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Assessment of Oxidative and Antioxidant Status in Relation to Selected Trace Elements Among Leukemia Patients in Thi Qar Governorate

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Abstract. The present study aimed to assess selected antioxidant markers and trace elements in patients with hematological malignancies and to examine their variations among different disease groups. The study focused on serum glutathione peroxidase 1 (GPx1), vitamin D3, copper, zinc, and selenium in patients with chronic myeloid leukemia (CML), acute myeloid leukemia (AML), acute lymphoblastic leukemia (ALL), and multiple myeloma (MM). The study included 96 patients diagnosed with CML, AML, ALL, or MM, comprising 41 males and 55 females, with ages ranging from 20 to 85 years. Blood samples were collected from patients attending the Hematology Consultation Unit at Nasiriyah Teaching Hospital between November 2025 and April 2026. A control group of 26 apparently healthy individuals, matched for age and socioeconomic status, was also included. Serum GPx1 and vitamin D3 concentrations were determined using enzyme-linked immunosorbent assay (ELISA), while serum copper, zinc, and selenium concentrations were measured by atomic absorption spectrophotometry (AAS). Data were expressed as median and range, and differences among the studied groups were evaluated using the Kruskal–Wallis test. A p-value of less than 0.05 was considered statistically significant. Serum vitamin D3 levels were significantly higher in all patient groups compared with the control group, with the highest median values observed in MM and AML patients. GPx1 levels differed significantly among the studied groups, with the highest level found in MM patients and the lowest level in CML patients. Serum copper levels were significantly increased in AML and MM patients, whereas lower levels were observed in CML and ALL compared with the control group. Zinc levels showed no statistically significant differences among the studied groups. Selenium levels were significantly decreased in ALL patients and increased in MM patients compared with the control group. The findings indicate that hematological malignancies are associated with alterations in selected antioxidant-related markers and trace elements. The differences in GPx1, vitamin D3, copper, and selenium levels among CML, AML, ALL, and MM patients may reflect variations in oxidative and antioxidant status associated with the different disease types. In contrast, serum zinc did not show a significant difference among the studied groups. These findings support the importance of further investigation of antioxidant markers and trace elements in patients with hematological malignancies.

Keywords: Leukemia, Multiple myeloma, Oxidative stress, Antioxidant status, GPx1, Vitamin D3, Trace elements, Copper, Zinc, Selenium

Introduction

Leukemia is the term used to describe tumors that damage the bone marrow and are derived from blood-forming cells. One characteristic of leukemia is the unregulated growth of white blood cells in the bone marrow and blood[1] Damage to the spleen, bone marrow, and lymph nodes are characteristics of leukemia Large numbers of immature leukocytes, which are normally only present

in the lymph nodes and bone marrow[2][3][4]. One translocation seen in nearly all cases of chronic myelogenous leukemia and infrequently in other types of white blood cell disease is a DNA exchange between chromosomes 9 and 22. The result of this process is a Philadelphia chromosome.[5]

Leukemia is classified as either acute or chronic depending on how quickly it progresses. Leukemia can be further categorized as lymphoid or myeloid based on the type of cell. Acute lymphoid leukemia (ALL), acute myeloid leukemia (AML), chronic lymphoid leukemia (CLL), and chronic myeloid leukemia (CML) are the four forms of leukemia.[6] Beside MM. Multiple myeloma is regarded as a malignant hematological tumor originating from plasma cells in the bone marrow, but not being categorized as a form of leukemia. In the US, multiple myeloma accounts for over 36,000 new cases and over 12,000 deaths annually, accounting for around 10% of all newly diagnosed hematological malignancies. It results in bone deterioration, anemia, poor kidney function, and hypercalcemia.[7]

An imbalance between the production of reactive oxygen species (ROS) and their buildup in the biological system leads to oxidative stress, a biological mechanism.[8] An excess of free radicals and/or a decrease in antioxidants, which are defense mechanisms, seem to be the causes of oxidative stress.[9] Excessive ROS damage cellular structures and macromolecules,leading to cellular dysfunction and ultimately cell death"[10]

Nicotinamide adenine dinucleotide phosphate oxidases (NOX) and mitochondria are the two primary producers of endogenous ROS in tumor cells. ROS have conflicting functions in cells.[11]Oxidative stress, which destroys proteins, lipids, and DNA and promotes the growth of tumor cells, can be brought on by an imbalance between ROS and antioxidants.[12] An "antioxidant" is a molecule that prevents oxidative damage to the cell's lipids, proteins, DNA, RNA, and carbohydrates by blocking or scavenging reactive radicals like ROS and RNS (reactive nitrogen species).[13] ROS are crucial for maintaining cell proliferation, differentiation, and homeostasis in vivo. Antioxidants including GPx,VD3, SOD, catalase, and DNA repair proteins constitute cells' main defense against oxidative stress.[14]

