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EVALUATION OF SOME INFLAMMATORY AND OXIDATIVE PARAMETERS IN INFERTILE FEMALE PATIENTS IN DHI QAR GOVERNORATE, IRAQ

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ABSTRACT
Study Objective: This study was designed to evaluate certain inflammatory (IL4, IL8, CRP, TNF) and oxidative (SOD, MDA, GPx) markers in women with primary and secondary infertility in Dhi Qar Governorate.
Methodology: The study sample consisted of 230 infertile female patients. The required analyses were performed on 30 of them: 15 female patients with primary infertility (Group 1) and 15 female patients with secondary infertility (Group 2), while the control group consists of 10 healthy females don't suffer from any diseases. The analysis was performed according to the number of measurements used for each inflammatory and oxidative marker.
Results: The current study showed a significant decrease in the concentration of both interleukin-4, interleukin-8 and tumor necrosis factor (TNF), and a significant increase in the concentration of C-reactive protein (CRP) in the first group (those with primary infertility) and the second group (those with secondary infertility) when compared with the third group (healthy females) at the probability level $P \leq 0.05$. On the other hand, the results showed a significant increase in the concentration of superoxide dismutase (SOD) and a significant decrease in the concentration of malondialdehyde (MDA) in both the primary and secondary infertility groups compared to the control group, and a decrease in the primary infertility group compared to the secondary infertility group at a probability level of $P \leq 0.05$. Also, a significant increase in the concentration of glutathione peroxidase (GPX) was observed in the secondary infertility group compared to both the primary infertility group and the healthy group at a probability level of $P \leq 0.05$.
Conclusions: Infertility is associated with clear and distinct changes in the studied inflammatory and oxidative parameters.

KEYWORDS: Infertility, inflammatory parameters, oxidative parameters, primary infertility, secondary infertility

1.INTRODUCTION

Infertility is a disease that affects the reproductive system and refers to the inability to conceive after a full year of regular sexual intercourse without using contraception [2][1]. Infertility is a global health problem that affects multiple aspects of life, whether marital, social, or economic [3].
The World Health Organization (WHO) indicated that approximately 8-12% of couples worldwide suffer from infertility, which is about 60-80 million couples around the world.[5][4] Infertility is divided into two types: Primary Infertility, which is the inability of a woman to conceive at all, and Secondary Infertility, which refers to the inability of a woman to conceive again after at least one previous successful pregnancy.[6]
The prevalence rates of the two types vary among the countries of the world, as developed countries show high rates of primary infertility compared to developing countries, where secondary infertility is more common [7].
Irregular menstrual cycles, thyroid disorders, ovulation disorders, fallopian tube abnormalities, uterine and cervical abnormalities, diabetes, weight gain, polycystic ovary syndrome (PCOS), and endometriosis are among the most important causes of infertility [8][9][10][11].
Inflammation is one of the common and influential causes of infertility in both sexes, leading to anatomical and functional disorders in the female reproductive system.[12] Inflammatory cytokines such as tumor necrosis factor (TNF), interleukin-6 (IL-6), and interleukin-8 (IL-8) play an important role in regulating the reproductive environment. However, their abnormal elevation is associated with fertility disorders and poor gamete quality, due to their effect on cellular and immune processes within the ovaries and uterus. These

inflammatory factors also interact with oxidative stress to form a vicious cycle that leads to increased cellular damage and continued dysfunction in the reproductive system [13]. Oxidative stress is one of the main factors associated with infertility, and it results from an imbalance between the production of free radicals or reactive oxygen species (ROS) and the antioxidant systems in the body. This imbalance leads to damage to lipids, proteins, and DNA within cells, which negatively affects egg quality and endometrial function, thus weakening fertility [14]. Furthermore, studies have shown that many infertility-related conditions such as endometriosis are closely linked to increased oxidative stress and inflammation, which leads to poor egg quality and disruption of the endometrial environment, this hinders pregnancy in the uterus [15] and oxidative stress resulting from mitochondrial dysfunction is considered the main cause of chromosomal division disorders and failure of maturation and fertilization [16].

