REV SEN
rev-sen.ec

Risk factors associated with acute kidney injury in patients in intensive care with COVID-19. A single-center observational study.

María Isabel León Baquero [ID] [1], Ramiro Iván López Pulles [ID] [1], María Gabriela Cobo Jaramillo [ID] [1]

1. Postgraduate Nephrology, Faculty of Medical Sciences, Universidad Central del Ecuador, Quito-Ecuador.

Abstract

Introduction: Patients with COVID-19 admitted to intensive care units are at high risk of developing acute kidney injury (AKI). SARS-CoV-2 can directly infect kidney cells, causing an intense inflammatory response with lymphocytic infiltration and severe tubular necrosis. These factors, together with others not yet fully understood, contribute to the development of acute kidney failure. This study aimed to identify risk factors in this specific group of patients.

Methods: The present observational study was conducted at the Pablo Arturo Suárez Hospital Intensive Care Unit in Quito, Ecuador, from January 2020 to December 2021. With a probabilistic sample, adult patients in intensive care with COVID-19 were included. The variables were age, sex, education, body mass index, comorbidities, increase in serum creatinine, severity scales, vital signs, and the PAO2/FIO2 ratio. Presence of respiratory distress. Laboratory parameters: Interleukin 6, lactate dehydrogenase, ferritin, and serum lactate levels; blood count; days in the ICU; and mortality. The odds ratio is obtained to present the risk.

Results: A total of 294 patients were included in the study. The prevalence of AKI was 16.0% (95% CI 12.1% -20.6%). The risk factor for developing AKI was the presence of comorbidities, which presented an influential association with the development of renal failure, 8.7% vs. 20.4% (P = 0.02), indicating an OR of 2.68 (95% CI: 1.24, 5.78; P = 0.02). Female sex constituted a protective factor with an OR of 0.30 (95% CI: 0.09, 0.85; P = 0.03).

Conclusion: The leading risk factor for the development of acute kidney injury was comorbidities related to male sex, and female sex was a protective factor.

Keywords:

COVID-19, Acute kidney injury, Risk factors, Mortality, Comorbidities.

Received: July 11, 2024.
Accepted: August 26, 2024.
Published: August 29, 2024.
Editor: Dr. Franklin Mora Bravo.

Cite:
León M, López R, Cobo M. Risk factors associated with acute kidney injury in patients in intensive care with COVID-19. A single-center observational study. REV SEN 2024;12(2):158-166.

DOI: http://doi.org/10.56867/84
Sociedad Ecuatoriana de Nefrología, Diálisis y Trasplantes.

ISSN-L: 2953-6448

* Corresponding author

Email: María Isabel León Baquero <mileonb@uce.edu.ec >/Address: Iquique 132, Quito 170136. Central University of Ecuador School of Medicine, Quito, Ecuador. Tel [593] 022 528 690.

Patients with COVID-19 are at high risk of developing acute kidney injury, manifested as an increase in serum creatinine levels ≥ 0.3 mg/dl in 48 hours or an increase in serum creatinine ≥ 1.5 times greater than that of patients with COVID-19 or a decrease in urine volume production of 0.5 ml/h for at least 6 hours [1].

SARS-CoV-2 can directly infect kidney cells, causing an intense inflammatory response with lymphocytic infiltration and severe tubular necrosis. This inflammatory response, along with other factors not yet fully understood, contributes to the development of acute renal failure in patients with COVID-19 [2].

Elevated levels of cytokines, activation of the angiotensin two signaling pathway, complement dysregulation, and hypercoagulability have also been described. Histologically, peritubular erythrocyte adhesion, fibrin thrombi and ischemia, endothelial deterioration, hemosiderin deposits, and casts associated with rhabdomyolysis and inflammation are observed [3].

There are reports of kidney involvement in COVID-19. Cheng et al. described 710 patients who were diagnosed and hospitalized for COVID-19 and reported that 44% had proteinuria and that 26.7% had hematuria since admission. The incidence of acute kidney injury ranges between 0.5% and 29%, depending on the severity of the presentation. The occurrence of acute kidney failure is related to the seriousness of COVID-19. Between 2% and 3% of hospitalized patients and those who require admission to the intensive care unit, the reported incidence ranges from 8.3% to 29% [4].