GPx in humans is made up of at least eight different members, known as GPx1 through GPx8.[15] Due to their critical role in antioxidant activity, GPx polymorphisms are associated with a variety of diseases, including cancer, hypertension, vitiligo, neurological disorders, and cardiovascular disease. Glutathione peroxidase 1 (GPx1), also known as cellular GPx, is encoded by the GPX1 gene and is crucial for antioxidant defense mechanisms.[16]

Despite being called a "vitamin," 1,25-Dihydroxyvitamin D(D3) is an active metabolite of vitamin D, which is actually a steroid hormone.[17] Humans can receive vitamin D from food, supplementation, or sun exposure.[18] Antiproliferative, pro-apoptotic, and anti-inflammatory qualities of vitamin D aid in preventing and halting the development of cancer cells.[19] Trace elements are minerals that are present in biological tissues in trace amounts.[20]The human body normally contains trace elements in small amounts, which are essential to the enzyme systems involved in a variety of metabolic processes.[21] Zinc (Zn), cuivre (Cu), selenium (Se). sont des oligo-elements essentiels a la sante humaine. prevents free radicals from forming because it is an antioxidant mineral"[22]

Research shows that zinc increases the expression of metallothionein proteins, which protect DNA and lessen the build-up of ROS.[23] On the other hand, a lack of zinc causes these proteins to be expressed less frequently and increases oxidative stress, which is strongly linked to the onset of leukemia. Reduced levels of zinc have been seen in patients with leukemia and multiple myeloma, indicating a potential role for zinc in the development of these hematological malignancies. Zinc deficiency also compromises immunological function and results in decreased immune effectiveness.[24] Increased formation of free radicals may result from elevated copper levels, which can lead to oxidative stress and the growth and spread of malignant tumors. In addition to influencing the activity of specific enzymes and binding to cellular locations to promote cancer cell proliferation and increase malignancy, copper is a stimulant for angiogenesis, a process required for tumor growth and dissemination.[25][26] "Selenium is a crucial tracelement needed for a variety of biological processes.At least 25 human selenoproteins include selenium,and more specifically the amino acid selenocyysteine"[27]

Higher blood selenium levels are linked to a decreased incidence of malignant tumors, and

epidemiological studies have shown an inverse association between blood selenium concentration and the risk of malignant tumors and associated mortality rates. Additionally, selenium is crucial for controlling the immunological response and boosting immune system effectiveness, which may help lower the incidence of malignant disorders.

Methodology

A total of 96 patients diagnosed with leukemia and multiple myeloma were enrolled in the present study. The study population included 41 males and 55 females. Among the patients, 31 were diagnosed with CML, 22 with AML, 20 with ALL, and 23 with MM. The patients ranged in age from 20 to 85 years. Based on the relevant clinical characteristics, blood samples were collected from patients attending the Hematology Consultation Unit at Nasiriyah Teaching Hospital between November 2025 and April 2026.

The control group consisted of 26 apparently healthy individuals, including 13 males and 13 females. The controls were age-matched with the patient group. The two groups were also comparable in terms of their socioeconomic status.

1. Sample collection and storage.

Approximately 5 mL of venous blood was collected from each participant in the morning. The collected samples were allowed to stand at room temperature for 15–20 minutes to facilitate clot formation. The samples were then immediately centrifuged at 3,000 rpm for 5 minutes. Following centrifugation, two serum aliquots of 500 µL each were transferred from each participant into plastic tubes and stored at −80°C until the time of analysis.

2.1.1. Determination of serum antioxidant and elements.

The concentrations of the antioxidant markers GPx1 and VD3 were determined using the enzyme-linked immunosorbent assay (ELISA) technique. In addition, the serum levels of the trace elements Zn, Cu, and Se were measured using atomic absorption spectrophotometry (AAS) with a Beckman 200 atomic absorption spectrophotometer. This technique is based on the principle that atoms of an element absorb light at a specific wavelength corresponding to the characteristic wavelength of the element. The amount of light absorbed is then used to determine the concentration of the respective element in the sample.

2. Statistical Analysis.

The results were presented as median and range for the studied parameters, and differences between the cancer patient and control groups were evaluated using the Kruskal–Wallis test. The results were also illustrated using bar charts. A p-value of less than 0.05 was considered statistically significant.