2. MATERIALS AND METHODS

2.1. Study Design

This study was conducted between July 2025 and June 2026 and included 230 women. Biochemical analyses (inflammatory and oxidative) were performed on 30 female patients, divided into two groups. The first group consisted of 15 female patients with primary infertility, and the second group consisted of 15 female patients with secondary infertility. The female patients with primary infertility were 18 to 40 years old. The third group consisted of 10 healthy females 18 to 38 years old, who did not suffer from any menstrual irregularities, fertility problems, or other diseases. The female patients with infertility were diagnosed by a specialist physician, and the necessary analyses were performed on them.

2.2. Measurement of Inflammatory and Oxidative Markers

The following parameters were measured: superoxide dismutase (SOD), malondialdehyde (MDA), glutathione peroxidase (GPx), interleukins 4 and 8, and tumor necrosis factor (TNF) were measured using a kit supplied by USCNK (China) and a Paramedical PKL Italy Microplate Reader ELISA analyzer. C-reactive protein (CRP) was measured using a Cobas c111 analyzer (ROCHE, Germany).

2.3. Statistical Analysis

The data for all tests were statistically analyzed using the Statistical Package for the Social Sciences (SPSS) version 27, employing a t-test at a probability level of 0.05 to determine the significance of differences between the group means.

3. RESULTS AND DISCUSSION

3.1. The Relationship between Infertility and Interleukin-4 and Interleukin-8 Concentrations

The results of the current study (Table 1) showed a significant decrease in the concentration of both interleukin-4 and interleukin-8 in the first group (female patients with primary infertility) and the second group (female patients with secondary infertility) when compared to the third group (healthy females) at a probability level of $P \leq 0.05$.

Table (1): The relationship between infertility and the concentration of interleukins 4 and 8 (Mean ±SD)

The Standards / The Groups	Interleukin 8 pg/mL	Interleukin 4 pg/mL
The First Group (female patients with primary infertility)	11.716 b ± 2.760	8.062 b ± 2.164
The Second Group (female patients with secondary infertility)	9.541 b ± 1.848	11.602 b ± 2.817
(The Third Group (Healthy females)	21.188 a ± 4.629	53.360 a ± 14.957
P.VaLue	0.0001	0.0001

The decrease in interleukins may be due to disorders of the immune response within the reproductive system. [17] has been indicated that changes in the immune response may be a cause of the decrease in interleukin-4. When there is an imbalance or an increase in the immune response of type 1 T cells (Th1) at the expense of type 2 T cells (Th2), this causes a decrease in the secretion of interleukin-4, since interleukin-4 is associated with Th2 cells, which leads to an inflammatory environment that is not suitable for ovulation and embryonic

development. This happens frequently in cases of unexplained infertility and infertility associated with autoimmunity.

The decrease in interleukins may be explained by the imbalance in oxidation-reduction that was demonstrated by the results of the current study in female patients with infertility. A study of [18] indicated that the imbalance in oxidative stress leads to a decrease in interleukin-4, which causes an impairment in the growth and function of regulatory T cells and type II helper T cells, which are necessary to maintain a healthy reproductive environment. This decrease may also be due to repeated abortions or previous surgeries that may cause persistent inflammation or inflammation for any other reason. [17] indicated that repeated abortions and chronic inflammation lead to a decrease in the concentration of interleukin-4, which is necessary for the process of fetal development, and this is consistent with the results of the current study.