Another study of 107 geriatric patients with COVID-19 who required treatment in an intensive care unit in Wuhan, China, included two groups with COVID-19, one with 37 patients with severe compromise and 70 in the critical phase. It is evident that 48 of the 107 (44.9%) presented with acute kidney injury during their hospitalization (7 participants with severe kidney injury and 41 critical participants). A total of 35.4% of the participants with acute renal failure required renal replacement therapy [5].

These alterations in kidney function occur in patients with comorbidities such as hypertension and diabetes mellitus. In addition, risk factors such as advanced age, male sex, obesity, and the use of mechanical ventilation together cause high mortality [6]. For example, in a study presented by Gameiro J et al., 106 of the 192 patients with acute kidney injury who were hospitalized for COVID-19 developed acute kidney injury. Among these, 55.7% were men whose average age was 75.6 years ± 14.6 years, with 34% having diabetes mellitus, 78.3% having arterial hypertension, and 28.3% having chronic kidney disease [6].

In another study of 55 patients diagnosed with severe COVID-19 and 166 with moderate COVID-19, 8 (14.5%) patients with severe disease developed kidney damage; the characteristics they shared were advanced age, 48.9% were men, 24.4% had arterial hypertension, 10% had diabetes, 10% had cardiovascular disease, and 2.7% had chronic kidney disease [7].

The development of acute kidney injury is also associated with a greater risk of mechanical ventilation, with an OR of 6.46 and 95% CI of 5.52--7.57; mortality, with an OR of 6.71 and 95% CI of 5.62--8.04; and long-term hospitalization, with an OR of 5.56 and 95% CI of 4.78--6.34 [8].

The objective of this study was to determine the risk factors related to the development of acute kidney injury in patients who were diagnosed with COVID-19 and admitted to the intensive care unit of the Pablo Arturo Suárez Hospital of Ecuador during the period 2020--2021.

Materials and methods

Research type

The present study is observational and analytical. The source is retrospective.

Stage

This study was conducted in the Pablo Arturo Suarez Hospital intensive care unit of the Ministry of Public Health of Ecuador in Quito, Ecuador, from January 1, 2020, to December 30, 2021.

Universe and sample

The study population corresponds to the anonymized documentary records of patients in intensive care with COVID-19. The sampling was simple and random.

Inclusion criteria

Patients who were older than 18 years, had a confirmed diagnosis of COVID-19 and were hospitalized in the intensive care unit were included. The control group included patients who did not develop acute kidney injury. The study group included patients who developed acute kidney injury.

Exclusion criteria

Patients with chronic renal failure were excluded. Records with incomplete data were removed from the inclusion analysis.

Variables

The variables used were age, sex, education, body mass index, comorbidities, increase in serum creatinine, and severity scale scores: SOFA score, SAPS score, and APACHE II score. Pulse pressure, mean arterial pressure, heart rate, respiratory rate, PAO_2/FIO_2 ratio, and presence of respiratory distress were also measured. Laboratory studies included interleukin 6, lactate dehydrogenase, ferritin, serum lactate levels, hematic biometry, intensive care unit (ICU) days, and mortality.

Data sources/measurements

The source was retrospective; the database of the DI-22-COVID-19 project, created for monitoring patients in intensive care during the

pandemic, was reviewed, including all the study variables. The KDIGO criterion was used to diagnose acute kidney injury as an absolute increase in serum creatinine ≥0.3 mg/dl in 48 hours, a serum creatinine increase of ≥ 1.5 times the baseline value in 7 days, or a decrease in the urine volume of 0.5 ml/kg/h for at least 6 hours [1].

Biases

To avoid possible interview, information, and memory biases, the principal investigator kept the data with a guide and records approved by the research protocol. Observation and selection biases were avoided by applying the participant selection criteria. All the clinical and paraclinical variables from the previous period were recorded. Two researchers independently analyzed each record in duplicate, and the variables were recorded in the database once their agreement was verified.

Study size

The sample was probabilistic. Through access to the institution's database, 328 patients admitted to the ICU for COVID-19 were identified. With an unknown incidence of acute kidney injury, an expected frequency of 50.0% was established, with a confidence limit of 5%, and the confidence level of 99% was 219 cases. Epi info ™ (CDC, Atlanta, USA, October 2023) was used to calculate the sample size.

