Does ABO Blood Groups Affect Outcomes in Hospitalized COVID-19 Patients?

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Abstract

Background: Blood group type A has been associated with increased susceptibility for coronavirus disease 2019 (COVID-19) infection when compared to group O. The aim of our study was to examine outcomes in hospitalized COVID-19 patients among blood groups A and O.

Methods: This is an observational study. Kruskal-Wallis and Chi-square tests were used to compare continuous and categorical variables. Multivariable logistic regression models were used to examine association of blood groups with rates of mortality and severity of disease. All adult patients (> 18 years) admitted with COVID-19 infection between March 1, 2020 and March 10, 2021 at a large community hospital in Northeast Georgia were included. We compared mortality, severity of disease (use of mechanical ventilation, vasopressor, and acute renal failure), rates of venous thromboembolism and inflammatory markers between the blood groups. We used multivariable logistic regression model to adjust for demographical and clinical characteristics, use of COVID-19 medications and severity.

Results: A total of 3,563 of 5,204 admitted patients had information on blood groups. Of these, 1,301 (36.5%) were group A, 377 (10.6%) were group B, 133 (3.7%) were group AB and 1,752 (49.2%) were group O. On adjusted analysis, there were no significant differences in rates of intensive care unit (ICU) admissions, mechanical ventilation, vasopressors, acute renal failure, venous thromboembolism and readmission rate between the blood groups A and O. In-hospital mortality was also not statistically different among the blood groups A and O (17.5% vs. 20.1%; P = 0.07). On adjusted analysis, in-hospital mortality was not lower in blood groups O (odds ratio (OR): 1.06; 95% confidence interval (CI): 0.80 - 1.40, P = 0.70).

Conclusions: Once hospitalized with COVID-19 infection, blood groups A and O are not associated with increased severity or in-hospital mortality.

Introduction

Blood group O has been reported to be at lower risk of certain disease like diabetes mellitus, atherosclerosis, cardiac disease and certain infections due to certain underlying molecular traits [1-6]. In the beginning of this pandemic, Zhao et al reported lower risk of blood group O as compared to non-O population [7]. This was followed by GWAS study identifying a 3p21.31 gene cluster as a genetic susceptibility locus in patients with coronavirus disease 2019 (COVID-19) with respiratory failure [8]. They reported association of signal at locus 9q34.2 with ABO blood group locus and higher risk in blood group A and a protective effect in blood group O when compared to other blood groups. Pare et al had earlier showed similar observation that 9q34.2 locus was associated with plasma soluble intercellular adhesion molecule 1 (sICAM-1) concentration, a molecule involved in leucocytes recruitment in inflammatory disease, which has been associated with other disease processes like acute myocardial infarction, diabetes and stroke [4]. Whether these associations

Key Points

• Question: Does blood group types affect outcomes in hospitalized COVID-19 patients?
• Findings: In this observational study of 3,563 patients, there were no significant differences in rates of mechanical ventilation, use of vasopressors, acute kidney injury requiring hemodialysis, in-hospital mortality or rates of readmission between the blood group types.
• Meaning: Once hospitalized, blood group subtypes are not associated with increased risk for severity of disease or in-hospital mortality in COVID-19 infection.
result in clinically worse outcomes with different blood groups has been debated. Multiple observational studies reported increased risk and worse outcome in blood group A as compared to blood group O; however, many other observational studies did not find any significant differences [9-15].

We studied hospitalized COVID-19 patients and examined relationship between the blood groups and in-hospital mortality and severity of this disease.

Materials and Methods

Study design and data source

We performed a retrospective analysis of adult COVID-19 patients (age ≥ 18 years) admitted to a large community hospital in a rural setting in Northeast Georgia between March 1, 2020 and March 10, 2020. COVID-19 patients were identified from our Epic© electronic medical record (EMR) using International Classification of Disease, 10th Revision, Clinical Modification (ICD-10-CM) and/or Current Procedural Terminology (CPT) codes for COVID-19 infection and/or positive COVID-19 polymerase chain reaction (PCR) testing. We obtained clinical and demographical details from Epic© Caboodle data warehouse and Cerner Acute Physiology and Chronic Health Enquiry Score (APACHE®) Outcomes. Systems integration was provided by IPC Global by leveraging their in-process data factory innovation running on an Amazon Web Services (AWS®) VPC. We excluded COVID-19 patients who required readmission to the hospital after initial discharge. The study was reviewed and found exempt by the Northeast Georgia Health System Institutional Review Board (IRB); and this study was conducted in compliance with the ethical standards of the responsible institution on human subjects as well as with the Helsinki Declaration.