The results of the current study also revealed a significant decrease in interleukin-8. This decrease may be explained by the presence of inactivity in the uterine lining and difficulty in implantation of the fertilized egg, and thus the loss of the means of supplying that egg with nutrients, which ultimately leads to the loss of the chance of pregnancy. Or it may be due to the decrease in the concentration of interleukin-4, which indirectly contributes to the decrease in the concentration of interleukin-8 through its role in regulating gene expression for the production of interleukin-8. Both studies of [19][20] indicated that weak activity of the uterine lining or the occurrence of disturbances in the implantation process leads to a decrease in interleukin-8, which in turn stimulates the uterine cells to be active, proliferate, and form the blood vessels necessary for the success of the embryo implantation process. On the other hand, it was explained that interleukin-4 regulates the gene expression of interleukin-8, and this is what was proven by the results of the study, which showed a decrease in the concentration of interleukin-4.

On the other hand, [21] indicated that interleukin-4 regulates chronic inflammation, and if it is low, it affects the cytokines associated with type II T cells (Th2), including interleukin-8. The results of the current study were consistent with the results of the studies of [22][23][24], which concluded that there is a correlation between high levels of interleukin-8 in the blood serum and the occurrence of infertility.

3.2. The Relationship between Infertility and C-Reactive Protein (CRP) and Tumor Necrosis Factor (TNF) Concentrations

The results of the current study (Table 2) indicate a significant increase in CRP concentration and a significant decrease in TNF concentration in the first and second groups compared to the third group (healthy females) at a probability level of $P \leq 0.05$.

Table (2): The relationship between infertility and CRP and TNF concentrations (Mean ± SD)

The Standards / The Groups	C-reactive protein (CRP) mg/L	Tumor necrosis factor (TNF) mg/L
The First Group (female patients with primary infertility)	2.329 a ± 1.517	4.603 b ± 0.920
The Second Group (female patients with secondary infertility)	2.206 a ± 0.893	4.777 b ± 0.877
(The Third Group (Healthy females)	0.341 b ± 0.170	9.416 a ± 4.001
P.VaLue	0.0001	0.0001

The significant increase in C-reactive protein (CRP) levels in female patients with infertility may be explained by chronic inflammation in the reproductive system. Studies of [25][26] have indicated that elevated CRP levels in female with infertility suggest a chronic inflammatory condition that can affect reproductive physiology. This increase may also be attributed to polycystic ovary syndrome (PCOS), a common condition in females with infertility. A study of [27] indicated that females with PCOS have higher CRP levels compared to healthy females, suggesting a correlation between PCOS and CRP levels. The results of the current study are consistent with those of a study of [28] which also found an increase in CRP levels in female patients with infertility.

Regarding the significant decrease in tumor necrosis factor (TNF) concentration in infertile females compared to healthy females, this may be attributed to immune response disturbances. [29] indicated that the decrease in TNF concentration is due to an imbalance in the immune response between type I and type II T cells (Th1 and Th2), or to abnormal cytokine levels in follicular fluid. [30] also pointed out that cytokine imbalances, including decreased TNF, occur in cases of unexplained infertility or immune disorders, affecting reproductive processes such as ovulation, fertilization, and implantation. This decrease in TNF concentration is also explained by a weakened inflammatory environment in the endometrium.
[31] indicated that a weakened endometrial environment leads to a decrease in TNF concentration, which is essential for maintaining physiological balance within the endometrium and facilitating implantation. When TNF levels are low, the immune signals necessary for interaction between the embryo and the endometrium are reduced, leading to implantation failure and consequently infertility. The results of the current study differ from those of [32], which found elevated TNF concentrations in females with endometriosis associated with infertility.

3.3. The relationship between infertility and some parameters of oxidative stress

The results of the current study showed a significant increase in the concentration of the Superoxide Dismutase (SOD) enzyme and a significant decrease in the concentration of Malondiadehyde (MDA) in the first and second groups when compared with the third group (healthy females). A decrease in MDA was also observed in the first group when compared with the second group at the probability level $P \leq 0.05$. Additionally, a significant increase in the concentration of the Glutathione Peroxidase (GPX) enzyme was found in the second group when compared with the first and third groups at the aforementioned probability level, as shown in (Table 3).