Quantitative variables

Descriptive statistics were used. The quantitative variables were the result of scale measurements. Categorical data, such as sex, are presented as proportions. Delta values, which consisted of the difference between the control and baseline values, were established for the laboratory tests.

Statistical analysis

Inferential statistics are used. The quantitative variables are reported as the means ± standard deviations (X ± SDs) or as medians (M) and interquartile ranges (q25 - q75). The qualitative variables are reported with their absolute and relative frequencies as percentages. Comparisons and bivariate hypothesis tests for quantitative variables were performed via Student's t-tests after verification of normality assumptions; if necessary, a logarithmic transformation was performed to normalize the values or analyses were performed with robust methods (limited average of 10%) or, in the last case, with nonparametric methods (Wilcoxon). For variables with more than two levels, one-way ANOVA or its nonparametric equivalent was performed.

For longitudinal evaluations (initial evaluation, subsequent evaluations), ANOVA was used for repeated measures, and post hoc tests were performed when necessary, with Holm adjustment for repeated measures either with logarithmic transformation or its nonparametric equivalents. Differences between assessments are reported as the means with their respective 95% confidence intervals. Comparisons for qualitative variables were made with tests of independence for proportions and goodness of fit with the chi-square (Pearson) test, with continuity correction; if necessary, Fisher's exact test was used. Stratified comparisons of the Cochran–Mantel–Haenszel chi-square test were performed when required.

The multivariate analyses were performed with binary logistic regression. The variables included in each model are indicated in the table of annexes (see table), and selecting the best variables to determine the association with the dependent variable (acute kidney injury) was performed via algorithms of bidirectional selection (AIC), the limits of exclusion or permanence were established in (0.10); some variables were maintained when their exclusion significantly modified the test of variance between models. We tried to retain balanced data to construct the models, excluding missing data or variables with missing data. Risks are reported as opportunity ratios (odds ratios, ORs) with their respective 95% confidence intervals. All analyses assumed an alpha error of 5% ($P \leq 0.05$). The data were analyzed via the statistical package R (R-Cran) in version 4.3.0.

Results

Study participants

The study included 294 patients with severe COVID-19 who were treated in the intensive care unit. The prevalence of acute kidney injury in this group of patients was 16.0% (95% CI 12.1% -20.6%).

Characteristics of the study groups

There were 294 patients, 83 women (28%) and 211 men (71.8%), with a mean age of 51 ± 13 years. The percentage of immunization recorded in this population was 7.5% (n = 22). The summary of the demographic variables is shown in Table 1. Among the patients with acute kidney injury (16.0%), Group 1 was formed. The control group included 246 patients (84%) without acute kidney injury. There were no differences in age, sex, education, or body mass index between the groups. No differences between the groups were established between the severity scales SOFA, SAPS II, and APACHE II.

There was no difference in vital signs between the study groups. There was a difference in the presence of comorbidities, which were more prevalent in the group that developed acute kidney injury (P = 0.02). The percentage of patients with respiratory distress syndrome (ARDS) was similar in both groups: 94.7% (n = 233) in the group without acute kidney injury and 95.8% (n = 46) in the group with kidney injury.

Laboratory measurements

There were no differences between the baseline laboratory measurements between the groups; however, apparent differences were established between the delta values (control values minus the baseline test values). In patients with acute kidney injury, interleukin 6 levels increase, serum ferritin levels increase, neutrophil levels increase, and hemoglobin and hematocrit levels decrease more intensely (Table 2).

Multivariate analysis

Female sex and the presence of comorbidities were the only factors that entirely determined the probability of developing kidney failure.

Female sex was a protective factor, whereas the presence of comorbidities was a risk factor. Age, ferritin at admission, and the increase in serum lactate at 24 hours were not statistically significant.

Table 1. Characteristics of the study population.

