Oxidative Stress Assessment in Colorectal Cancer Patients: Erbil Population Study

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***Abstract*—Colorectal cancer (CRC), a global health challenge, exhibits rising incidence in low-income nations due to lifestyle changes. Oxidative stress, indicated by reactive oxygen species imbalance and Malondialdehyde (MDA), is linked to CRC. This study investigates oxidative stress markers, antioxidant enzymes, genetic markers, cellular regulation markers, and Vitamin E in CRC patients in Erbil. Ninety CRC patients and 30 healthy controls provided blood samples, processed and stored at –20°C. Enzyme-linked immunosorbent assay kits quantified oxidative stress, antioxidant markers, and Vitamin E. Oxidative stress markers showed significant differences, with elevated MDA and 8-hydroxy-2'-deoxyguanosine levels in patients. Nitrotyrosine exhibited lower expression in patients. Antioxidant enzymes glutathione peroxidase and superoxide dismutase were enhanced in patients, while glutathione (GSH), glutathione reductase and catalase levels were significantly lower in patients. The genetic marker KRAS showed a substantial decrease in patients (<0.0001) but both adenomatous polyposis coli (APC) and CRC antigen (CCA) were higher. Serum vitamin E levels were significantly lower in patients (71.78 ± 6.368) compared to controls (142.3 ± 4.828, $p < 0.0001$). Elevated oxidative stress, altered enzymatic activity, significantly lower expression of KRAS, and higher expression of APC and CCA in the patient group. Furthermore, reduced Vitamin E levels were observed in the patient group, highlighting potential challenges in antioxidant defense.**

***Index Terms*—Colorectal cancer, Colorectal cancer patients, Erbil city, Oxidative stress markers, Vitamins.**

I. Introduction

Colorectal cancer (CRC) is one of the most common malignancy in the world which poses a significant global health challenge, prompting extensive exploration into the molecular intricacies underlying its development (Zińczuk, et al., 2019a; Janion, et al., 2020a), and (Beniwal, et al., 2023). Over 50% of cases are diagnosed in countries with a high or very high human development index. The rising incidence in low-income countries is linked to urbanization (Western lifestyles) or a shift in dietary habits, marked by increased consumption of animal fat and simple sugars (Fedacko, et al., 2019, Janion, et al., 2020a), and (Lewandowska, et al., 2022). In 2017, there were 1.8 million global CRC cases, with an age-standardized incidence rate of 23.2/100,000 person-years, marking a 9.5% increase from 1990 to 2017 (Lewandowska, et al., 2022). The precise causes of colorectal neoplasms remain unclear, though extensive research has identified various risk factors (Wong, et al., 2019). These include nonmodifiable elements such as age and heredity, along with modifiable factors linked to lifestyle and the environment (Wang, et al., 2019). Early diagnosis is crucial in detecting CRC during its development, which typically spans from several to numerous years (Sawicki, et al., 2021).

Oxidative stress is characterized by an imbalance between reactive oxygen species (ROS) and antioxidant defenses (Zińczuk, et al., 2020) and (Basak, Uddin, and Hancock, 2020). A substantial and compelling body of evidence indicates a robust association between oxidative stress and its role in the development and progression of CRC, marked by elevated levels of ROS in chronic gastrointestinal tract diseases (Basak, Uddin, and Hancock, 2020) and (Rasool, et al., 2021). Malondialdehyde (MDA), a prominent and deleterious byproduct arising from lipid peroxidation, represents a common and harmful consequence capable of causing cellular damage by interacting with free amino groups in proteins and nucleic acids (Rašić, et al., 2018). Particularly noteworthy is its mutagenic activity (Chatterjee and Walker, 2017). Elevated MDA levels serve as a recognized marker of oxidative stress, providing reliable indicators of damage to cellular membranes and offering valuable insights into the extent of oxidative stress in cancer (Marrocco, Altieri and Peluso, 2017) and (Janion, et al., 2022). Deoxyribonucleic acid (DNA) Damage 8-hydroxy-2'-deoxyguanosine (8-OHdG), serves as a crucial marker of oxidative damage to DNA (Borrego, et al., 2013). Marked elevation in oxidative stress is a prominent feature across diverse cancer types, substantiated by the presence of heightened levels of oxidized DNA base 8-OHdG and lipid peroxidation products in clinical specimens (Demirci-Cekic,