Table (3): The relationship between infertility and some parameters of oxidative stress (Mean ±SE)

The Standards / The Groups	Superoxide Dismutase (SOD) ng/mL	Malondiadehyde (MDA) ng/mL	Glutathione Peroxidase (GPX) ng/mL
The First Group (female patients with primary infertility)	687.610 a ± 775.233	12.551 c ± 4.504	4.38 b ± 2.401
The Second Group (female patients with secondary infertility)	288.054 a ± 82.469	16.976 b ± 4.513	8.242 a ± 4.226
(The Third Group (Healthy females)	39.849 b ± 13.294	24.550 a ± 8.982	3.186 b ± 3.674
P.VaLue	0.006	0.0001	0.002

The results of the current study indicate clear disturbances in antioxidant enzymes in female patients with primary and secondary infertility compared to the third group, which consists of healthy females. The increase in the concentration of the (SOD) enzyme can be explained as a result of the body's defensive response to reduce the increased production of Reactive Oxygen Species (ROS) and Reactive Oxygen (ROS). This enzyme is considered the first line of defense against free radicals by converting toxic superoxide radicals into less harmful hydrogen peroxide (H_2O_2). Therefore, the increase in this enzyme is a result of the body's attempt to reduce the oxidative stress that occurs during primary and secondary infertility. [33][34] indicated that the increase in the concentration of SOD comes as a reaction of the body to reduce oxidative stress, especially in cases of primary and secondary infertility, as this enzyme works to convert supertoxic oxygen radicals into less harmful oxygen and hydrogen peroxide and reduces the likelihood of cell damage resulting from ROS.
It was also noted in [35][36] that elevated SOD levels in female patients with infertility due to polycystic ovary syndrome (PCOS), endometriosis, chronic pelvic inflammatory disease, or insulin resistance all contribute to the body increasing its secretion of this enzyme as a protective measure. Excessive production of ROS also affects egg maturation, fertilization, and embryo implantation, thus leading to infertility. A study of [37] suggests that elevated SOD activity is a result of a deficiency in dietary antioxidants such as vitamins C and E and zinc, causing the body to increase SOD production to compensate for this antioxidant deficiency. The results of the current study are consistent with those of [38], which also found elevated SOD activity.
As for the decrease in the concentration of MDA enzyme, it may be due to the increase in the concentration of SOD enzyme, which was proven by the results of the current study, which came as a reaction to protect

the body from the effects of oxidation. The studies of [39][40] indicated that the MDA enzyme, which is used as a good indicator for measuring oxidative stress in the blood, and that the decrease in this enzyme, as a result of the increased activity of the body's antioxidant immune systems, led to a decrease in MDA resulting from the breakdown of fats due to free radicals. Therefore, this decrease indicates the success of the body's antioxidant systems in preventing damage to cell membranes and the stages of fetal development. The lower levels of MDA in primary infertility compared to secondary infertility may be explained by the fact that oxidative stress is more severe and persistent in secondary infertility. Furthermore, studies of [41][42][43][44] have suggested that the decrease in MDA may be due to the use of antioxidants such as vitamins C, E, and D, omega-3 fatty acids, and selenium by female patients with infertility. The results of the current study differ from those of the study of [45] which found an increase in MDA activity.

The results of the current study indicated a significant increase in the concentration of the glutathione peroxidase (GPx) enzyme, which may be explained by the presence of chronic inflammation and reproductive system problems such as PCOS. These conditions lead to an increase in free radicals, which in turn stimulates the body to increase the activity of this enzyme to balance these compounds [46]. The results of the current study are consistent with those of the study of [47], which indicated an increase in GPx concentration in female patients with infertility.