Outcomes

Our primary outcome of interest was in-hospital mortality. We also determined the association of blood groups with severity of COVID-19 infection. We defined COVID-19 infections as severe if patients required invasive mechanical ventilation (IMV), vasopressor support (shock) or had acute kidney injury (AKI) requiring hemodialysis. We also used 4C score as an additional severity score. We compared inflammatory markers (ferritin, C-reactive protein (CRP), lactate dehydrogenase (LDH), fibrinogen, and D-dimer) along with rates of venous thromboembolism (VTE), and readmissions within the blood groups.

Statistics

We described categorical data using frequency count and percentages. We reported medians and inter quartile ranges for continuous variables as they were not normally distributed. We compared categorical variables using Chi-square tests and continuous variables with Kruskal-Wallis tests. For all analyses we deemed statistical significance a P value < 0.05.

We developed multivariable logistic regression models to examine differences in blood groups for rates of mortality or severity of COVID-19 infection. This was adjusted for the confounders of age, gender, comorbidities, use of COVID-19 medications (steroids, remdesivir, hydroxychloroquine and tocilizumab), organ failures (IMV, AKI and shock), 4C score [16] and complications such as acute VTE, blood transfusions and hospital-acquired infections. We checked variables used in the final model for multicollinearity using tolerance and variance inflation factor (Supplementary Material 1, www.thejh.org). These models were bootstrapped using 2,000 bootstrap replicates and case resampling with replacement from the original dataset. All analyses were done in STATA/MP ver. 16.0.

Results

Of 5,204 patients admitted with COVID-19 infection, blood group data were available for 3,563 patients. Of these, 1,301 (36.5%) were group A, 377 (10.6 %) were group B, 133 (3.7%) were group AB and 1,752 (49.2%) were group O.

The demographical and clinical characteristics of patient according to ABO blood groups are shown in Tables 1 and 2. The groups were well matched in terms of age and gender but were different in their racial distribution. Amongst comorbidities present on admissions, end-stage renal disease (ESRD) was observed to be higher in blood group O while VTE was found to be higher in blood group A.

Most COVID-19 medication except steroids and remdesivir were distributed unequally among the blood group type. However, when comparing only blood groups A and O, the use of steroids was not statistically different. Severity of COVID-19 as per 4C score was similar in all groups.

The rates of intensive care unit (ICU) admission were similar among the blood groups. However, blood group O had significantly higher rates of IMV (those admitted to ICU) (60.1% vs. 48.9%, P = 0.001), and vasopressor use (56% vs. 48.2%, P = 0.016) when compared to blood group A. Once on IMV, use of paralytic or inhaled vasodilators and the duration of IMV were not different between the blood groups. Rates of tracheostomy were not significantly different in various blood groups A and O, but were observed to be significantly higher in group AB.

Rates of acute stroke or intracerebral hemorrhage (ICH), AKI (with and without hemodialysis) and health care-associated infections (HAIs) were not significantly different between the blood groups (Table 3). However, rates of VTE were significantly higher in blood group AB. There was no difference in VTE between blood groups A and O (5.7% vs. 6.6%, P = 0.32). Rates of blood transfusions were significantly higher in blood group O.

In-hospital mortality was significantly higher in blood group B (A: 17.5%, B: 20.4%, AB: 11.3% and O: 20.1%; P = 0.03). Length of stay in survivors and length of stay in those who died was not significantly different between the blood groups (Table 3).

Initial levels of inflammatory markers were not significantly different within the blood groups (Table 4). However,
blood groups AB and O had significantly higher levels of ferritin during the admission.