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et al., 2022). Nitrotyrosine (NT) is a marker of oxidative stress resulting from the reaction between reactive nitrogen species (RNS), such as peroxynitrite and tyrosine residues in proteins (Kreutzmann, et al., 2023). The existence of NT within proteins indicates a heightened level of oxidative modifications to proteins, promoting processes that lean toward pro-oxidation (Demasi, et al., 2021) and (Bartesaghi and Radi, 2018). Examination of human biopsies from individuals with colitis and colon cancer indicated heightened protein expression levels of inducible nitric oxide synthase, with a corresponding marked increase in NT expression (Gochman, et al., 2012). This occurs as NT serves as an indicator of oxidative stress arising from the interaction between RNS, including peroxynitrite, and tyrosine residues present in proteins (Bandookwala and Sengupta, 2020).

On the other hand, in response to elevated levels of ROS induced by environmental factors, cells deploy a variety of antioxidants, thereby establishing antioxidative systems to counteract oxidative stress (Gochman, et al., 2012). This intricate balance between oxidants and antioxidants is essential for maintaining cellular homeostasis (He, et al., 2017). The GSH system represents a pivotal cellular antioxidant network, actively collaborating to both uphold and synergize the redox balance (Lv, et al., 2019). This intricate system plays a crucial role in neutralizing ROS and maintaining the cellular redox equilibrium, highlighting its significance in cellular defense against oxidative stress (Lv, et al., 2019) and (Kennedy, et al., 2020). Moreover, deviations in the levels of ROS-scavenging enzymes, including superoxide dismutase (SOD), glutathione peroxidase (GPx), and peroxiredoxin, serve as markers of disrupted redox homeostasis within tumor cells (Mohan, et al., 2022). Elevated GPX1 levels may indicate an increased antioxidant response, suggesting a cellular attempt to counteract oxidative stress (Nalkiran, et al., 2015). SOD is a primary defense against oxidative stress, catalyzing the breakdown of superoxide radicals (Zińczuk, et al., 2019b). Higher SOD levels may suggest an enhanced cellular response to oxidative stress, potentially reflecting an adaptive mechanism against ROS (Irawan, et al., 2020). Excessive free radicals in cells can induce damage to DNA, proteins, and cell membranes, with antioxidants such as Vitamins A, C, and E, β-carotene, and selenium playing a crucial role in reducing oxidative stress by neutralizing these harmful free radicals (Katona and Weiss, 2020). Glutathione reductase (GR) is an enzyme that plays a crucial role in maintaining the cellular antioxidant defense by reducing oxidized glutathione (GSSG) back to its reduced form (GSH), in living cells (Raj Rai, et al., 2021). Conversely, the quantity of GSH and its ratio to the oxidized form plays a crucial role in regulating the activity of other redox-sensitive proteins, implying a fundamental role in controlling cellular function (Lorestani, et al., 2018). Given the impact of oxidative stress on the development of malignancies, alterations in the expression and activity of the GR enzyme may be pivotal in cancer progression (Cecerska-Heryć, et al., 2021). Catalase (CAT) (natural antioxidant) is an enzyme that catalyzes the breakdown of hydrogen peroxide (H_2O_2) into water and oxygen, playing a crucial role in protecting cells from oxidative damage (Bratovcic, 2020). CAT is advantageous for breaking down hydrogen peroxide and generating oxygen in solid cancers like CRC (Najafi, et al., 2023).

KRAS is a proto-oncogene that, when mutated, can become an oncogene and contribute to the development of various cancers, including CRC (Arrington, et al., 2012) and (Zhu, et al., 2021). In addition, the majority of studies conducted in Western nations explore the correlation between the risk of CRC and both Vitamin A and Vitamin E (Luo, et al., 2019) and (Alves Ribeiro, et al., 2022). The adenomatous polyposis coli (APC) protein functions as a tumor suppressor and plays a crucial role in the canonical (β-catenin-dependent) (Aghabozorgi, et al., 2019). Beyond its canonical functions, APC has the capacity to independently inhibit the initiation and progression of colorectal tumors (Hankey, Frankel, and Groden, 2018). In addition, APC contributes to various cellular processes, including chromosome segregation, establishment of cellular polarity and migration, and repression of DNA replication, highlighting its multifaceted roles in maintaining cellular homeostasis and preventing tumorigenesis (Daly, 2013) and (Aghabozorgi, et al., 2019). CRC antigen (CCA) is a marker associated with CRC, this antigen is often used as a diagnostic tool in assessing the presence and progression of CRC (Li, et al., 2018).

