Journal of Biomedicine and Biochemistry
Volume 1 Issue 3 (2022), pp. 6–14
ISSN:2958-0528

ORIGINAL A R T I C L E

Evaluation of Some Biochemical Markers in Relation to COVID-19 mRNA Vaccine

Meaad Falah Fadhil[1,] and Buthainah Abbas Al-Azzawi[1,*]

[1]Department of Clinical Biochemistry, College of Medicine, University of Al-Qadisiyah, Al Diwaniyah, Iraq

Corresponding author:

buthainah.alazzawi@qu.edu.iq

[1]Department of Clinical Biochemistry, College of Medicine, University of Al-Qadisiyah, Al Diwaniyah, Iraq

Received:September 09, 2022,
Revised:September 16, 2022,
Accepted:September 17, 2022,

DOI: 10.57238/jbb.2022.20105

OPEN ACCESS

Abstract

Background The coronavirus disease 2019 (COVID-19) has become a national pandemic for more than 2 years, and it continues to have an unimaginable impact on our way of life and quality of life. It is critical to gain a deeper understanding of how immunity is regulated in response to SARS-CoV-2 infection. The C-reactive.protein.(CRP) was the first acute phase protein to be identified, and it serves as a highly sensitive systemic indication of tissue damage, infection, as well as inflammation. Smooth muscle cells, lymphocytes, macrophages, endothelial cells, and adipocytes are all involved in the production of this protein. Interleukin.10.(IL-10), commonly described as human.cytokine.synthesis.inhibitory.factor (CSIF). The IL-10 gene in humans produces interleukin 10, a pleiotropic cytokine with strong anti-inflammatory as well as immunosuppressive activities.
The Aim the aim of this study is to evaluate the vaccine effectiveness using diagnostic biochemical markers.
Material and method this study included 125 patients (56 males and 69 females) with vaccinated and non-vaccinated COVID-19 with an age range of 20–70 years. These patients are divided into two main groups: 1. vaccinated (vaccinated with COVID-19 infection, vaccinated without COVID-19 disease, vaccinated recovered from the CoV-19 virus), 2. Unvaccinated (infected with the CoV-19 virus and non-vaccinated, recovered from COVID-19 and unvaccinated). The outcome is measured using the enzyme-linked immunosorbent assay (ELISA) technique. This study was conducted during the period from November 2021 to May 2022 at Al-Shifaa medical center and the vaccine unit at Al-Diwaniyah Educational Hospital, Diwaniyah governorate, Iraq.
Results The results showed an increase in CRP level for the vaccinated groups was significantly higher (P<0.0001) in group G2 (vaccinated with COVID) more than in G1 (vaccinated without COVID) and G3 (vaccinated recovered COVID). For non-vaccinated groups, it was significantly higher (P<0.01) in group G4 (no vaccine with COVID) more than in group G5 (no vaccine recovered COVID). The results also showed that the IL-10 in the 2nd and 4th weeks after vaccination had a higher level in G1 (vaccinated without COVID) and G2 (vaccinated with COVID) than in any other time incident. For G4 (no vaccine with COVID) showed that a significant increase was noticed in the 2nd week after diagnosis more than other time incidents. While G3 (vaccinated recovered COVID), G5 (no vaccine recovered COVID) showed that no significant increase was noticed among the different time incidents.
Conclusion the use of mRNA for CoV-19 vaccination significantly modulates the increment of C-reactive protein and interleukin-10 and improves the immune response in patients with COVID-19 infection.

Keywords: COVID-19, COVID-19 vaccination, C- reactive protein, Interleukin-10.

1 Introduction

The COVID-19 family of viruses includes a diverse range of enclosed, positive-sense, single-stranded RNA viruses. In both animals and humans, they cause a variety of disorders that have varying degrees of severity and disrupt the respiratory, digestive, hepatic, and neurological systems [1]. The messenger RNA (mRNA) vaccine is a form of vaccine that triggers an immunological response by using a copy of the mRNA molecule. Individuals who have taken the COVID-19 vaccine are much less likely than those who have not had it to experience severe symptoms [2].

C-reactive protein (CRP) was the first acute phase protein identified, and it serves as a highly sensitive systemic marker of tissue damage, infection, as well as inflammation [3]. Smooth muscle cells, lymphocytes, macrophages, endothelial cells, and adipocytes are all involved in the production of this protein. During the six hours of acute inflammatory stimuli, it is excreted in large volumes [4]. Interleukin (IL)-6, a pro-inflammatory cytokine, is the principal inducer of its excretion by the liver. CRP is a protein that belongs to the pentraxin family. These proteins are extraordinarily well maintained throughout development and predate the immune response's emergence. Pentraxin has a unique structure made up of five conformable subunits arranged in a cyclic pentamer configuration, which may be seen as a doughnut in electron microscopy [5]. As a result, the CRP concentration is a very useful, non-specific biochemical indicator of inflammation, whose measurement plays a significant role in: (A) investigation for organic disease, (B) observing the response to treating inflammation and infection, (C) identifying concurrent infections in immunocompromised individuals, as well as in few particular diseases characterized by simple or truant acute-phase responses [6].