**Regression models**

On adjusted analysis, in-hospital mortality was not significantly different among the blood groups A, B and O (Table 5). The odds were lower in blood group AB (odds ratio (OR) 0.32; 95% confidence interval (CI): 0.11 - 0.96, P = 0.04); however, the sample size of this group was the lowest. We did not observe any significant difference in rates of ICU admissions, IMV, AKI, VTE, vasopressor use and readmissions between the blood groups. Rh-positive status was also not associated

| Table 1. Demographical and Clinical Characteristics of COVID-19 Patients According to ABO Groups |
|---------------------------------|--------|--------|--------|--------|--------|
|                                | A      | B      | AB     | O      | P      |
| Total                          | 1,301  | 377    | 133    | 1,752  |        |
| Age, median (IQR)              | 67 (54 - 77) | 67 (52 - 78) | 68 (53 - 77) | 66 (52 - 76) | 0.20  |
| Male (%)                       | 53.8   | 52.8   | 54.9   | 50.3   | 0.23   |
| Race (%)                       |        |        |        |        | < 0.001|
| White                          | 81.8   | 58.4   | 68.4   | 67.4   |        |
| Blacks                         | 5      | 18.6   | 15.0   | 8.3    |        |
| Hispanics                      | 10.8   | 13.5   | 9.0    | 20.5   |        |
| Asians/Pacific Islander        | 1.1    | 5.8    | 2.2    | 1.3    |        |
| Not answered                   | 1.4    | 3.7    | 5.3    | 2.5    |        |
| Rh positive                    | 89.5   | 89.4   | 88.7   | 91.2   | 0.33   |
| BMI                            | 30.3   | 30.6   | 29.7   | 30.2   | 0.58   |
| Comorbidities (%)              |        |        |        |        |        |
| Hypertension                   | 74.6   | 76.4   | 69.9   | 72.1   | 0.17   |
| Congestive heart failure       | 33.2   | 39.5   | 33.8   | 35.1   | 0.15   |
| Diabetes mellitus              | 48.7   | 49.1   | 45.1   | 45.0   | 0.17   |
| COPD                           | 38.5   | 38.9   | 32.3   | 37.7   | 0.54   |
| ESRD                           | 3.6    | 3.2    | 5.3    | 6.3    | 0.003  |
| Cirrhosis                      | 13.1   | 13.0   | 15.8   | 12.8   | 0.81   |
| Cancer                         | 14.6   | 12.2   | 12.0   | 13.8   | 0.58   |
| VTE                            | 8.1    | 7.7    | 11.3   | 5.2    | 0.002  |
| Medications                    |        |        |        |        |        |
| Anticoagulation                | 14.1   | 13.5   | 15.0   | 12.9   | 0.73   |
| Aspirin                        | 17.9   | 16.7   | 18.1   | 16.8   | 0.86   |
| ACEI                           | 30.6   | 28.1   | 30.8   | 29.0   | 0.7    |
| Statins                        | 33.6   | 30.2   | 26.5   | 30.6   | 0.16   |
| COVID-19 medications (%)       |        |        |        |        |        |
| Hydroxychloroquine             | 3.3    | 4.5    | 5.3    | 4.3    | 0.42   |
| Tocilizumab                    | 6.6    | 9.3    | 6.0    | 7.8    | 0.28   |
| Steroids                       | 71.2   | 74.8   | 80.4   | 68.8   | 0.006  |
| Convalescent plasma            | 37.9   | 35.5   | 43.6   | 35     | 0.11   |
| Remdesivir                     | 60.9   | 61.5   | 63.2   | 55.1   | 0.003  |
| Anticoagulation                |        |        |        |        | 0.08   |
| Standard                       | 54.8   | 53.1   | 53.4   | 54.3   |        |
| High                           | 33.6   | 33.4   | 39.9   | 31.6   |        |
| 4C score                       | 11 (7 - 14) | 11 (7 - 14) | 11 (7 - 13) | 11 (7 - 14) | 0.47   |

COVID-19: coronavirus disease 2019; IQR: interquartile range; BMI: body mass index; COPD: chronic obstructive pulmonary disease; ESRD: end-stage renal disease; VTE: venous thromboembolism; ACEI: angiotensin-converting enzyme inhibitor.
Discussion