This study aims to investigate various markers in CRC patients in Erbil city, focusing on assessing key parameters, markers of oxidative stress: Such as 8-OHdG, NT, and MDA, antioxidant enzymes: Such as GSH, GPX1, SOD, CAT, GR, and genetic factors including: (KRAS oncogene), APC, and CCA. Furthermore, the levels of Vitamin E (VIT E).

II. Materials and Methods

A. Patients and Sample Collection

A total of 90 patients diagnosed with CRC were recruited for this study from Rezgari Hospital and Nanakali Hospital in Erbil city. Employing a case–control design, blood samples were systematically collected from CRC patients between April 15, 2022, and April 1, 2023. In addition, 30 healthy subjects were included as a control group for comparative analysis. The inclusion criteria for all patients involved the initial suspicion of diagnosis based on endoscopic observations, followed by confirmation through histopathological examination of colonic biopsies obtained during endoscopy. All enrolled patients were ultimately diagnosed with adenocarcinoma, presenting with varying degrees of differentiation.

B. Sample Processing and Storage

Briefly, after an overnight fast, blood samples were obtained using an ethylenediaminetetraacetic acid vacutainer for the separation of plasma specifically for MDA measurement. Following sample collection, the blood samples underwent centrifugation at 3.000 rpm for 10 min. In post-centrifugation, samples were meticulously processed and subsequently stored at –20°C. This cryopreservation step

ensured the preservation of sample integrity for subsequent analysis.

C. Analytical Techniques

The determination of carcinoembryonic antigen (CEA) levels was conducted using a Roche kit (Roche Company, Germany). Serum levels of oxidative stress markers, including: 8-OHdG, MDA, and NT. Furthermore, the concentration of the antioxidant markers was determined including: GPX1, SOD, CAT, and GR. Finally, the concentration level of both genetic markers and Vitamin E (VIT E) was reported.

D. Enzyme-linked Immunosorbent Assay (ELISA) Analysis

For the quantitative assessment of each enzyme and antigen, specific ELISA kits were employed. These kits were sourced from SunLong Biotech Co., Ltd, Zhejiang, China, ensuring a standardized and precise approach to biomarker quantification. The microplate reader utilized for ELISA analysis was sourced from BioTek Company, USA.

E. Statistical Analysis

Analysis of the data was performed utilizing Statistical Package for the Social Sciences software version 24 (IBM Corp., Armonk, NY, USA). For the comparison of unpaired data, the Student's t-test was employed to assess the uptake values. A significance level of $p < 0.05$ was applied, ensuring a stringent criterion for determining the statistical significance of observed differences (Giovanni and Francesco, 2020).

III. Result and Discussion

A. Demographic and Clinical Characteristics

In Table I, the results reveal that the mean age for the CRC group was 55.65 years, slightly higher than the control group at 50.10 years, showing no significant difference ($p = 0.154$). Gender distribution indicated a higher percentage of females in the CRC group (56.41%) compared to the control group (42.86%), (Fig. 1a). The average body mass index for individuals with CRC was 26.12 kg/m². Regarding cancer staging, the majority of CRC cases were in Stage IV (67.95%), followed by Stage III (29.48%), and a small percentage in Stage II (2.564%), (Fig. 1b). The current study uncovered a higher incidence of CRC in females. This result contradicts previous findings that indicated an age-related increase in the prevalence of CRC, which is typically higher in males (Arnold, et al., 2017), (Patel, et al., 2018), and (Janion, et al., 2020b). Furthermore, our results do not align with those of another study conducted in Iraq, which asserted a male predominance in CRC (Ibrahem, Ahmed and Zangana, 2022). Another study in Iraq similarly noted a slight male predominance (Alrubaie, Alkhalidi, and Abd-Alhusain, 2019).