C-reactive protein (CRP) may be used to early identify pneumonia, and individuals with acute pneumonia showed higher CRP levels [7]. The liver generates high levels of acute-phase proteins (APPs), such as CRP, in response to infections. This highly inflammatory protein is a much more sensitive indicator of inflammation, tissue injury, and infection. CRP levels have been linked to levels of inflammation in several studies [8]. A positive feedback cycle of proinflammatory cytokines known as the cytokine storm occurs in certain individuals with acute COVID-19, which may worsen lung damage and, in rare circumstances, lead to vasodilatory shock and organ failure. Interleukin-6 (IL-6) is a cytokine released by airway macrophages that has been linked to the immunological response to COVID-19 taking on maladaptive forms. The primary signal for the synthesis of CRP is IL-6 [9]. Interleukin 10 (IL-10), commonly known as human cytokine synthesis inhibitory factor (CSIF). The IL-10 gene in humans produces the pleiotropic cytokine il-10, which has strong anti-inflammatory as well as immunosuppressive properties [10]. Initially thought to be produced by T helper 2 cells, IL-10 is now established to be produced by a variety of myeloid as well as lymphoid-derived immune cells involved from both innate immunity and adaptive immunity [10]. The host immune system's response to pathogens as well as microbiota is inhibited by IL-10 upon infection, which reduces immunopathology as well as tissue damage. In order to achieve this, IL-10 inhibits excessive T cell activation and proliferation as well as antigen presentation and the production of pro-inflammatory cytokines in activated monocytes/macrophages, dendritic cells, and other immune cells. The interaction between IL-10 and the IL-10 receptor, which is most abundantly expressed on monocytes and macrophages, stimulates the JAK1-TYK2-STAT3 pathway and causes STAT3 to direct the transcription of genes that suppress the inflammatory reaction [11].

Patients with severe COVID-19 cases frequently exhibit overproduction of pro-inflammatory cytokines that is fueled by excessive immune cell activation (cytokine storm), which is thought to be the cause of mortality [12]. The dramatic early rise in IL-10 – canonically classified as an anti-inflammatory cytokine – appears to be a distinguishing feature of hyperinflammation during severe SARS-CoV-2 infection [13] and several studies indicate that IL-10 levels predict poor outcomes in patients with COVID-19 [14]. Depending on its well-known anti-inflammatory as well as immunosuppressive properties [11], the dramatic increase in IL-10 could be regarded as an attempt to control hyperinflammation as well as protect tissue.

2 Materials and methods

2.1 The Subjects

One hundred and twenty-five subjects participated in this study. All of them attended Al-Shifaa medical center and the vaccine unit at Al-Diwaniyah Educational Hospital. During the period, extending from November 2021 to May 2022, samples were collected from males and females infected with COVID-19 and non-COVID-19 patients, also vaccinated and non-vaccinated from Al-Qadisiyah Governorates. Divided into 5 groups (each group has 25 subjects). The first main group was divided into the following subgroups:

- Group 1: individuals with a positive vaccine for COVID-19. [15]
- Group 2: patients with positive COVID-19 and vaccinated. [15]
- Group 3: patients with recovered COVID-19 and vaccinated. [15]

The second main group was also further subdivided into:

- Group 4: patients with positive COVID-19 but non-vaccinated. [15]
- Group 5: patients with recovered COVID-19 but non-vaccinated. [15]

About 5ml of venous blood was obtained from each participant. Blood samples were left for 15 minutes at room temperature to clot. Ten minutes of centrifugation at 3000 rpm were used to isolate serum after coagulation. Serum was aspirated and divided into small aliquots and the serum was converted into an Eppendorf tube, labeling of the tube, and stored at (-80 °C) until assayed for C – reactive protein and Interleukin-10.

2.2 Statistical Analysis

Data were summarized, analyzed, and presented using GraphPad Prism 9.2.0 and Microsoft Office Excel 2013, presented as mean ± standard deviation. T-test, ANOVA, and correlation analysis were used to measure the degree of significant. P-value was considered significant at (p-value $\leq$0.05).

2.3 Measurement of C-reactive protein as well as Interleukin-10

The sandwich ELISA technique was used to assess serum C-reactive protein [16] as well as interleukin-10 levels [17] using Elabscience (USA) kits.

3 Result

Table 1: Comparison of the clinical and hemodynamic variables for the study groups.