Published experience suggests that people with blood group A are genetically more susceptible to COVID-19 and maybe hospitalized more frequently [8]. Whether this phenomenon translates to worse outcomes in these individuals is currently debated. We did not observe increased likelihood of death and developing severe disease in COVID-19 according to blood groups in about 3,500 patients. The levels of inflammatory markers, rates of IMV, AKI, VTE and degree of shock also did not differ significantly between blood groups. The rates of readmissions also did not vary significantly within the groups.

| Table 3. Outcomes of Hospitalized COVID-19 Patients According to ABO Groups |
| A | B | AB | O | P |
|---|---|---|---|---|
| In-hospital mortality (%) | 17.5 | 20.4 | 11.3 | 20.1 | 0.03 |
| 28-day mortality (%) | 16.4 | 18.6 | 9.6 | 18.8 | 0.04 |
| LOS in survivors (in days), median (IQR) | 5 (3 - 11) | 6 (4 - 12) | 6 (3 - 15) | 6 (3 - 11) | 0.09 |
| Time to death (in days), median (IQR) | 14 (7 - 24) | 14 (8.5 - 27.5) | 24 (8 - 39) | 14 (7 - 22) | 0.52 |
| Disposition (%) | 0.20 |
| Home | 62.0 | 62.4 | 54.7 | 63.4 |
| Home with health | 20.9 | 20.0 | 22.2 | 19.5 |
| Rehab/SNF/LTAC/acute care | 15 | 15.6 | 17.1 | 13.7 |
| Others | 2.1 | 2.0 | 6 | 3.5 |
| Readmission | 16.4 | 17.3 | 17.8 | 16.3 | 0.95 |
| Complications (%) | | | | |
| Acute stroke | 2.3 | 4.0 | 5.3 | 2.7 | 0.11 |
| Acute ICH | 1.1 | 2.7 | 1.5 | 1.2 | 0.14 |
| Acute kidney injury | 18.2 | 19.9 | 18.8 | 21.9 | 0.09 |
| Acute kidney injury requiring hemodialysis | 3.1 | 2.6 | 1.5 | 4.5 | 0.19 |
| Acute VTE | 5.7 | 6.9 | 12.0 | 6.6 | 0.04 |
| Blood transfusion | 11.7 | 13.5 | 15.0 | 15.8 | 0.01 |
| HAI | 4.3 | 5.0 | 4.5 | 6.1 | 0.17 |

COVID-19: coronavirus disease 2019; IQR: interquartile range; LOS: length of stay; ICH: intracerebral hemorrhage; SNF: skilled nursing facility; LTAC: long-term acute care; HAI: health care-associated infection.
Persons with blood group O have some basic differences when compared to other blood groups. They have been reported to have 25-30% lower levels of circulating factors VII and von Willebrand factors [2, 17]. There is reported association of variation at the ABO locus with sICAM-1, soluble P-selectin, and soluble E-selectin levels. These molecules are involved in leucocytes recruitment in inflammatory disease and have been associated with risk of atherosclerosis, diabetes and heart diseases [18]. Other associations of lower angiotensin-converting enzyme (ACE) activity in blood group O have been identified [1, 19]. Another genomic study reported increased interleukin-6 (IL-6) levels in blood group O [20]. Ellinghaus et al identified a 3p21.31 gene cluster as a genetic susceptibility locus in patients with COVID-19 with respiratory failure [8]. They reported association of signal at locus 9q34.2 with ABO blood group locus, and higher risk in blood group A, and a protective effect in blood group O, when compared to other blood groups. This has led to slurry of papers on this topic where authors have attempted to study clinical outcomes in COVID-19 as per blood groups.

Leaf et al performed the largest study investigating the predisposition of blood group A with outcomes in critically ill patients [9]. While rates of admission were higher in people with blood group A, the investigators were unable to discern mortality differences. Conversely, Zhao et al observed both higher admission and death rates people in blood group A when compared with group O [7]. A drawback of these studies is the extrapolation of data for their population from surveys and blood donor data. Since surveys and blood donor data predated their studies, they may have resulted in erroneous assumptions for blood group distribution in the local population. Boudin et al did not find differences in symptoms and rates of COVID-19 infection between blood groups, but they did not report outcome differences [21]. Latz et al did not find significant differences in peak inflammatory markers, clinical severity and in-hospital mortality between the blood groups [10]. May et al also did not observe any association of severity and mortality among the blood groups [11]. In a cross-sectional study, Solmaz et al reported higher rate of hospitalization in blood group A in a community in Turkey; however, they did not find increased rate of ICU hospitalization or death among the various blood groups [14].