	Without acute kidney injury n = 246	With acute kidney injury n = 48	*P*
Age (Years)	49.0 ±13.0	52.0 ±14.0	0.16
Sex, n%			
Male, n%	174 (70.7%)	37 (77.1%)	0.47
Female, n%	72 (29.3%)	11 (22.9%)	
Instruction			
None, n%	8 (3.3%)	2 (4.2%)	0.48
Primary, n%	79 (32.1%)	15 (31.2%)	
Secondary, n%	113 (45.9%)	18 (37.5%)	
Superior, n%	46 (18.7)	13 (27.1%)	
Body mass index, by class, n%			
Normal weight, N%	31 (12.6%)	4 (8.33%)	0.60
Overweight, N%	111 (45.12%)	21 (43.75%)	
Obesity, N%	102 (41.46%)	23 (47.92%)	
Comorbidities			
Comorbidities, n%	152 (61.8%)	39 (81.2%)	0.02
Arterial hypertension, n%	32 (13.0%)	11 (22.9%)	0.12
Type 2 diabetes, n%	17 (6.9%)	5 (10.4%)	0.38
Severity scale			
SOFA	7 (4, 10)	8 (4, 10)	0.41
SAPS II	37 (29, 50)	42 (34, 49)	0.19
APACHE II	16 (11, 20)	17 (11, 20)	0.90
Vital sign measurements			
Pulse pressure (mmHg)	51.5 ±15.4	51.9 ±17.0	0.88
Mean arterial pressure (mmHg)	85.3 ±14.0	86.7 ±12.7	0.54
Freq. Cardiac (BPM)	76.0 ±22.0	75.0 ±20.0	0.69
Freq. Respiratory (RPM)	23.0 ±5.0	24.0 ±4.0	0.92
PAO_2/FIO_2	133.0 ±47.8	129.0 ±55.3	0.62

FREQ: Frequency, ODP_2 : Blood pressure of oxygen, FIO_2 : Fraction of inspiration of oxygen. mmHg: millimeters of mercury, BPM: beats per minute, RPM: breaths per minute.

Associated complications in patients with COVID-19 who developed kidney injury

Patients who developed acute kidney injury had longer stay times in the intensive care unit than those who did not experience kidney injury. The stay was for the first 15.3 days vs. 11.3 days. On average, this represented an increase of 3.9 days (95% CI: 0.0--7.9 days; $P = 0.05$). Mortality rates were also higher in the group that developed acute kidney injury. The risk of death in patients with acute kidney injury vs. those without acute kidney injury was 58.3% (n = 28/48) vs. 34.1% (n = 84/246); $P = 0.003$ (Figure 1).

Discussion

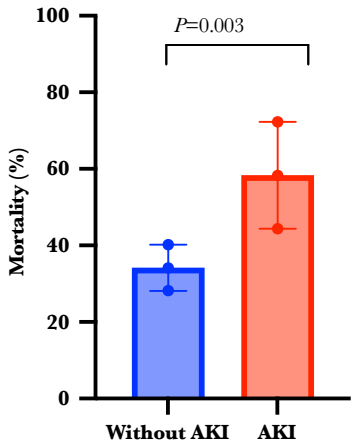
In this study, the risk factors associated with the development of acute kidney injury in patients with severe COVID-19 who were admitted to the intensive care unit of the Pablo Arturo Suárez Hospital in Ecuador were investigated, revealing that 16.3% (95% CI 12.1%-20.6%) presented with acute kidney injury. Additionally, the presence of comorbidities and the male sex are risk factors for the development of acute kidney injury, whereas the female sex is a protective factor.

The incidence of acute kidney injury reported in the present study was lower than that reported globally. For example, in a study conducted in China with 5,449 patients admitted with a diagnosis of COVID-19, an incidence of acute kidney injury of 36.6% was described [9], whereas in a study from Portugal, the incidence of acute kidney injury was 55.2% (n = 106) [6].

This high variability could be due to population differences and the inclusion criteria because, in the studies cited, patients not only from critical areas but also with a diagnosis of mild COVID-19 were included.

Regarding the characteristics of the population that developed acute kidney injury, male sex was a risk factor, which is consistent with previous studies [6,7 9, 10]. In the present study, 70% of the population was men. It is hypothesized that SARS-CoV-2 enters cells through the protein angiotensin-converting enzyme 2 (ACE 2), found in pulmonary endothelial cells and is highly expressed in men. Uncoded isoforms are found in the testes [4]. Another hypothesis is that high levels of testosterone are associated with better rates of lung function; in contrast, lower levels of testosterone are related to the suppression of the immune system and serine transmembrane protease 2 (TMPRSS 2), which facilitates the entry of SARS-CoV-2 into the cell through angiotensin-converting enzyme 2 (ACE 2) [11], may also be expressed.