Characteristic	G1 n = 25	G2 n = 25	G3 n = 25	G4 n = 25	G5 n = 25	P
Age (years)						
Mean ± SD	28 ± 4	31±10	30.4±8	34±9	32.4±8.8	NS
Range	20-41	21-45	22-70	20-70	22-70	
Gender						
Male, n (%)	8 (32%)	15 (60%)	11 (44%)	9 (36%)	13 (52%)	NS
Range	20-41	21-45	22-70	20-70	22-70	
BMI[1](kg/m^2)						
Mean ±SD	25± 2	24.7±1.7	25± 3	25.5±2.1	24.3±2	NS
Range	19.9-27.9	21.8-27.2	21-28	21-29	19.9-27.7	

3.1 Estimation of Serum C-reactive protein Concentrations

. The measurement of serum C-reactive protein level (ng/ml) for the vaccinated groups (G1, G2, and G3) showed that the concentration of C-reactive protein was significantly higher (P<0.0001) in group G2 (vaccinated with COVID-19) more than in groups G1 and G3, and also in G3 more than in G1 (P<0.05) as shown in Figure 1.

[1]BMI: Body Mass Index, SD: standard deviation, NS: not significant.

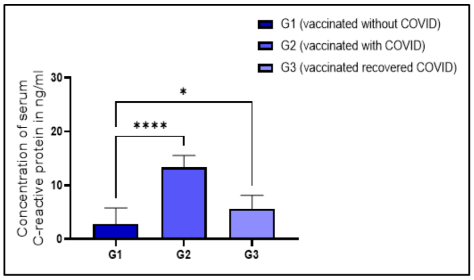

Figure 1: The measurement of serum C-reactive protein level (ng/ml).Group 1 (vaccinated without COVID-19), Group 2(vaccinated with COVID-19) and Group 3 (vaccinated recovered COVID-19). C-reactive protein was significantly higher (P<0.0001) in group G2 (vaccinated with COVID-19) more than group G1 and G3, also in G3 more than G1 (P<0.05).

For non-vaccinated groups (G4 and G5), the C-reactive protein was significantly higher (P<0.01) in group G4 (no vaccine with COVID-19) than in group G5 (no vaccine recovered COVID-19), as shown in Figure 2.

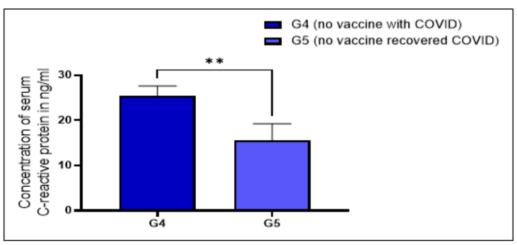

Figure 2: The measurement of serum C-reactive protein level (ng/ml).Group 4 (no vaccine with COVID-19) and Group 5 (no vaccine recovered COVID-19) C-reactive protein was significantly higher (P<0.01) in group G4 (no vaccine with COVID-19) more than group G5 (no vaccine recovered COVID-19).

The level of serum C-reactive protein in ng/ml was significantly lower in G1 than in G2, 4, and 5 (P<0.0001), in addition to G3 (P<0.05).

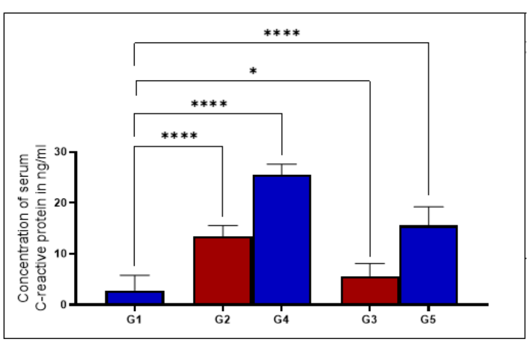

Figure 3: Estimation of C-reactive protein concentrations (ng/ml) for all study. The level of serum C - reactive protein in ng/ml was significantly low in G1 more than G2, 4, and 5 (P<0.0001), in addition to G3 (P<0.05).

The comparison between G2 (vaccinated) and G4 (no-vaccine) showed that G4 has a significantly higher level of serum C-reactive protein. As shown in Figure 4.

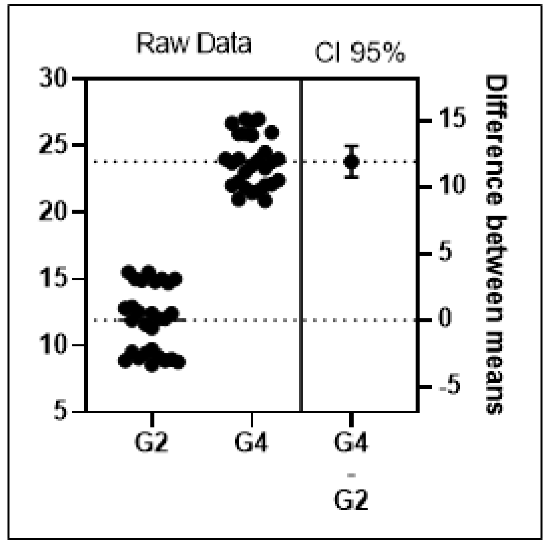

Figure 4: Estimation Plot showing the degree of significant between G2 (vaccinated) and G4 (no-vaccine) G4 has a significantly higher level of serum C - reactive protein.