TABLE I
Demographic and Clinical Characteristics of Colorectal Cancer Patients Compared to the Control Group

Characteristics	Study groups		p-value
	Colorectal cancer (n=90)	Control group (n=30)	
Age (yrs.) Mean±SE	55.65±1.752	50.10±3.656	0.154
Geneder distribution No. (%)			
Male	43 (43.59%)	27 (57.14%)	
Female	57 (56.41%)	23 (42.86%)	
BMI (kg/m²) Mean±SE	26.12±0.815		
TNM stage of cancer			
Stage (IV) 67.95%			
Stage (III) 29.48			
Stage (II) 2.564			
CEA at the time of case diagnosis mean±SEM	35±10.38 (ng/mL)		
CA19.9 at the time of case diagnosis mean±SEM	78.13±16.67 (ng/mL)		

CEA: Carcinoembryonic antigen, BMI: Body mass index

This study used CEA and CA19-9 for the diagnosis and monitoring of CRC in patients of Erbil city. The levels of CEA at the time of case diagnosis were 35 ± 10.38 ng/mL, while carbohydrate antigen 19–9 (CA19.9) levels were 78.13 ± 16.67 ng/mL. CEA and CA19-9 have been extensively investigated for their utility in screening, post-diagnosis follow-up, and treatment monitoring in CRC patients; current guidelines have traditionally endorsed the exclusive use of CEA for prognosis determination, surveillance post-curative resection, and treatment monitoring (Lakemeyer, et al., 2021). Despite CA19-9 not being officially recommended as a valuable marker in CRC patients, assessing pre-operative CEA and CA19-9 levels remains crucial for ongoing monitoring and treatment, with CEA specifically acknowledged as a valuable predictor of overall survival according to guidelines (Hidaka, et al., 2019) and (Lakemeyer, 2023).

B. Oxidative Stress Markers

MDA, the ultimate product of lipoperoxidation, reacts with several nucleic acids, resulting in MDA-DNA oxidation products with pro-mutagenic properties that induce mutations in oncogenes/tumor suppressor genes in human tumors (Zińczuk, et al., 2019b). Oxidative DNA damage, pivotal in the onset and advancement of diseases such as CRC, is closely tied to ROS (Kang, et al., 2023). The inherent instability of ROS hinders precise measurements, leading to the utilization of stable metabolites like 8-OHdG as reliable indicators of oxidative stress and cancer, commonly

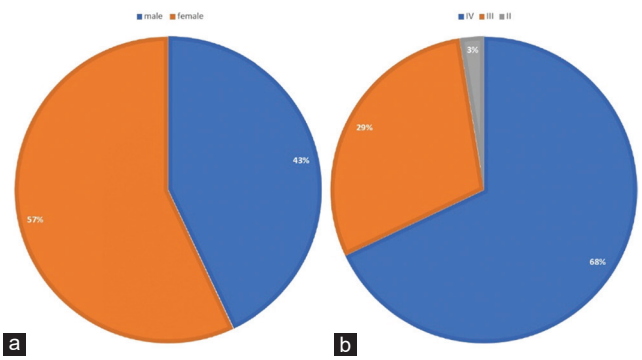

Fig. 1. (a) Represents gender distribution, (b) Represents stages of cancer.

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employed to assess DNA damage in individuals exposed to carcinogens like cigarettes and asbestos (Jelic, et al., 2021).

MDA: MDA levels were significantly elevated in the patient group (1179 ± 74.38 ng/mL, n = 32) compared to the control group (844.1 ± 75.92 ng/mL, n = 40) with a p = 0.0028, suggesting increased lipid peroxidation and oxidative stress, as shown in (Fig. 2).

8-OHdG: The patient group (5682 ± 133.1 ng/mL, n = 32) showed significantly higher (8-OHdG) levels compared to the control group (4783 ± 196.7 ng/mL, n = 39) with a p = 0.0006, as shown in (Fig. 3).

NT: as presented in (Fig. 4), NT showed significant differences (p = 0.0313) between the patient group (19.59 ± 1.339 pg/mL, n = 32) and the control group (25.34 ± 2.301 pg/mL, n = 32). These differences, as indicated by the respective p-values, show lower expression parameters in the patient group.

According to the results, CRC patients exhibited significantly elevated oxidative stress markers including MDA levels and 8-OHdG. Furthermore, it indicates a significant difference in NT levels between the control group (25.34 ± 2.301 pg/mL) and the patient group (19.59 ± 1.339 pg/mL), with a p = 0.0313. These findings align with those of other studies, indicating significantly higher levels of MDA in colorectal patients compared to the control group (Zińczuk, et al., 2019b). Conversely, in a study conducted in Iraq by (Balaky, 2023), the increase in 8-OHdG was non-significant (p = 0.054). The previous study concluded that concentrations of peroxynitrite, and NT were considerably higher in CRC tissue than in normal mucosa, (p < 0.0009) and p = 0.0004, respectively (Zińczuk, et al., 2021).

