed an observational study which returned 62.7% AKI percentage in deceased patients compared with 8.5% in discharged ones (4). However, due to the scarcity of data, it is yet to develop a conclusion.

Two studies that specifically included kidney transplant recipients who were admitted due to COVID-19 were analyzed. It was shown that 64% of patients developed AKI. AKI is a critical complication in kidney transplant patients, because of its possible contribution to allograft rejection.

Several variables were assessed to determine if they had an impact on AKI occurrence by meta-regression. Two predictors, death outcome and kidney transplantation, were revealed. We assume that the high percentage of AKI development in deceased patients might partly be contributed to multiple organ failure in the terminal phase of severe disease. Further research should be performed to evaluate the impact of AKI as a variable on the survival of COVID-19 patients, limiting confounders effect.

Our review faced some limitations. The data on COVID-19 patients was limited due to the novelty of the disease, and more data might influence the proportion. There was heterogeneity regarding type of study, definition of AKI, and study population. The quality of

included studies was varied. Some of the included articles did not mention specific data on AKI occurrence. A serum creatinine cut-off was set to determine AKI in those reports.

## Conclusion

To the best of our knowledge, this is the first systematic review and meta-analysis to measure the prevalence of AKI in hospitalized COVID-19 patients in Iran. We showed that 24% of patients developed AKI. The geographical dissimilarities in the proportion of AKI among COVID-19 patients suggest a role for ethnical and racial differences in the tendency to develop renal involvement. Further research is warranted to determine the significance of ethnicity, while other factors like the quality of hospital care might also play a role. COVID-19 needs a comprehensive clinical and research approach, and our understanding of this disease is still insufficient. Large-scale studies are recommended to unfold more accurate characteristics of COVID-19.

## Authors' contribution

AS, MA, and HS contributed equally to prepare the study concept and design. AS and HS carried out the acquisition of data. MA performed the statistical analysis and interpreted data. AS wrote the primary manuscript. HS critically revised the manuscript. All authors read and signed the final manuscript.

## Conflicts of interest

The authors declare no conflict of interest.

## Ethical considerations

The study was approved by the ethics committee of Qom University of Medical Sciences (Code: IR.MUQ.REC.1399.226). Ethical issues (including plagiarism, data fabrication, double publication) have been completely observed by the authors.

## Funding/Support

None.

## Supplementary files

Online Supplementary file 1 shows search strategies used in this study.

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