Also, the comparison between G3 (vaccinated) and G5 (no-vaccine) showed that G5 has a significantly higher level of serum C-reactive protein. As shown in Figure 5.

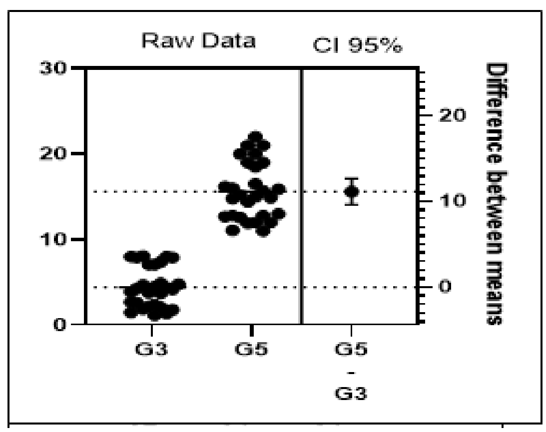

Figure 5: Estimation Plot showing the degree of significant between G3 (vaccinated) and G5 (no-vaccine) G5 has a significantly higher level of serum C - reactive protein.

Studying the difference among different age groups, for G2 and G4, the results showed that non-vaccinated patients have C-reactive protein concentrations significantly higher (P<0.0001) than vaccinated groups at all age groups. However, the (60-70) years old have the highest concentration as compared to other age groups, whether vaccinated or not. As shown in Figure 6.

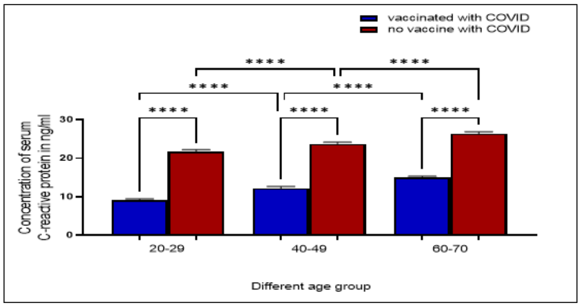

Figure 6: Evaluation of serum C-reactive protein concentration in ng/ml for vaccinated and non-vaccinated patients with COVID-19 infection based on different age groups.

A simillar trend was observed for G3 and G5. The results showed that non-vaccinated patients have C-reactive protein concentrations significantly higher (P<0.0001) than vaccinated groups at all age groups. However, the (60-70) years old have the highest concentration as compared to other age groups, whether vaccinated or not.

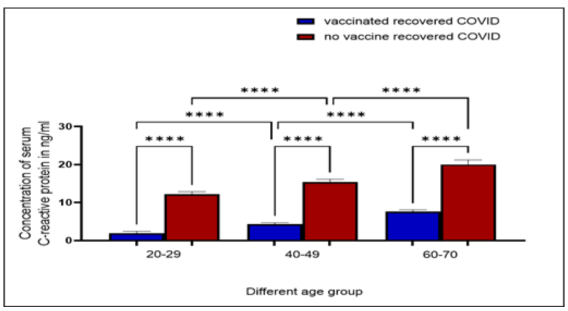

Figure 7: Evaluation of serum C-reactive protein concentration in ng/ml for vaccinated and non-vaccinated patients recovered from COVID-19 infection based on different age groups.

4 Estimation Serum level of IL-10

Measurement of IL-10 concentration in pg/ml for G1, the results showed that the 2nd and 4th weeks after vaccination had a higher level (P<0.01) more than other time incident.

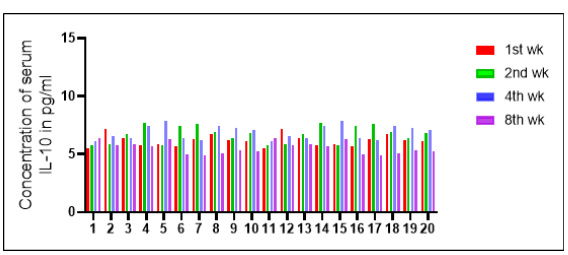

Figure 8: Serum level of IL-10 concentration in pg/ml.

Measurement of IL-10 concentration in pg/ml for G2, the results showed that the 2nd and 4th weeks after vaccination had a higher level (P<0.01) more than other time incident.