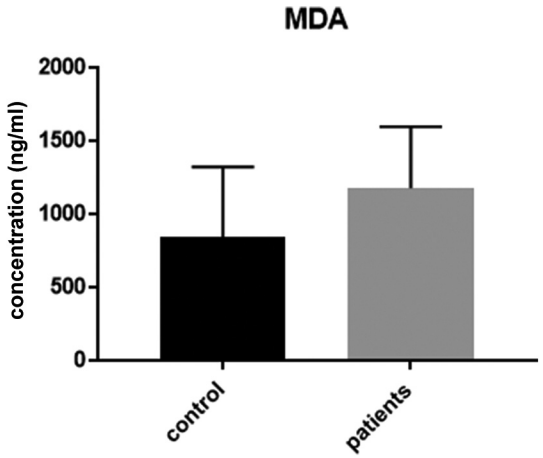

Fig. 2. Malondialdehyde levels in colorectal cancer patients versus control.

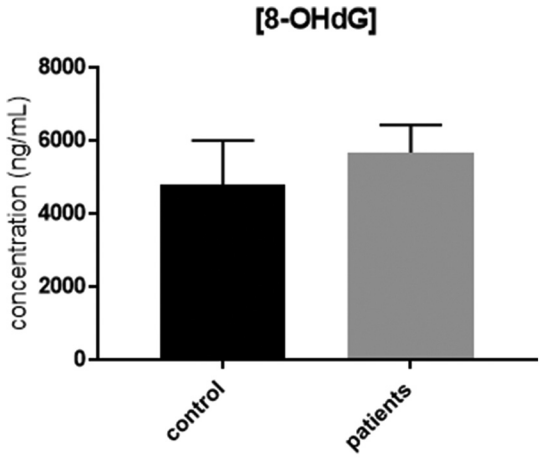

Fig. 3. Circulating concentration of 8-hydroxy-2'-deoxyguanosine.

C. Antioxidant Enzymes

Gpx-1, an antioxidant enzyme, is implicated in cancer development and progression, regulating various cellular processes. The previous study revealed that the first to assess Gpx-1 in European colon adenocarcinoma patients, found high Gpx-1 expression in 78% of specimens, primarily in the cytoplasm, associated with distinct cellular compartments (Zhao, et al., 2022). Statistical analysis revealed significant correlations between elevated Gpx-1 levels and tumor characteristics, suggesting its potential as a prognostic biomarker (Wei, et al., 2020). Specifically, high Gpx-1 expression was significantly associated with tumor histological grade, depth of invasion, angioinvasion, and PCNA immunohistochemical expression (Brzozowa-Zasada, et al., 2023). Notably, Gpx-1 levels varied across tumor grades and stages, emphasizing its diverse roles in different cancer contexts (Borkowska, et al., 2022) and (Brzozowa-Zasada, et al., 2023). SOD, a crucial antioxidant enzyme, showed significantly increased activity in CRC patients, suggesting an adaptive response to elevated ROS formation (Gopčević, et al., 2013) and (Bardelčíková, Šoltys and Mojžiš, 2023). In addition, patients with CRC displayed higher concentrations of uric acid, a key non-enzymatic antioxidant, emphasizing the reinforcement of the antioxidant barrier as a fundamental defense mechanism against heightened free radical production and oxidative stress (Bardelčíková, Šoltys, and Mojžiš, 2023).

Table II and Figs. 5-9 highlight significant distinctions between the control and patient groups, particularly concerning

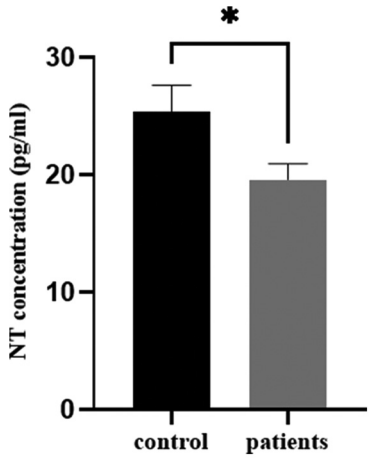

Fig. 4. Comparison of oxidative stress-related parameter between control and patient groups in (Nitrotyrosine).