Figure 1. Bar graph of mortality rates in intensive care patients with acute kidney injury.



AKI: Acute kidney injury.

Table 2. Laboratory measurements upon admission and discharge of the patient in intensive care.

Variable	Without acute kidney injury n = 246	With acute kidney injury n = 48	*P*
Login parameters			
Interleukin 6 (pg/ml)	30.0 (12.6, 59.6)	21.0 (9.38,42.4)	0.31
Lactic dehydrogenase (IU/l)	842.0 (694.0,1092.0)	855.0 (645.0,1116.0)	0.96
Ferritin (ug/l)	1155.0 (664.0,1650.0)	1232.0 (564.0,1650.0)	0.70
Lymphocytes (k/ml)	0.63 (0.42, 0.94)	0.66 (0.37, 1.12)	0.95
Neutrophils (k/ml)	9.24 (6.4, 11.60)	9.12 (6.79, 12.96)	0.49
Platelets (k/ml)	270.0 (133.3, 371.3)	242.0 (182.5, 319.0)	0.54
Hemoglobin gr/dl	14.5 (13.0, 16.1)	15.1 (13.58, 16.58)	0.22
Hematocrit%	43.4 (39.2, 48.1)	45.0 (41.63, 50.58)	0.09
Neutrophil-lymphocyte index	13.3 (8.49, 21.47)	14.1 (8.46, 24.18)	0.62
Platelet-lymphocyte index	383.0 (99.54, 690.42)	380.0 (205.93, 600.13)	0.71
Control parameters			
Interleukin 6 (pg/ml)	-5.2 (12.6,66.7)	+19.5 (25.1,107.0)	<0.001
Lactic dehydrogenase (IU/l)	-208.0 (512,754.0)	-277.0 (479.0,752.0)	0.56
Ferritin (ug/l)	-35.0 (763.0,1650.0)	+213.0 (438.0,1650.0)	<0.001
Lymphocytes (k/ml)	+0.23(0.54, 1.21)	+0.08 (0.48, 1.38)	0.54
Neutrophils (k/ml)	-1.46 (5.61, 10.63)	+0.76 (7.00, 13.34)	0.001
Platelets (k/ml)	+85.0 (274.0, 459.0)	+ 28.0 (201.5, 380.3)	0.001
Hemoglobin gr/dl	-1.60 (11.3, 14.4)	-2.8 (9.9, 13.9)	0.001
Hematocrit%	-4.4 (34.0, 43.5)	-6.9 (30.0, 41.9)	0.001
Neutrophil-lymphocyte index	-4.2 (5.1, 18.1)	-1.9 (5.3, 26.7)	0.01
Platelet-lymphocyte index	+50 (282.0, 646.3)	-20.0 (228.1, 563.4)	0.001

Table 3. Risk factors for the development of acute kidney injury.

Variable	OR	IC 95%	*P*
Sex female	0.35	0.11–0.98	0.06
Age > 50 years	2.09	0.87–5.20	0.10
Presence of comorbidities	7.56	2.57–27.90	0.0007
Increased serum lactate	1.42	0.88–2.21	0.13
Ferritin	0.99	0.998–1.000	0.17

This protective factor in women is attributed to estrogens because they promote both an innate and adaptive immune response, which leads to rapid elimination of the pathogen. Estrogens are also associated with decreased angiotensin-converting enzyme (ACE 2) receptor expression [11].

On the other hand, concerning age, as described in the studies by Yang Y et al., Zhang G. et al., and Gameiro J et al., the average age was 60 years [6,7 10]. In the present study, the average age in the two groups was 51 years, possibly because the data analyzed corresponded to the beginning of the pandemic when the health systems collapsed, there were not enough beds in intensive care units, so triage of patients should be made where they considered their age and the most significant probability of survival for their admission, which makes our population younger about the data described in the studies mentioned.

Likewise, the presence of comorbidities in this study was statistically significant, considering it a grouped category, increasing the risk of developing acute kidney injury by seven times. A previous meta-analysis showed that comorbidities exceed other factors, such as age and sex, in developing kidney injury [6,9].