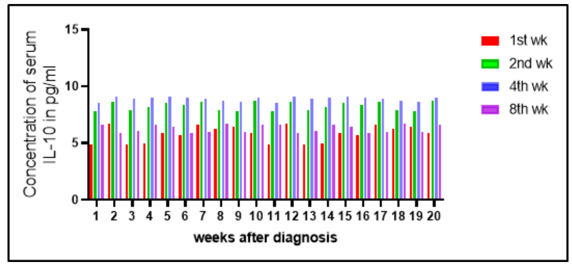

Figure 9: Serum level of IL-10 concentration in pg/ml, G2 (vaccinated with COVID-19)

Measurement of IL-10 concentration in pg/ml for G3 showed that no significant increase was noticed among the different time incidents.

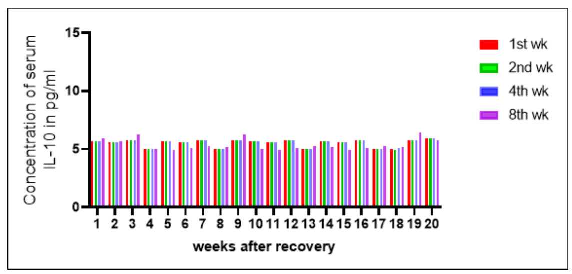

Figure 10: Serum level of IL-10 concentration in pg/ml.

Measurement of IL-10 concentration in pg/ml for G4 showed that a significant increase (P<0.01) was noticed at the 2nd week after diagnosis more than other time incident.

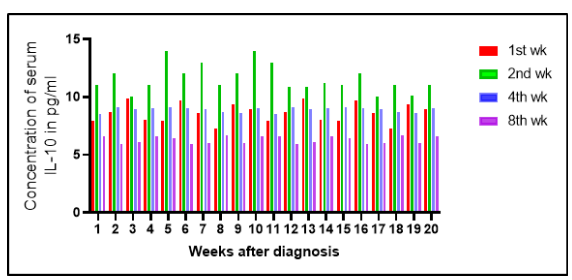

Figure 11: Serum level of IL-10 concentration in pg/ml

Measurement of IL-10 concentration in pg/ml for G5 showed that no significant difference was found among the different time incident.

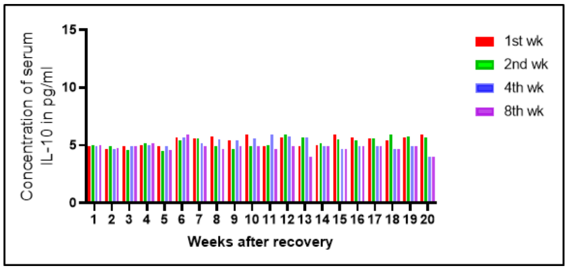

Figure 12: Serum level of IL-10 concentration in pg/ml.

5 Discussion

Estimation of Serum C -reactive protein (CRP)

The present results demonstrated a significant increase in CRP levels in patients with COVID-19 compared to recovery group, and this result agrees with study conducted by S. Saswati Das, V. Shailza, et al., It suggests that the pro-inflammatory marker CRP should be measured in COVID -19 patients as part of their follow-up strategy in order to monitor individuals' recovery [18]. The result by N. Smilowitz, D. Kunichoff, et al., it suggests that CRP, is strongly associated with acute respiratory distress syndrome (ARDS), critical illness, and in-hospital mortality in patients with COVID-19. Inflammatory biomarker-based approaches to risk stratification and treatment should be evaluated to improve outcomes of patients with SARS-CoV-2 infection [19, 20]. Also a significant increase was found in vaccinated with COVID-19 more than vaccinated without COVID-19, and in vaccinated recovered with COVID-19 more than vaccinated without COVID-19, and this result agrees with study conducted by H. Edelman-klapper, E. Zittan, et al., which reveal the CRP was not increased following vaccination [21]. There are no previous studies of CRP levels in people who have been vaccinated or have recovered from COVID-19. CRP was discovered as the first acute-phase protein, and it acts as a highly sensitive general indicator of inflammation, infection, as well as tissue damage [3, 4]. That protein is produced by cells derived from smooth muscle, lymphocytes, endothelial cells, macrophages, and adipose cells [22]. It during 6 hours of inflammatory process stimulation, substantial quantities are ejected [4, 23]. The overproduction of inflammatory cytokines may be responsible for the increased CRP values [24]. Although cytokines work to combat pathogens, lung tissue can be harmed when the immune system is overactive [25]. In COVID-19 patients, tissue damage and inflammatory cytokines both cause CRP production [15, 26].