antioxidant enzymes and key parameters. Specifically, GSH levels were lower in the patient group (66.84 ± 5.072) compared to the control group (89.11 ± 5.226), with a p = 0.0034. The patient group exhibited significantly higher GPX1 levels (3.395 ± 1.129 ng/mL, n = 16) compared to the control group (1.783 ± 0.1248 ng/mL, n = 48) with a p = 0.0203, indicating an enhanced antioxidant response. SOD levels were significantly higher in the patient group (2.099 ± 0.2936 ng/mL, n = 47) compared to the control group (0.9832 ± 0.06143 ng/mL, n = 24) with a p = 0.0089, indicating an enhanced response to oxidative stress. Noteworthy differences were observed in the levels of GR and CAT between the control and patient groups. The control

TABLE II
Comparison of Oxidative Stress-Related Enzymes in Control and Colorectal Cancer Groups

Parameters	Control group Mean±SEM	Patient group Mean±SEM	p-value
GSH	89.11±5.226, n=35	66.84±5.072, n=31	0.0034
GPX1 (ng/mL)	1.783±0.1248, n=48	3.395±1.129, n=16	0.0203
SOD (ng/mL)	0.9832±0.06143, n=24	2.099±0.2936, n=47	0.0089
GR (pg/mL)	388.9±75.87	145.5±19.13	<0.0001
CAT (pg/mL)	0.6282±0.06614	0.4272±0.01397	<0.0001

GPX1: Glutathione peroxidase, SOD: Superoxide dismutase, CAT: Catalase, GR: Glutathione reductase

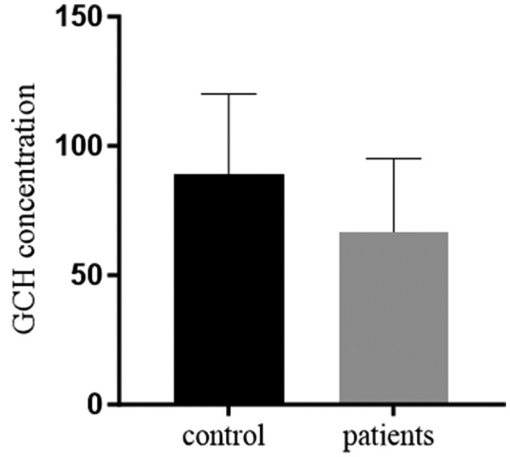

Fig. 5. Displays the concentrations of GSH in both control and patient groups.

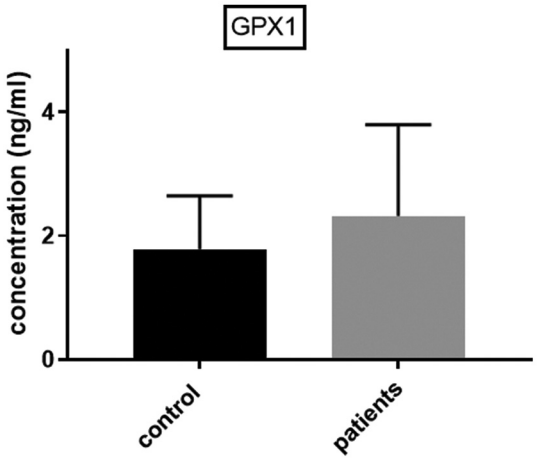

Fig. 6. Depicts the concentrations of glutathione peroxidase in both control and patient groups.

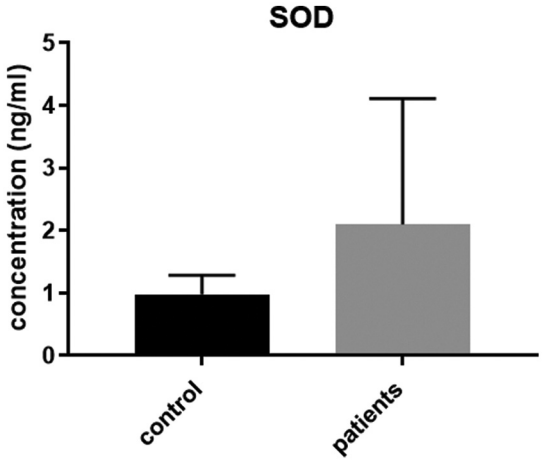

Fig. 7. The levels of superoxide dismutase in both control and patient groups.

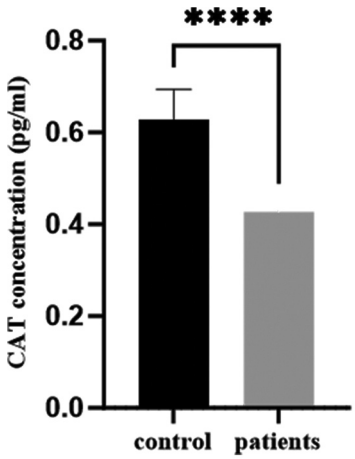

Fig. 8. The levels of catalase in both control and patient groups.