REFERNCES

[1]Kumaran, M., Raja, D., & Nirupama, A. Y. (2024). Association Between Body Mass Index and Infertility Among Women: An Age-Matched Case-Control Study. *Asian Journal of Interdisciplinary Research*, *7*(1), 13-19.https://doi.org/10.54392/ajir2412

[2]Franjić, S. (2024). *WINSOME PUBLISHING LLC Maternity and Reproductive Health Sciences Infertility on a Global Level*. 1–5. https://doi.org/10.1875/mrhs.2024/001

[3]Kundu, S., Ali, B., & Dhillon, P. (2023). Surging trends of infertility and its behavioural determinants in India. *PloS one*, *18*(7), e0289096. https://doi.org/10.1371/journal.pone.0289096

[4]Napitupulu, E., Sembiring, I. S., Suherni, T., Elnia, E., & Andriani, R. (2023). Faktor – Faktor Yang Mempengaruhi Terjadinya Infertilitas Primer Pada Pasangan Usia Subur Di Puskesmas Pegajahan Kec. Pegajahan Kab. Serdang Bedagai Tahun 2023. *Jurnal Ventilator/Jurnal Ventilator,Semarang*, *1*(3), 258–272. https://doi.org/10.59680/ventilator.v1i3.650

[5]Ombelet W. (2020). WHO fact sheet on infertility gives hope to millions of infertile couples worldwide. *Facts, views & vision in ObGyn*, *12*(4), 249–251.

[6]Waheed, K. B., Albassam, M. A., AlShamrani, A. G., Aloumi, S. A., Amin, M. S., Rashid, L., AlGodayan, S. M., & Ahmad, S. B. (2019). Hysterosalpingographic findings in primary and secondary infertility patients. *Saudi medical journal*, *40*(10), 1067–1071. https://doi.org/10.15537/smj.2019.10.24538

[7]Mazurek, A. J., Machaj, D., Polák, J., Lis, J., Machaj, D., & Raczkiewicz, P. (2023). Infertility - causes, diagnosis, preventive measures and methods of treatment. *Journal of Education, Health and Sport*, *25*(1), 83–88. https://doi.org/10.12775/jehs.2023.25.01.008

[8]Behera, M. R., Sahoo, P. K., & Mishra, B. (2024). *Investigation of Primary and Secondary Infertility through Different Hormonal Assays*. https://doi.org/10.5281/zenodo.11493372

[9]Vayena, E., ROWE, P., & GRIFFIN, P. (2002). Current Practices and Controversies in Assisted Reproduction. *Report of a Meeting*.

[10]Hussain, S. S., & Raees, M. (2024). *Causes of Primary Versus Secondary Infertility in Women Undergoing Diagnostic Laparoscopy*. *5*(1), 22–26. https://doi.org/10.70905/bmcj.05.01.0261

[11]Evens, E.M. (2004) A Global Perspective on Infertility: An Under Recognized Public Health Issue. Carolina Papers in International Health, No. 18. University Center North Carolina at Chapel Hill.

[12]Walker, C. K., & Wiesenfeld, H. C. (2007). Antibiotic therapy for acute pelvic inflammatory disease: the 2006 Centers for Disease Control and Prevention sexually transmitted diseases treatment guidelines. *Clinical infectious diseases : an official publication of the Infectious Diseases Society of America*, *44 Suppl 3*, S111–S122. https://doi.org/10.1086/511424

[13]Moustakli, E., Stavros, S., Katopodis, P., Skentou, C., Potiris, A., Panagopoulos, P., Domali, E., Arkoulis, I., Karampitsakos, T., Sarafi, E., Michaelidis, T. M., Zachariou, A., & Zikopoulos, A. (2025). Oxidative Stress and the NLRP3 Inflammasome: Focus on Female Fertility and Reproductive Health. *Cells*, *14*(1), 36. https://doi.org/10.3390/cells14010036