Muniz-Diaz et al found higher proportion of blood donors with group O in patients who presented for convalescent plas-

### Table 4. Inflammatory Markers in COVID-19 Patients According to ABO Groups

| Inflammatory markers | A (Median, IQR) | B (Median, IQR) | AB (Median, IQR) | O (Median, IQR) | P |
|----------------------|-----------------|-----------------|-----------------|-----------------|---|
| Initial ferritin      | 436 (194 - 868) | 456 (223 - 954) | 544 (253 - 945) | 457 (209 - 987) | 0.13 |
| Initial CRP           | 8 (3 - 13)      | 8 (4 - 14)      | 8 (5 - 14)      | 8 (4 - 14)      | 0.36 |
| Initial LDH           | 318 (240 - 425) | 334 (261 - 471) | 352 (251 - 432) | 324 (244 - 441) | 0.15 |
| Initial D-dimer       | 0.9 (0.5 - 1.7) | 0.9 (0.5 - 1.8) | 0.8 (0.5 - 1.5) | 1 (0.6 - 1.9)   | 0.09 |
| Initial fibrinogen    | 545 (431 - 682) | 559 (453 - 657) | 542 (414 - 704) | 543 (423 - 695) | 0.93 |
| Highest ferritin      | 551 (1,081 - 1,060) | 574 (273 - 1,182) | 696 (304 - 1,210) | 614 (267 - 1,260) | 0.04 |
| Highest CRP           | 9 (4 - 15)      | 10 (5 - 16)     | 10 (6 - 16)     | 10 (5 - 16)     | 0.39 |
| Highest LDH           | 346 (256 - 471) | 375 (277 - 521) | 370 (268 - 458) | 350 (263 - 504) | 0.09 |
| Highest D-dimer       | 1.2 (0.7 - 4)   | 1.3 (0.7 - 4)   | 1.2 (0.6 - 4)   | 1.4 (0.8 - 4)   | 0.06 |
| Highest fibrinogen    | 574 (459 - 721) | 599 (453 - 725) | 572 (440 - 738) | 574 (453 - 725) | 0.93 |

*Median (IQR), total samples. COVID-19: coronavirus disease 2019; CRP: C-reactive protein; LDH: lactate dehydrogenase.*

### Table 5. Comparison Between Blood Groups With Regards to Rates of ICU Transfers, AKI, Acute VTE, Mechanical Ventilation, Use of Vasopressors, In-Hospital Mortality and Readmissions in COVID-19

|                  | B (Odds Ratio, 95% CI) | A (Odds Ratio, 95% CI) | AB (Odds Ratio, 95% CI) | O (Odds Ratio, 95% CI) |
|------------------|------------------------|------------------------|------------------------|------------------------|
| ICU transfer     | 0.74 (0.49 - 1.09)     | 0.62 (0.33 - 1.17)     | 0.14 (0.07 - 0.29)     | 1.01 (0.79 - 1.28)     |
| Acute kidney injury | 0.83 (0.56 - 1.24)   | 0.66 (0.35 - 1.25)     | 0.20 (0.06 - 0.63)     | 1.01 (0.78 - 1.29)     |
| Acute VTE        | 1.07 (0.63 - 1.78)     | 2.25 (1.18 - 4.29)     | 0.014 (0.01 - 0.10)    | 1.05 (0.75 - 1.46)     |
| Mechanical ventilation | 1.06 (0.59 - 1.90) | 1.16 (0.48 - 2.79)     | 0.72 (0.31 - 1.64)     | 1.35 (0.92 - 1.99)     |
| Pressor use      | 1.28 (0.72 - 2.29)     | 0.58 (0.21 - 1.64)     | 0.31 (0.14 - 0.70)     | 0.82 (0.57 - 1.29)     |
| In hospital mortality | 1.03 (0.66 - 1.59) | 0.34 (0.12 - 0.96)     | 0.04 (0.01 - 0.31)     | 1.05 (0.79 - 1.39)     |
| Readmission      | 1.12 (0.78 - 1.58)     | 1.39 (0.81 - 2.39)     | 0.22 (0.10 - 0.49)     | 1.04 (0.83 - 1.31)     |