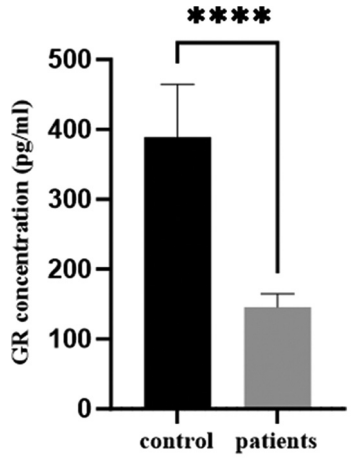

Fig. 9. The levels of glutathione reductase in both control and patient groups.

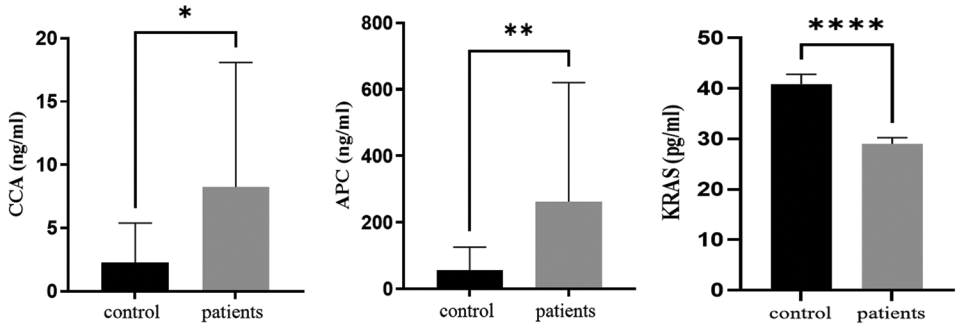

Fig. 10. Genetic markers colorectal cancer antigen, adenomatous polyposis coli, and KRAS concentration in Control and Patient groups.

group exhibited a mean GR level of 388.9 ± 75.87 pg/mL, while the patient group showed a significant decrease at 145.5 ± 19.13 pg/mL ($p < 0.0001$). Similarly, CAT levels displayed a significant decrease in the patient group compared to the control group (0.6282 ± 0.06614 pg/mL vs. 0.4272 ± 0.01397 pg/mL, $p < 0.0001$).

The findings of the present study suggest that GSH levels are significantly lower in the patient group compared to the control group, indicating a potential association between reduced GSH levels and CRC. The finding regarding the serum level of the GSH in CRC patients agree with previous findings (Acevedo-León, et al., 2021) and (Acevedo-León, et al., 2022). Upregulated GPX1 and SOD enzymes compared to controls, which collectively indicating heightened oxidative stress, DNA damage, and altered antioxidant response. The increased concentrations of antioxidant enzymes, such as GPX-1 and SOD, in the serum of cancer patients can be attributed to various factors, including ROS that led to oxidative stress and damage to cellular components. In response, the body upregulates antioxidant enzymes (Zhao, et al., 2022). On the other hand, chronic inflammation, a common feature in many cancers, also contributes to ROS production, prompting an increased expression of antioxidant enzymes (Wang, et al., 2021). In addition, the metabolic changes in cancer cells influence ROS production, and the body's adaptive response involves elevating GPX-1 and SOD levels (Kennedy, et al., 2020) and (Irazabal and Torres, 2020).

These findings agree with studies that concluded significantly elevation of SOD in colorectal patients compared to the control group (Zińczuk, et al., 2019b) and (Balaky, 2023). A study by (Al-Ansari, Al-Gebori, and Sulaiman, 2020) concluded that values of all the tested (GPx) in blood samples were significantly lower in all CRC patient groups as compared to healthy subjects. A study carried out at the Medical University in Łódź affirmed a notable rise in GPx and SOD ($p < 0.05$) among patients in comparison to the healthy control group (Malinowska, et al., 2015).