[14]Banerjee, P & Bhattacharya, J. (2019). Impact of Oxidative stress on Infertility, with emphasis on infertility management strategies. Global Journal of Fertility and Research. https://doi.org/10.17352/gjfr.000012

[15]Dymanowska-Dyjak, I., Frankowska, K., Abramiuk, M., & Polak, G. (2024). Oxidative Imbalance in Endometriosis-Related Infertility-The Therapeutic Role of Antioxidants. *International journal of molecular sciences*, *25*(12), 6298. https://doi.org/10.3390/ijms25126298
[16]Alam, F., Amjad, S., Alam, F., Khan, T. A., Amjad, S., & Rehman, R. (2019). *Association of oxidative stress with female infertility - a case control study Association of oxidative stress with female infertility - A case control study*. *69*, 627–631.
[17]Chatterjee P, Chiasson VL, Bounds KR and Mitchell BM (2014) Regulation of the Anti-Inflammatory Cytokines Interleukin-4 and Interleukin-10 during Pregnancy. Front. Immunol. 5:253. https://doi.org/10.3389/fimmu.2014.00253
[18]Ojo, O. A., Nwafor-Ezeh, P. I., Rotimi, D. E., Iyobhebhe, M., Ogunlakin, A. D., & Ojo, A. B. (2023). Apoptosis, inflammation, and oxidative stress in infertility: A mini review. *Toxicology reports*, *10*, 448–462. https://doi.org/10.1016/j.toxrep.2023.04.006
[19]Ivanov, D., Drobintseva, A., Rodichkina, V., Mironova, E., Zubareva, T., Krylova, Y., Morozkina, S., Marasco, M. G. P., Mazzoccoli, G., Nasyrov, R., & Kvetnoy, I. (2024). Inflammaging: Expansion of Molecular Phenotype and Role in Age-Associated Female Infertility. *Biomedicines*, *12*(9), 1987. https://doi.org/10.3390/biomedicines12091987
[20]Sikora, J., Smycz-Kubańska, M., Mielczarek-Palacz, A., & Kondera-Anasz, Z. (2017). Abnormal peritoneal regulation of chemokine activation-The role of IL-8 in pathogenesis of endometriosis. *American journal of reproductive immunology (New York, N.Y. : 1989)*, *77*(4), 10.1111/aji.12622. https://doi.org/10.1111/aji.12622
[21]Kruger, T. E., Brown, E. G., Malik, R. K., Majid, A., & Baier, J. (1998). Interleukin-4 (IL-4) and Interleukin-13 (IL-13) inhibit IL-1β induction of Interleukin-8 (IL-8) and Epithelial neutrophil activating protein (ENA-78) in alveolar type II cells. 1958. *Pediatric Research*, *43*(4), 334. https://doi.org/10.1203/00006450-199804001-01981
[22]Rahmawati, N. Y., Ahsan, F., Santoso, B., Mufid, A. F., Sa, A., Dwiningsih, S. R., Tunjungseto, A., Yohanes, M., & Widyanugraha, A. (2023). *IL-8 and IL-12p70 are associated with pelvic pain among infertile women with endometriosis*. *June*, 1262–1269. https://doi.org/10.1093/pm/pnad080