Estimation of Serum Interleukin 10 (IL-10)

IL-10 is a cytokine that reduces inflammation and keeps the immune system's response in check, enabling infection to be cleared while causing the least amount of host-related harm [27, 28].
In the present result, IL-10 levels were significantly higher at 2nd and 4th weeks after vaccination more than other time incident in group 1 (vaccinated without COVID-19) and group 2 (vaccinated with COVID-19), we did not find any previous research on this topic. My interpretation of these results of elevated IL-10 levels at 2 weeks or longer following may be reflected the typical immunological reaction to reestablish the homeostasis.
In the present result, showed that no significant increase was noticed among the different time incident in IL-10 levels in recovery individual with or without vaccine, IL-10 is a crucial part of the cytokine system [29] that controls and inhibits the production of proinflammatory cytokines during the recovery phases [10] of infections and consequently reduces the damage caused by inflammatory cytokines [29]. This results agrees with study conducted by Y. Pan, X. Jiang, et al., [30] that revealed no significant differences were observed in IL-2, IL-12, IFN-γ, IL-5, IL-6, IL-1β, IL-17, IL-10, IFN-α, and TNF-α during the follow-up of convalescent individuals.
In the present study, the levels of IL-10 in serum of non-vaccinated COVID-19 infected patients was significantly increased at second week more than other time, this result agrees with study conducted by H. Islam, T. Chamberlain, et al., [10] that revealed the dramatic elevation in IL-10 could be interpreted as an attempt to temper hyperinflammation and prevent tissue damage. However, the concurrent elevations in IL-10 and various pro-inflammatory cytokines, and the observed relationship between elevated IL-10 levels and disease severity, suggest that IL-10 is either failing to appropriately suppress inflammation (as observed in other inflammatory conditions or acting in a manner that deviates from its traditional role as an anti-inflammatory molecule. Also similar to our results, study by R. Luporini, J. Rodolpho, et al., [31] demonstrated not only elevated IL-10 level in some COVID-19 patients, but also that this unbalanced cytokine production predicts disease severity and IL-10 were independently associated with mortality.
Additionally, there was a notable correlation between the levels of IL-10, IL-6, and other inflammatory indicators including C-reactive protein. However, it has become clear that IL-10 is significant as a potential immunological biomarker for assessing the severity of COVID-19 disease. High IL-10 expression is a marker for poor outcomes in COVID-19 patients, just like IL-6. Clinically significant levels of IL-10 have been seen

in the serum of COVID-19 patients, and this finding has often been interpreted as a biomarker for an immune-inhibitory or anti-inflammatory mechanism that is being triggered by the rapid buildup of proinflammatory cytokines as a negative feedback loop [32]. Additionally, some researchers have suggested recombinant IL-10 for treatment ARDS in COVID-19 patients due to its immunoregulatory as well as antifibrotic properties [13,33].
Studies have shown that serum levels of interleukin-10 (IL-10) in the cytokine storm in patients with COVID-19 infection increase significantly [34, 35]. It has also been shown that COVID-19 patients admitted to the intensive care unit (ICU) have significantly more elevated serum levels of interleukin-10 than other non-ICU patients [36]. Importantly, elevated serum interleukin-10 levels in patients with COVID-19 infection can be both an anti-inflammatory mechanism and an immunosuppressive biomarker [32]. Additionally, increased gene expression in macrophages, which may be due to LPS, is inhibited by IL-10 [37].

6 Conclusion

1. It's possible that COVID-19 patients' increased CRP levels are caused by their overproduction of inflammatory cytokines.
2. Elevated IL-10 levels 2 weeks or longer after immunization can be an indication of a healthy immune response that promotes homeostasis.

Conflict of Interest: None
Ethical consideration: from ethical committee in the in the Department of Clinical Biochemistry, College of Medicine, University of Al-Qadisiyah, Al Diwaniyah, Iraq

References

[1] Heidary F, Gharebaghi R. Ivermectin: a systematic review from antiviral effects to COVID-19 complementary regimen. The Journal of antibiotics. 2020;73(9):593-602. doi:10.1038/s41429-020-0336-z. [Backref page 7]

[2] Bokemper SE, Gerber AS, Omer SB, Huber GA. Persuading US White evangelicals to vaccinate for COVID-19: Testing message effectiveness in fall 2020 and spring 2021. Proceedings of the National Academy of Sciences. 2021;118(49):e2114762118. doi:10.1073/pnas.2114762118. [Backref page 7]

[3] Zarzour W, Dehneh N, Rajab M. High-sensitive c-reactive protein levels in a group of syrian university male students and its associations with smoking, physical activity, anthropometric measurements, and some hematologic inflammation biomarkers. International Journal of Inflammation. 2017;2017. doi:10.1073/pnas.2114762118. [Backref page 7], [Backref page 11]