The results for GR levels show a substantial difference between the control group (388.9 ± 75.87 pg/mL) and the patient group (145.5 ± 19.13 pg/mL), with a highly significant $p < 0.0001$. This significant decrease in the mean concentration of GR in CRC patients compared to the control group suggests potential alterations in redox homeostasis associated with cancer development. Research conducted by (Gopčević, et al., 2013) and (Zińczuk, et al., 2019b), determined that the activity of GR is diminished in all colorectal carcinoma groups when compared to the control. The data for CAT levels indicates a significant difference between the control group (0.6282 ± 0.06614 pg/mL) and the patient group (0.4272 ± 0.01397 pg/mL), with a highly significant $p < 0.0001$. This finding may contribute to the understanding of oxidative stress dynamics in CRC and could be relevant for therapeutic considerations. Results regarding CAT consistent with findings from other studies (Zińczuk, et al., 2019b) and (Acevedo-León et al., 2022).

D. Genetic Markers

The substantial decrease in KRAS concentration in the patient group (<0.0001) indicates a lower expression of the KRAS oncogene in CRC patients (29.03 ± 1.184 pg/mL) compared to the control group (40.85 ± 1.963 pg/mL). APC levels exhibited a substantial increase in the patient group (262.6 ± 52.22 ng/mL) compared to the control group (55.68 ± 13.94 ng/mL), with a $p = 0.0057$. CCA levels were also markedly higher in the patient group (8.255 ± 1.28 ng/mL) compared to the control group (2.255 ± 0.87 ng/mL), with a $p = 0.0338$, as shown in (Fig. 10). The data for all parameters showed significant differences, both APC and CCA levels demonstrate significant increases in the patient group with the $p = 0.0057$ and 0.0338, respectively. Suggesting their potential relevance as markers or indicators associated with CRC. KRAS levels (pg/mL) show that there is a significant difference ($p < 0.0001$) between the patient group (29.03 ± 1.184) and the control group (40.85 ± 1.963). This substantial decrease in the mean concentration of KRAS in CRC patients compared to the control group suggests a potential association between KRAS levels and the presence of CRC. A prior investigation conducted in the same geographical region of Iraq affirmed the presence of APC protein expression in CRC, whereas it was absent in histologically normal-looking colorectal tissue (Altoriah, et al., 2020). As per the findings, the KRAS gene exhibited markedly elevated expression at 15.6 ± 1.82 ($p = 0.001$) in Stage IV CRC cases in comparison to the early stages (Jafri, Mushtaq, and Baig, 2021).

E. Serum Vitamin E

(Fig. 11), Vitamin E levels were significantly lower in the patient group (71.78 ± 6.368, $n = 59$) compared to the

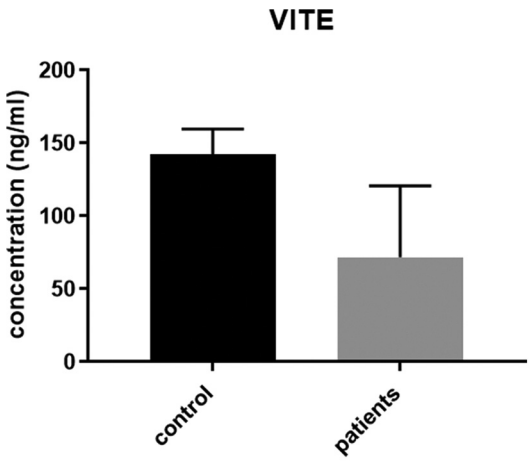

Fig. 11. Serum Vitamin E concentration level.

control group (142.3 ± 4.828, n = 13) with a $p < 0.0001$. Vitamin E levels in the patient group (71.78 ± 6.368 ng/mL, n = 59) were significantly lower than those in the control group (142.3 ± 4.828 ng/mL, n = 13) with a $p < 0.0001$, indicating a potential deficiency or altered metabolism. This observation aligns with another study's results, which reported significantly reduced serum concentrations of Vitamins C and E in the study group compared to the control group ($p < 0.01$) (Chang, et al., 2008).

IV. Conclusion

The present study concluded the following:

- CRC patients exhibited elevated levels of MDA and (8-OHdG), indicating increased oxidative stress, while the concentration of NT was lower in CRC group
- The study identified higher GPX1 and SOD levels in patients, suggesting altered enzymatic activity, while GSH levels are significantly lower
- Notably, oxidative stress-related parameters, including GR, CAT, and the KRAS Oncogene, demonstrated significantly lower expression in patients, while APC and CCA levels demonstrate significant increases in the patient group
- Vitamin E levels were significantly reduced in the patient group.

These findings collectively underscore distinct differences in oxidative stress markers and related enzymes in CRC patients.

V. Conflicts of Interest

The authors have no conflicts of interest to declare.

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