[23]Malvezzi, H., Hernandes, C., de Azevedo Piccinato, C., & Podgaec, S. (2019). Interleukin in endometriosis-associated infertility-pelvic pain: systematic review and meta-analysis. *Reproduction*, *158*(1), 1–12. https://doi.org/10.1530/REP-18-0618
[24] Xie, J., Yan, L., Cheng, Z., Qiang, L., Yan, J., Liu, Y., Liang, R., Zhang, J., Li, Z., Zhuang, L., Hao, C., Wang, B., & Lu, Q. (2020). Potential effect of inflammation on the failure risk of *in vitro* fertilization and embryo transfer among infertile women. *Human fertility (Cambridge, England)*, *23*(3), 214–222. https://doi.org/10.1080/14647273.2018.1543898
[25]Brouillet, S., Boursier, G., Anav, M., Du Boulet De La Boissière, B., Gala, A., Ferrieres-Hoa, A., Touitou, I., & Hamamah, S. (2020). C-reactive protein and ART outcomes: a systematic review. *Human reproduction update*, *26*(5), 753–773. https://doi.org/10.1093/humupd/dmaa012
[26]Zhang, H., Li, X., Zhang, F., Li, F., Jin, H., Su, Y., & Li, G. (2023). Serum C-reactive protein levels are associated with clinical pregnancy rate after *in vitro* fertilization among normal-weight women. *Frontiers in endocrinology*, *14*, 934766. https://doi.org/10.3389/fendo.2023.934766
[27]Alissa, E.M., Algarni, S.A., Khaffji, A., & Al Mansouri, N. (2023). Relationship Between Metabolic Syndrome and Polycystic Ovary Syndrome with Special Reference to C Reactive Protein. *Journal of obstetrics and gynaecology Canada : JOGC = Journal d'obstetrique et gynecologie du Canada : JOGC*, 102255 . https://doi.org/10.1016/j.jogc.2023.102255
[28]Al-Lami, R. A., Taha, S. A., Jalloul, R. J., & Taylor, H. S. (2021). High-sensitivity C-reactive protein is not independently associated with self-reported infertility in National Health and Nutrition Examination Survey 2015-2018 data. *F&S reports*, *3*(1), 63–70. https://doi.org/10.1016/j.xfre.2021.12.003
[29]Younis, A., Hawkins, K., Mahini, H., Butler, W., & Garelnabi, M. (2014). Serum tumor necrosis factor-α, interleukin-6, monocyte chemotactic protein-1 and paraoxonase-1 profiles in women with endometriosis, PCOS, or unexplained infertility. *Journal of assisted reproduction and genetics*, *31*(11), 1445–1451. https://doi.org/10.1007/s10815-014-0237-9
[30]Huang, J., Liu, B., Xiang, Y., Zhang, Y., Kuang, L., Xi, D., Wang, B., Lu, X., Kwak-Kim, J., & Wang, W. (2025). Follicular fluid cytokine phenotypes reflect underlying etiologies for infertility. *Journal of reproductive immunology*, *171*, 104620. https://doi.org/10.1016/j.jri.2025.104620
[31]Salama, K. M., Alloush, M. K., & Al Hussini, R. M. (2020). Are the cytokines TNF alpha and IL 1Beta early predictors of embryo implantation? Cross sectional study. *Journal of reproductive immunology*, *137*, 102618. https://doi.org/10.1016/j.jri.2019.102618