Patients with COVID-19 who have metabolic pathologies are more likely to self-complicate. This is due to an imbalance in inflammatory systemic markers associated with inadequate control of chronic diseases, leading to an imbalance in the immune system at the time of infection. Alterations in clinical parameters such as renal function through urea, creatinine, and the glomerular filtration rate have been reported [12].

In addition, alterations in the microvasculature cause hemodynamic alterations, including decreased renal blood flow, which increases these patients' susceptibility to developing acute kidney injury [13].

The other variables analyzed in this study include hematic biometry, which highlights the high hematocrit values in the group that developed acute kidney injury, which could be caused by dehydration situations that patients with COVID-19 may have presented thoughtfully. It is known that acute kidney injury may have a prerenal origin characterized by hypoperfusion, which leads to a decrease in glomerular filtration as an adaptive response to volume depletion, among other causes, which would explain the importance of these parameters for patient management [14].

On the other hand, the absolute counts of leukocytes with lymphoid depletion and thrombocytopenia are the primary altered hematological markers in patients with COVID-19. The analysis of this

variable type is vital since the persistence of lymphopenia, considering the normal range of 1000--3800, is associated with an adverse prognosis [15]. In this group of patients, lymphopenia and platelet deficiency were present in patients who developed acute kidney injury; however, no statistically significant difference was found.

Likewise, infection by SARS-CoV-2 results in hyperactivity of immune system cells, with an increase in several inflammatory markers within these levels of IL-6 [16]. In this context, in our study, an increase in IL-6 was observed in the group that developed acute kidney injury, but no statistically significant difference was found between the groups.

In patients with COVID-19 who develop acute kidney injury, the number of complications increases, and the number of hospitalization days in the intensive care unit increases. According to a meta-analysis, the mean length of stay in the intensive care unit is more significant in patients who develop acute kidney injury, with an average of 15 days. For those who do not have acute kidney injury, it is five days [17]. This increase is due to the need for ventilatory support and replacement therapy for renal function [17].

In this study, the mortality rate in patients with severe COVID-19 who developed acute kidney injury was 58%, and in the group that did not develop acute kidney injury, it was 34%. In a study by Xu H, patients with acute kidney injury had a mortality rate of 38%, whereas patients without acute kidney injury had a 13% mortality rate [18].

This increase in the mortality rate of patients with COVID-19 who develop acute kidney injury may be explained by a combination of complications, such as alterations in the immune response, hypercoagulability, acute tubular necrosis due to dehydration, sepsis and hemodynamic instability during SARS-CoV-2 infection [19].

The study's weaknesses included the patients being from a single center, the data being analyzed at the beginning of the pandemic when the immunization rate was low, and the retrospective sample. Therefore, the study needs to represent the current situation of the disease. Other studies should address these limitations, and later studies should analyze the longitudinal progression from acute kidney injury to chronic kidney failure.

Conclusions

Acute kidney injury occurred in 16.3% of patients with severe COVID-19 admitted to an intensive care unit. Male sex and the presence of comorbidities are strongly associated with risk factors in patients with severe COVID-19 who develop acute kidney injury, unlike female sex, which is a protective factor. The complications associated with acute kidney injury in patients diagnosed with COVID-19 include an increase in the number of days in the hospital and high mortality.

Abbreviations

AKI: Acute kidney injury.

Supplementary information

The supplementary materials have yet to be declared.

Acknowledgments

Does not apply.

Authors' contributions

María Isabel León Baquero: Conceptualization, methodology, research, Writing - Original draft.
Ramiro Iván López Pulles: Conceptualization, research, acquisition of funds, data curation, software, resources.
María Gabriela Cobo Jaramillo: Conceptualization, Project management, Supervision, validation, visualization, Writing - review and edition.
All the authors read and approved the final version of the manuscript.

Financing

The study was self-financed by the authors.

Availability of data or materials

Does not apply.

Declarations

Ethics committee approval and consent to participate

The research protocol was approved by the Ethics Committee of the Faculty of Medical Sciences of the University of Central del Ecuador in December 2019 in Quito-Ecuador.