[4] Sproston NR, Ashworth JJ. Role of C-reactive protein at sites of inflammation and infection. Frontiers in immunology. 2018;9:754. doi:10.3389/fimmu.2018.00754. [Backref page 7], [Backref page 11]

[5] Du Clos TW. Function of C-reactive protein. Annals of medicine. 2000;32(4):274-8. doi:10.3109/07853890009011772. [Backref page 7]

[6] Pepys MB, Hirschfield GM, et al. C-reactive protein: a critical update. The Journal of clinical investigation. 2003;111(12):1805-12. doi:10.1172/jci18921c1. [Backref page 7]

[7] Malik P, Patel U, Mehta D, Patel N, Kelkar R, Akrmah M, et al. Biomarkers and outcomes of COVID-19 hospitalisations: systematic review and meta-analysis. BMJ evidence-based medicine. 2021;26(3):107-8. doi:10.1172/jci18921c1. [Backref page 7]

[8] Sadeghi-Haddad-Zavareh M, Bayani M, Shokri M, Ebrahimpour S, Babazadeh A, Mehraeen R, et al. C-reactive protein as a prognostic indicator in COVID-19 patients. Interdisciplinary Perspectives on Infectious Diseases. 2021;2021. doi:10.1155/2021/5557582. [Backref page 7]

[9] Sproston NR, Ashworth JJ. Role of C-Reactive Protein at Sites of Inflammation and Infection. Frontiers in Immunology. 2018;9. Available from: https://www.frontiersin.org/articles/10.3389/fimmu.2018.00754. doi:10.3389/fimmu.2018.00754. [Backref page 7]

[10] Islam H, Chamberlain TC, Mui AL, Little JP. Elevated interleukin-10 levels in COVID-19: potentiation of pro-inflammatory responses or impaired anti-inflammatory action? Frontiers in Immunology. 2021:2485. doi:10.3389/fimmu.2021.677008. [Backref page 7], [Backref page 11]

[11] Saraiva M, Vieira P, O'garra A. Biology and therapeutic potential of interleukin-10. Journal of Experimental Medicine. 2020;217(1). doi:10.1084/jem.20190418. [Backref page 7]

[12] Tang Y, Liu J, Zhang D, Xu Z, Ji J, Wen C. Cytokine Storm in COVID-19: The Current Evidence and Treatment Strategies. Frontiers in Immunology. 2020;11. Available from: https://www.frontiersin.org/articles/10.3389/fimmu.2020.01708. doi:10.3389/fimmu.2020.01708. [Backref page 7]

[13] Lu L, Zhang H, Dauphars DJ, He YW. A potential role of interleukin 10 in COVID-19 pathogenesis. Trends in Immunology. 2021;42(1):3-5. doi:10.1016/j.it.2020.10.012. [Backref page 7], [Backref page 12]

[14] Han H, Ma Q, Li C, Liu R, Zhao L, Wang W, et al. Profiling serum cytokines in COVID-19 patients reveals IL-6 and IL-10 are disease severity predictors. Emerging Microbes & Infections. 2020;9(1):1123-30. doi:10.1080/22221751.2020.1770129. [Backref page 7]

[15] Luan Yy, Yin Ch, Yao Ym. Update advances on C-reactive protein in COVID-19 and other viral infections. Frontiers in Immunology. 2021:3153. [Backref page 8], [Backref page 11]

[16] Reserved A. Human CRP(C-Reactive Protein) ELISA Kit. Elabscience. 2021;7368:240-52. doi:p-human_crp_c_reactive_protein_elisa_kit-17908. [Backref page 8]

[17] Reserved A. Human IL-10(Interleukin 10) ELISA Kit. Elabscience. 2021. doi:p-human_il_10_interleukin_10_elisa_kit-532925. [Backref page 8]

[18] Das S, Verma S. P5-88: Study of C reactive protein (HS-CRP) in post COVID-19 geriatric patients. Respirology. 2021;26(S3):192-2. doi:https://doi.org/10.1111/resp.14150 _295. [Backref page 11]

[19] Galliera E, Massaccesi L, Yu L, He J, Ranucci M, Corsi Romanelli MM. SCD14-ST and new generation inflammatory biomarkers in the prediction of COVID-19 outcome. Biomolecules. 2022;12(6):826. doi:10.3390/biom12060826. [Backref page 11]

[20] Pepys MB. C-reactive protein predicts outcome in COVID-19: is it also a therapeutic target? European heart journal. 2021;42(23):2280. doi:10.1093/eurheartj/ehab169. [Backref page 11]

[21] Edelman-Klapper H, Zittan E, Shitrit ABG, Rabinowitz KM, Goren I, Avni-Biron I, et al. Lower serologic response to COVID-19 mRNA vaccine in patients with inflammatory bowel diseases treated with Anti-TNFα. Gastroenterology. 2022;162(2):454-67. doi:10.1053/j.gastro.2021.10.029. [Backref page 11]