[32]Al-Azawy, V.S. (2017). Levels of Tumor Necrosis Factor Alpha and Interleukin-17 in Fertile and Infertile Women with Endometriosis.
[33]Sheng, Y., Abreu, I. A., Cabelli, D. E., Maroney, M. J., Miller, A. F., Teixeira, M., & Valentine, J. S. (2014). Superoxide dismutases and superoxide reductases. *Chemical reviews*, *114*(7), 3854-3918 https://doi.org/10.1021/cr4005296.
[34]Gupta, M. (2024). *Endogenous Antioxidants-I*. 132–139. https://doi.org/10.58532/nbennurdsch12
[35]Agarwal, A., Gupta, S., & Sharma, R. K. (2005). Role of oxidative stress in female reproduction. *Reproductive biology and endocrinology : RB&E*, *3*, 28. https://doi.org/10.1186/1477-7827-3-28
[36]Joó, J. G., Sulyok, E., Bódis, J., & Kornya, L. (2023). Disrupted Balance of the Oxidant–Antioxidant System in the Pathophysiology of Female Reproduction: Oxidative Stress and Adverse Pregnancy Outcomes. *Current Issues in Molecular Biology*, *45*(10), 8091-8111. https://doi.org/10.3390/cimb45100511
[37]Kabodmehri, R., Javaheri, F.S.H., Alami, F. *et al.* Female infertility and dietary antioxidant index (DAI); a case-control study. *BMC Women's Health* **23**, 608 (2023). https://doi.org/10.1186/s12905-023-02747-9
[38] al Hadrawi, Kais & ALGarawy, Raid. (2023). The role of some of the level Antioxidant enzymes and Obesity in development infertility women's infertility in Najaf Province Patients, IRAQ. BIO Web of Conferences. 65. 10.1051/bioconf/20236505050. https://doi.org/10.1051/bioconf/20236505050
[39]Anubha, B., Rinki, K., & GP, D. (2023). Evaluation of Malondialdehyde and Homocysteine Levels in Unexplained Infertility Females: A Retrospective, Hospital-Based, Case-Control Study. Annals of Medical and Health Sciences Research, 13(9), 806–809. https://doi.org/10.5281/zenodo.17091653
[40]Lu, J., Wang, Z., Cao, J., Chen, Y., & Dong, Y. (2018). A novel and compact review on the role of oxidative stress in female reproduction. *Reproductive biology and endocrinology : RB&E*, *16*(1), 80. https://doi.org/10.1186/s12958-018-0391-5
[41]MEMİŞOĞULLARI, RAMAZAN; GÜMÜŞTEKİN, KENAN; DANE, ŞENOL; and AKÇAY, FATİH (2006) "The Effect of Pre-Injury Supplementation with Selenium or Vitamin E on Lipid Peroxidation and Antioxidant Enzymes in Burn Injury," Turkish Journal of Medical Sciences: Vol. 36: No. 3, Article 2. Available at: https://journals.tubitak.gov.tr/medical/vol36/iss3/2
[42]Bergin, P., Leggett, A., Cardwell, C. R., Woodside, J. V., Thakkinstian, A., Maxwell, A. P., & McKay, G. J. (2021). The effects of vitamin E supplementation on malondialdehyde as a biomarker of oxidative stress in haemodialysis patients: a systematic review and meta-analysis. *BMC nephrology*, *22*(1), 126. https://doi.org/10.1186/s12882-021-02328-8
[43]D'souza, D., Subhas, B. G., Shetty, S. R., & Balan, P. (2012). Estimation of serum malondialdehyde in potentially malignant disorders and post-antioxidant treated patients: A biochemical study. *Contemporary clinical dentistry*, *3*(4), 448–451. https://doi.org/10.4103/0976-237X.107438
[44]Alam, F., Shahid, M., Riffat, S., Zulkipli, I. N., Syed, F., Ashraf, M., & Rehman, R. (2023). SIRT1 and antioxidants in infertile females: Exploration of the role of vitamin D. *PloS one*, *18*(7), e0287727. https://doi.org/10.1371/journal.pone.0287727
[45]Rashad, N.M., Ashour, W.M.R., Allam, R.M. *et al.* Oxidative stress and risk of polycystic ovarian syndrome in women with epilepsy: implications of malondialdehyde and superoxide dismutase serum levels on female fertility. *Egypt J Intern Med* **31**, 609–619 (2019). https://doi.org/10.4103/ejim.ejim_3_19
[46]Adeoye, O., Olawumi, J., Opeyemi, A., & Christiania, O. (2018). Review on the role of glutathione on oxidative stress and infertility. *JBRA assisted reproduction*, *22*(1), 61–66. https://doi.org/10.5935/1518-0557.20180003
[47]Özer, A., Bakacak, M., Kıran, H., Ercan, Ö., Köstü, B., Kanat-Pektaş, M., Kılınç, M., & Aslan, F. (2016). Increased oxidative stress is associated with insulin resistance and infertility in polycystic ovary syndrome. *Ginekologia polska*, *87*(11), 733–738. https://doi.org/10.5603/GP.2016.0079