A is the comparison group. The regression adjusts for age, gender, race, comorbidities, clinical characteristics, inflammatory markers, 4C score and COVID-19 medications including anticoagulation status. The model was bootstrapped 2,000 times with replacement. The values shown are odds ratio (95% confidence interval), P value. ICU: intensive care unit; AKI: acute kidney injury; VTE: venous thromboembolism; COVID-19: coronavirus disease 2019.
ma donations [22]. They also found higher mortality in blood group A as compared to O in patients receiving convalescent plasma. This was suggested to be a sign that blood group O was more likely to be affected. However, Gallian et al found lower seropositive rates in blood group O in 998 samples, and suggested that patients with blood group O are less likely to be infected [23]. Given limitations of testing neutralizing antibodies, extrapolation from these studies may not reflect true relationship between incidence and disease outcomes. In another large population-based cohort study, Ray et al reported lower risk for COVID-19 in blood group O when compared to others (A, B and AB together); however, they did not find any difference in risk when they compared only blood groups A and O [24]. Similarly, they reported lower risk of COVID-19 in blood group O when compared to all other (A, B and AB together), but did not find any differences in severity between blood groups A and O. Blood group B appeared to be at highest risk for COVID-19 and its severity.

Although a genome wide association study found that people with blood group A were predisposed to respiratory failure, in our study, patients with blood group A has similar rates and duration of IMV as compared to other blood groups [8]. Similarly, use of prone-positioning, paralytics and inhaled vasodilators were not different between blood groups. The length of mechanical ventilation and use of tracheostomy were also not different. In 1,732 ICU patients admitted for non-COVID-19 causes, ABO blood groups did not correlate with ICU mortality and ICU length of stay [25].

One possible explanation for finding no relationship between severity and mortality with ABO groups may be presence of other genetic associations with severe COVID-19, which are not related to the locus of the blood group types. In a study to examine the genome-wide association, GenOMICC study found many new associations with severity of COVID-19 [26]. They reported multiple other associations such as chromosome 12q24.13 (encodes antiviral restriction enzyme activators), chromosome 19p13.2 (encodes tyrosine kinase 2), chromosome 19p13.3 (encodes dipeptidyl peptidase 9) and chromosome 21q22.1 (encodes interferon receptor IFNAR2). Gavrilaki et al reported ADAMTS13 variants which were associated with increased risk for severity of disease or in-hospital mortality, once COVID-19 patients are admitted to hospital. Larger prospective observational studies may help confirm our findings.

Conclusions

Despite these limitations, our study provides additional data to this topic. We conclude that blood groups are not associated with increased risk for severity of disease or in-hospital mortality, once COVID-19 patients are admitted to hospital. Larger prospective observational studies may help confirm our findings.

Supplementary Material

Suppl 1. Evaluating for multicollinearity using collin function in STATA.
Suppl 2. Comparison between Rh groups with regards to rates of ICU transfers, AKI, acute VTE, mechanical ventilation, use of vasopressors, in-hospital mortality and readmissions in COVID-19 (Rh negative is the comparison group).

Acknowledgments

None to declare.

Financial Disclosure

None to declare.

Conflict of Interest

The authors declare no conflict of interest.

Informed Consent

The IRB had reviewed this retrospective study and have waived the requirement of an informed consent. It was based on the following criteria: no patient identifying data is being published, no patient interaction was involved and no patient intervention was done during the course of this retrospective study.
Author Contributions

Gagan Kumar MD: study design, data analysis, and manuscript writing; Mark Meersman CPA: data validation; Drew Dalton BS: data validation; Dhaval Patel MD: study design and manuscript writing; Rahul Nanchal MD: study design, data analysis, and manuscript writing; Ankit Sakhuja: study design, data analysis, and manuscript writing; Martin Hererra: manuscript writing; Achuta Kumar Guddati MD: study design, data analysis, and manuscript writing.