Results and Discussion

The results of statistical significance in vitamin D and GPx1 levels between patient groups and control groups are displayed in Table (1). According to the current results, all patient groups had considerably higher levels of vitamin D3. In contrast to the healthy group, Fig. (1). In terms of GPX, MM patients had the highest value, while CML patients had the lowest value,Fig(2). The results of statistical significance for Cu and Se levels in patient groups relative to the control group are displayed in Table (2). Zn, on the other hand, had a non-significant score both within and between patient groups.Fig. (4) According to the current results, the level of Cu dramatically dropped in other groups while increasing in both the AML and MM groups as compared to the control group.Fig. (3) in line with the conclusions of.[28]In comparison to the control group, the level of Se dramatically dropped in the ALL group and increased in the MM group Fig (5).

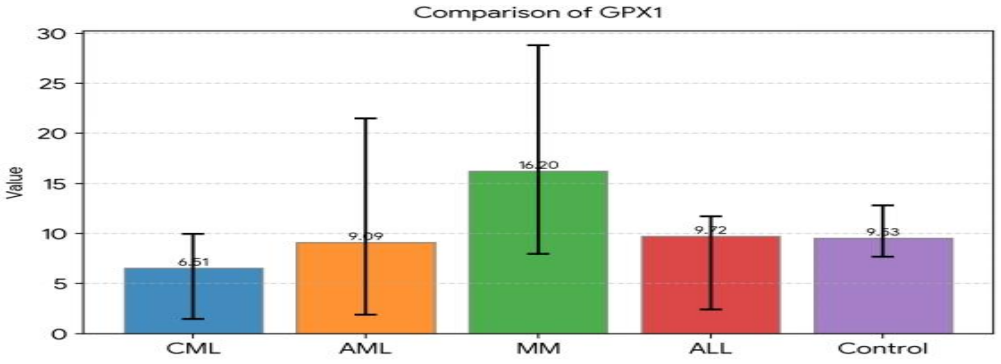
Table 1. Serum Vit-D and Gpx1 levels of studied groups.

Groups	Vit-D3	GPx1
	Median + Range	
CML	5831.3 (3950.7-7390.8)[b]	6.51 (1.47-9.97)[c]
AML	6852.3 (1658.6-8253.7)[a]	9.09 (1.86-21.5)[b]
MM	6865.3 (3875.5-68865.5)[a]	16.2 (7.97-28.8)[a]
ALL	6026.6 (4350.7-7707.4)[ab]	9.72 (2.38-11.7)[b]
Control	2462.0 (2263.6-4281.9)[c]	9.53 (7.65-12.8)[b]
Kruskal-Waillis **Kruskal-Waillis H**	<0.01[**] 55.2	<0.01[**] 48.1
Between Patients Groups **Kruskal-Waillis H**	0.014 10.5	<0.01[**] 39.7

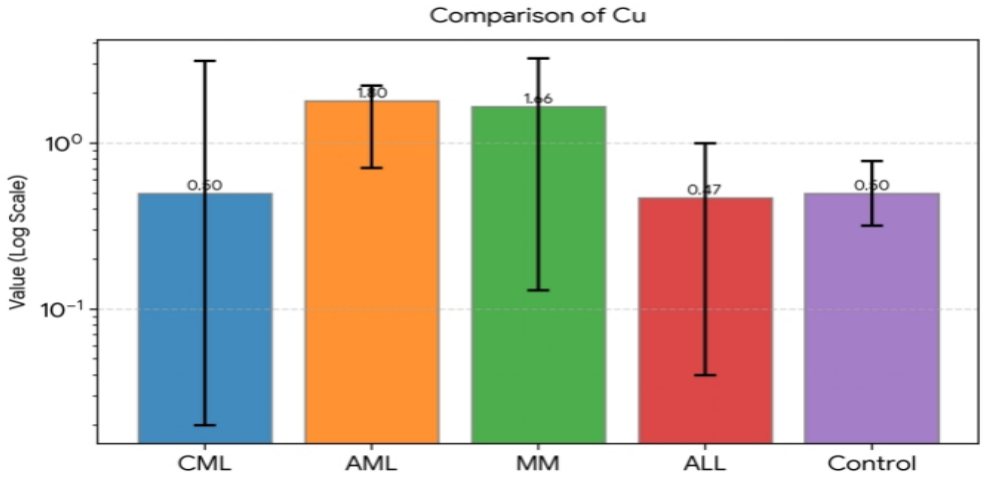
Table (2): Serum Cu ,Zn and Se levels of studied groups**.**