Consent for publication

It does not apply when specific images, radiographs, or photographs of patients are not published.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Author information

María Isabel León Baquero, Doctor of Medicine and Surgery from the Central University of Ecuador (Quito, 2007). Master of Occupational Safety and Health from the Central University of Ecuador (Quito, 2015). Master of health management for local development from the Private Technical University of Loja (Loja, 2018). Specialist in nephrology from the Central University of Ecuador (Quito, 2023).

ORCID https://orcid.org/0009-0007-2056-1445

Ramiro Iván López Pulles, Doctor of Medicine and Surgery from the Central University of Ecuador (Quito, 2004). Specialist in Basic Biomedical Sciences from the Central University of Ecuador (Quito, 2004). A higher fourth-level diploma in local development and health was obtained from the Private Technical University of Loja (Loja, 2005). Specialist in health management and strategic planning at the Private Technical University of Loja (Loja, 2005).

ORCID https://orcid.org/0000-0002-5216-9241

María Gabriela Cobo Jaramillo, Surgeon from the Pontifical Catholic University of Ecuador (Quito, 2009). Specialist in nephrology at Severo Ochoa University Hospital (Madrid, 2015). Doctor in the Biomedical Sciences program from the Complutense University of Madrid (Madrid, 2017).

ORCID https://orcid.org/0000-0001-6930-4174

References

1. Khwaja A. KDIGO clinical practice guidelines for acute kidney injury. Nephron Clin Pract. 2012;120(4):c179-84. doi: 10.1159/000339789. Epub 2012 Aug 7. PMID: 22890468.

2. Wang HE, Muntner P, Chertow GM, Warnock DG. Acute kidney injury and mortality in hospitalized patients. Am J Nephrol. 2012;35(4):349-55. doi: 10.1159/000337487. Epub 2012 Apr 2. PMID: 22473149; PMCID: PMC3362180.

3. Wang X, Sahu KK, Cerny J. Coagulopathy, endothelial dysfunction, thrombotic microangiopathy and complement activation: potential role of complement system inhibition in COVID-19. J Thromb Thrombolysis. 2021 Apr;51(3):657-662. doi: 10.1007/s11239-020-02297-z. Epub 2020 Oct 15. PMID: 33063256; PMCID: PMC7561230.

4. Cheng Y, Luo R, Wang K, Zhang M, Wang Z, Dong L, Li J, Yao Y, Ge S, Xu G. Kidney disease is associated with in-hospital death of patients with COVID-19. Kidney Int. 2020 May;97(5):829-838. doi: 10.1016/j.kint.2020.03.005. Epub 2020 Mar 20. PMID: 32247631; PMCID: PMC7110296.

5. Li Q, Zhang T, Li F, Mao Z, Kang H, Tao L, Zhou F, Cai Y. Acute Kidney Injury Can Predict In-Hospital Mortality in Elderly Patients with COVID-19 in the ICU: A Single-Center Study. Clin Interv Aging. 2020 Nov 9;15:2095-2107. doi: 10.2147/CIA.S273720. PMID: 33204075; PMCID: PMC7666828.

6. Gameiro J, Fonseca JA, Oliveira J, Marques F, Bernardo J, Costa C, Carreiro C, Braz S, Lopes JA. Acute kidney injury in hospitalized patients with COVID-19: A Portuguese cohort. Nefrologia (Engl Ed). 2021 Nov-Dec;41(6):689-698. doi: 10.1016/j.nefroe.2022.01.007. PMID: 36165158; PMCID: PMC8800378.

7. Zhang G, Hu C, Luo L, Fang F, Chen Y, Li J, Peng Z, Pan H. Clinical features and short-term outcomes of 221 patients with COVID-19 in Wuhan, China. J Clin Virol. 2020 Jun;127:104364. doi: 10.1016/j.jcv.2020.104364. Epub 2020 Apr 9. PMID: 32311650; PMCID: PMC7194884.

8. Bowe B, Cai M, Xie Y, Gibson AK, Maddukuri G, Al-Aly Z. Acute Kidney Injury in a National Cohort of Hospitalized US Veterans with COVID-19. Clin J Am Soc Nephrol. 2020 Dec 31;16(1):14-25. doi: 10.2215/CJN.09610620. Epub 2020 Nov 16. PMID: 33199414; PMCID: PMC7792643.