[22] Tavares P, Gonçalves DM, Santos LL, Ferreira R. Revisiting the clinical usefulness of C-reactive protein in the set of cancer cachexia. Porto Biomedical Journal. 2021;6(1). doi:10.1097/j.pbj.0000000000000123. [Backref page 11]

[23] Organization WH, et al. C-reactive protein concentrations as a marker of inflammation or infection for interpreting biomarkers of micronutrient status. World Health Organization; 2014. doi:10665/133708. [Backref page 11]

[24] Mohamed GA, Abd-Elrahman MZ, Bahriz R, Albehairy A. Inflammatory cytokine and plasma C-reactive protein response to ketoacidosis in adults with type 1 diabetes: Egyptian multicenter study. The Egyptian Journal of Internal Medicine. 2020;32(1):1-8. doi:10.1186/s43162-020-00011-2. [Backref page 11]

[25] Shi Y, Wang Y. Shao c. Huang J, Gan J, Huang X, Bucci E, Piacentini M, Ippolito G and Melino G: cOVId-19 infection: The perspectives on immune responses cell death differ. 2020;27:1451-4. doi:10.1038/s41418-020-0530-3 DOI: 10.1084/jem.20190418. [Backref page 11]

[26] Ali N. Elevated level of C-reactive protein may be an early marker to predict risk for severity of COVID-19. Journal of medical virology. 2020. doi:10.1002/jmv.26097. [Backref page 11]

[27] Saraiva M, Vieira P, O'garra A. Biology and therapeutic potential of interleukin-10. Journal of Experimental Medicine. 2020;217(1). doi:10.1084/jem.20190418. [Backref page 11]

[28] Ouyang W, O'Garra A. IL-10 family cytokines IL-10 and IL-22: from basic science to clinical translation. Immunity. 2019;50(4):871-91. doi:10.1016/j.immuni.2019.03.020. [Backref page 11]

[29] Rojas JM, Avia M, Martín V, Sevilla N. IL-10: a multifunctional cytokine in viral infections. Journal of immunology research. 2017;2017. doi:10.1155/2017/6104054. [Backref page 11]

[30] Pan Y, Jiang X, Yang L, Chen L, Zeng X, Liu G, et al. SARS-CoV-2-specific immune response in COVID-19 convalescent individuals. Signal Transduction and Targeted Therapy. 2021;6(1):1-10. doi:s41392-021-00686-1. [Backref page 11]

[31] Luporini RL, Joice MdA, Kubota LT, Martin ACBM, Cominetti MR, de Freitas Anibal F, et al. IL-6 and IL-10 are associated with disease severity and higher comorbidity in adults with COVID-19. Cytokine. 2021;143:155507. doi:10.1016/j.cyto.2021.155507. [Backref page 11]

[32] Zhao Y, Qin L, Zhang P, Li K, Liang L, Sun J, et al. Longitudinal COVID-19 profiling associates IL-1RA and IL-10 with disease severity and RANTES with mild disease. JCI insight. 2020;5(13). doi:10.1172/jci.insight.139834. [Backref page 12]

[33] Hasanvand A. COVID-19 and the role of cytokines in this disease. Inflammopharmacology. 2022:1-10. doi:10.1007/s10787-022-00992-2. [Backref page 12]

[34] Yang X, Yu Y, Xu J, Shu H, Liu H, Wu Y, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. The Lancet Respiratory Medicine. 2020;8(5):475-81. doi:10.1016/S0140-6736(20)30183-5. [Backref page 12]

[35] Zhou R, To KKW, Wong YC, Liu L, Zhou B, Li X, et al. Acute SARS-CoV-2 infection impairs dendritic cell and T cell responses. Immunity. 2020;53(4):864-77. doi:10.1172/jci.insight.137799. [Backref page 12]

[36] Diao B, Wang C, Tan Y, Chen X, Liu Y, Ning L, et al. Reduction and functional exhaustion of T cells in patients with coronavirus disease 2019 (COVID-19). Frontiers in immunology. 2020:827. doi:10.3389/fimmu.2020.00827. [Backref page 12]

[37] Odhong' C, Wilkes A, van Dijk S, Vorlaufer M, Ndonga S, Sing'ora B, et al. Financing large-scale mitigation by smallholder farmers: what roles for public climate finance? Frontiers in Sustainable Food Systems. 2019;3:3. doi:10.3389/fimmu.2019.01788. [Backref page 12]

How to cite

Fadhil M.F; Al-Azzawi B.A.; Evaluation of Some Biochemical Markers in Relation to COVID-19 mRNA Vaccine. Journal of Biomedicine and Biochemistry. 2022;1(3):6-14. doi: 10.57238/jbb.2022.20105