Data Availability

Any inquiries regarding supporting data availability of this study should be directed to the corresponding author.

Abbreviations

OR: odds ratio; CI: confidence interval; AWS: Amazon Web Services; EMR: electronic medical record; APACHE score: Acute Physiology and Chronic Health Enquiry score; ICD-10-CM: International Classification of Disease, 10th Revision, Clinical Modification; CPT: Current Procedural Terminology; ICU: intensive care unit; AKI: acute kidney injury; CRP: C-reactive protein; LDH: lactate dehydrogenase; VTE: venous thromboembolism; IMV: invasive mechanical ventilation; SNF: skilled nursing facility; LTAC: long-term acute care

References

1. Luo JQ, He FZ, Luo ZY, Wen JG, Wang LY, Sun NL, Tang GF, et al. Rs495828 polymorphism of the ABO gene is a predictor of enalapril-induced cough in Chinese patients with essential hypertension. Pharmacogenet Genomics. 2014;24(6):306-313.
2. Larson NB, Bell EJ, Decker PA, Pike M, Wassel CL, Tsai MS, Islam MM, Yusuf MA, et al. Association of ABO blood groups with presentation and outcomes of COVID-19 infection in children. J Coll Physicians Surg Pak. 2021;30(1):S57-S59.
3. Mahmud R, Rassel MA, Monayem FB, Sayeed S, Islam MS, Islam MM, Yusuf MA, et al. Association of ABO blood groups with presentation and outcomes of confirmed SARS CoV-2 infection: A prospective study in the largest COVID-19 dedicated hospital in Bangladesh. PLoS One. 2021;16(4):e0249252.
4. Solmaz I, Arac S. ABO blood groups in COVID-19 patients; Cross-sectional study. Int J Clin Pract. 2021;75(4):e13927.
5. Bari A, Ch A, Hareem S, Bano I, Rashid J, Sadiq M. Association of blood groups with the severity and outcome of COVID-19 infection in children. J Coll Physicians Surg Pak. 2021;30(1):S57-S59.
6. Gupta RK, Harrison EM, Ho A, Docherty AB, Knight SR, van Smeden M, Abubakar I, et al. Development and validation of the ISARIC 4C Deterioration model for adults hospitalised with COVID-19: a prospective cohort study. Lancet Respir Med. 2021;9(4):349-359.
7. Jenkins PV, O'Donnell JS. ABO blood group determines plasma von Willebrand factor levels of COVID-19 patients; Cross sectional study. J Thromb Thrombolysis. 2020;49(1):3-9.
8. Severe Covid GG, Ellinghaus D, Degenhardt F, Bujanda L, Buti M, Albillos A, Invernizzi P, et al. Genomewide Association Study of Severe Covid-19 with Respiratory Failure. N Engl J Med. 2020;383(16):1522-1534.
9. Leaf RK, Al-Samkari H, Brenner SK, Gupta S, Leaf DE. ABO phenotype and death in critically ill patients with COVID-19. Br J Haematol. 2020;190(4):e204-e208.
10. Latz CA, DeCarlo C, Boitano L, Png CYM, Patell R, Conrad MF, Eagleton M, et al. Blood type and outcomes in patients with COVID-19. Ann Hematol. 2020;99(9):2113-2118.
11. May JE, McGwin G Jr., Gangaraju R, Paschral R, Weaver K, Lima JLO, Marques MB. Questioning the association between ABO type and outcomes in patients with COVID-19. Ann Hematol. 2020.
12. Wu BB, Gu DZ, Yu JN, Yang J, Shen WQ. Association between ABO blood groups and COVID-19 infection, severity and demise: A systematic review and meta-analysis. Genet Evol. 2020;84:104485.
13. Bari A, Hareem S, Bano I, Rashid J, Sadiq M. Association of blood groups with the severity and outcome of COVID-19 infection in children. J Coll Physicians Surg Pak. 2021;30(1):S57-S59.
14. Galewicz B, Charytan B, Charytan M, Furey W, Nogueira G, Sheps SM, Jaffe JS, et al. ABO blood group and outcome of COVID-19: a systematic review and meta-analysis. Bmc Med. 2020;18(1):167.