9. Hirsch JS, Ng JH, Ross DW, Sharma P, Shah HH, Barnett RL, Hazzan AD, Fishbane S, Jhaveri KD; Northwell COVID-19 Research Consortium; Northwell Nephrology COVID-19 Research Consortium. Acute kidney injury in patients hospitalized with COVID-19. Kidney Int. 2020 Jul;98(1):209-218. doi: 10.1016/j.kint.2020.05.006. Epub 2020 May 16. PMID: 32416116; PMCID: PMC7229463.

10. Yang X, Yu Y, Xu J, Shu H, Xia J, Liu H, Wu Y, Zhang L, Yu Z, Fang M, Yu T, Wang Y, Pan S, Zou X, Yuan S, Shang Y. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. Lancet Respir Med. 2020 May; 8 (5): 475-481. doi: 10.1016/S2213-2600 (20) 30079-5. Epub 2020 Feb 24. Erratum in: Lancet Respir Med. 2020 Apr; 8 (4): e26. doi:10.1016/S2213-2600(20)30103-X . PMID: 32105632; PMCID: PMC7102538.

11. Ya'qoub L, Elgendy IY, Pepine CJ. Sex and gender differences in COVID-19: More to be learned! Am Heart J Plus. 2021 Mar;3:100011. doi: 10.1016/j.ahjo.2021.100011. Epub 2021 Apr 14. PMID: 34169297; PMCID: PMC8045422.

12. Zhu X, Yang L, Huang K. COVID-19 and Obesity: Epidemiology, Pathogenesis and Treatment. Diabetes Metab Syndr Obes. 2020 Dec 14;13:4953-4959. doi: 10.2147/DMSO.S285197. PMID: 33363393; PMCID: PMC7753883.

13. 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 Dec 6;8:719472. doi: 10.3389/fmed.2021.719472. PMID: 34938742; PMCID: PMC8685316.

14. Lameire NH, Bagga A, Cruz D, De Maeseneer J, Endre Z, Kellum JA, Liu KD, Mehta RL, Pannu N, Van Biesen W, Vanholder R. Acute kidney injury: an increasing global concern. Lancet. 2013 Jul 13;382(9887):170-9. doi: 10.1016/S0140-6736(13)60647-9. Epub 2013 May 31. PMID: 23727171.

15. Madrigal-Rojas JP, Quesada-Loría M, García-Sánchez M, Solano-Chinchilla A. SARS CoV-2, manifestaciones clínicas y consideraciones en el abordaje diagnóstico de COVID-19. Revista Médica de Costa Rica y Centroamérica. 2021;86(629):13-21. medigraphic.101548

16. Gabarre P, Dumas G, DuPont T, Darmon M, Azoulay E, Zafrani L. Acute kidney injury in critically ill patients with COVID-19. Intensive Care Med. 2020 Jul;46(7):1339-1348. doi: 10.1007/s00134-020-06153-9. Epub 2020 Jun 12. PMID: 32533197; PMCID: PMC7290076.

17. Lowe R, Ferrari M, Nasim-Mohi M, Jackson A, Beecham R, Veighey K, Cusack R, Richardson D, Grocott M, Levett D,

Dushianthan A; University Hospital Southampton Critical Care Team and the REACT COVID investigators. Clinical characteristics and outcome of critically ill COVID-19 patients with acute kidney injury: a single center cohort study. BMC Nephrol. 2021 Mar 15;22(1):92. doi: 10.1186/s12882-021-02296-z. PMID: 33722189; PMCID: PMC7957445.

18. Xu J, Xie J, Du B, Tong Z, Qiu H, Bagshaw SM. Clinical Characteristics and Outcomes of Patients With Severe COVID-19 Induced Acute Kidney Injury. J Intensive Care Med. 2021 Mar;36(3):319-326. doi: 10.1177/0885066620970858. Epub 2020 Dec 3. PMID: 33267722.

19. Chiappelli F, Khakshooy A, Greenberg G. CoViD-19 Immunopathology and Immunotherapy. Bioinformation. 2020 Mar 31;16(3):219-222. doi: 10.6026/97320630016219. PMID: 32308263; PMCID: PMC7147500.

DOI: Digital Object Identifier. **PMID**: PubMed Identifier.

Editor's Note

REV SENs remain neutral concerning jurisdictional claims on published maps and institutional affiliations.