15. Kiechl S, Pare G, Barbatic M, Qi L, Dupuis J, Dehghan A, Bis JC, et al. Association of variation at the ABO locus with circulating levels of soluble intercellular adhesion molecule-1, soluble P-selectin, and soluble E-selectin: a meta-analysis. Circ Cardiovasc Genet. 2011;4(6):681-686.
16. Gasso P, Ritter MA, Mas S, Lafuente A. Influence of ABO genotype and phenotype on angiotensin-converting enzyme plasma activity. J Renin Angiotensin Aldosterone Syst. 2014;15(4):580-584.
17. Jenkins PV, O'Donnell JS. ABO blood group determines plasma von Willebrand factor levels of COVID-19 patients; Cross sectional study. J Thromb Thrombolysis. 2020;49(1):3-9.
18. Severe Covid GG, Ellinghaus D, Degenhardt F, Bujanda L, Buti M, Albillos A, Invernizzi P, et al. Genomewide Association Study of Severe Covid-19 with Respiratory Failure. N Engl J Med. 2020;383(16):1522-1534.
19. Leaf RK, Al-Samkari H, Brenner SK, Gupta S, Leaf DE. ABO phenotype and death in critically ill patients with COVID-19. Br J Haematol. 2020;190(4):e204-e208.
20. Latz CA, DeCarlo C, Boitano L, Png CYM, Patell R, Conrad MF, Eagleton M, et al. Blood type and outcomes in patients with COVID-19. Ann Hematol. 2020;99(9):2113-2118.
21. May JE, McGwin G Jr., Gangaraju R, Paschral R, Weaver K, Lima JLO, Marques MB. Questioning the association between ABO type and outcomes in patients with COVID-19. Ann Hematol. 2020.
associations that underpin its complex regulation. PLoS Genet. 2012;8(1):e1002480.
21. Boudin L, Janvier F, Bylicki O, Dutasta F. ABO blood groups are not associated with risk of acquiring the SARS-CoV-2 infection in young adults. Haematologica. 2020;105(12):2841-2843.
22. Muniz-Diaz E, Llopis J, Parra R, Roig I, Ferrer G, Grifols J, Millan A, et al. Relationship between the ABO blood group and COVID-19 susceptibility, severity and mortality in two cohorts of patients. Blood Transfus. 2021;19(1):54-63.
23. Gallian P, Pastorino B, Morel P, Chiaroni J, Ninove L, de Lamballerie X. Lower prevalence of antibodies neutralizing SARS-CoV-2 in group O French blood donors. Antiviral Res. 2020;181:104880.
24. Ray JG, Schull MJ, Vermeulen MJ, Park AL. Association between ABO and Rh blood groups and SARS-CoV-2 infection or severe COVID-19 illness: a population-based cohort study. Ann Intern Med. 2021;174(3):308-315.
25. Rezooagli E, Gatti S, Villa S, Villa G, Muttini S, Rossi F, Faraldi L, et al. ABO blood types and major outcomes in patients with acute hypoxaemic respiratory failure: A multicenter retrospective cohort study. PLoS One. 2018;13(10):e0206403.
26. Pairo-Castineira E, Clohissey S, Klarc L, Bretherick AD, Rawlik K, Pasko D, Walker S, et al. Genetic mechanisms of critical illness in COVID-19. Nature. 2021;591(7848):92-98.
27. Gavriilaki E, Asteris PG, Touloumenidou T, Koravou EE, Koutra M, Papayanni PG, Karali V, et al. Genetic justification of severe COVID-19 using a rigorous algorithm. Clin Immunol. 2021;226:108726.
28. Niles JK, Karnes HE, Dlott JS, Kaufman HW. Association of ABO/Rh with SARS-CoV-2 positivity: The role of race and ethnicity in a female cohort. Am J Hematol. 2021;96(1):E23-E26.
29. Zalba Marcos S, Antelo ML, Galbete A, Etayo M, Ongay E, Garcia-Erce JA. Infection and thrombosis associated with COVID-19: Possible role of the ABO blood group. Med Clin (Engl Ed). 2020;155(8):340-343.