Groups	Cu	Zn	Se
	Median + Range	Median + Range	
CML	0.50 (0.02-3.14)[b]	0.78 (0.15-2.18)	7.42 (63.52-9.98)[b]
AML	1.80 (0.71-2.23)[a]	0.90 (0.00-1.72)	7.30 (3.79-9.76)[b]
MM	1.66 (0.13-3.26)[a]	0.90 (0.03-2.38)	10.3 (4.39-17.3)[a]
ALL	0.47 (0.04-1.00)[b]	0.82 (0.14-10.6)	6.05 (4.04-7.25)[c]
Control	0.50(0.32-0.78)[b]	1.20 (0.58-1.70)	6.77 (3.63-9.27)[bc]
Kruskal-Waillis **Kruskal-Waillis H**	<0.01[**] 31.5	0.461 3.61	<0.01[**] 19.7
Between Patients Groups **Kruskal-Waillis H**	<0.01[**] 22.5	0.915 0.517	<0.01[**] 19.2

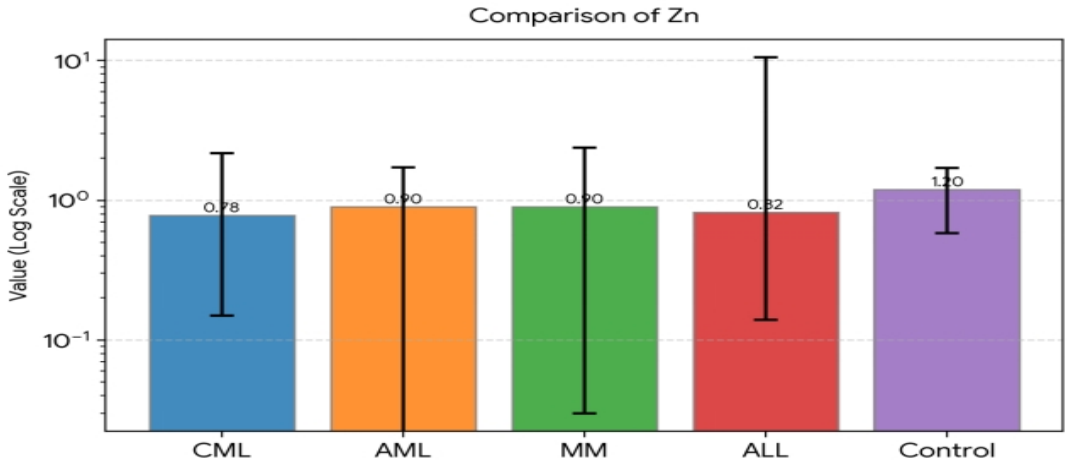
Fig(1): Level of Vit-D3 in studied groups



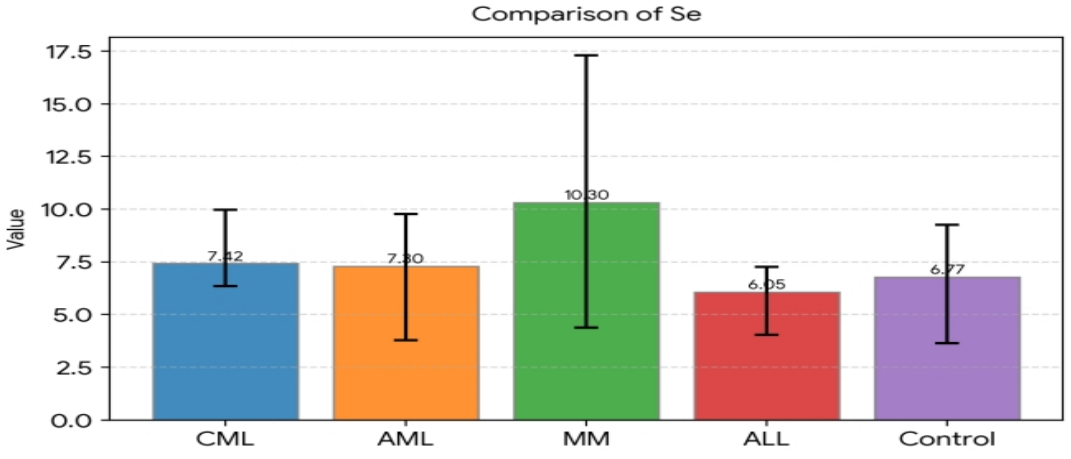
Fig(2): Level of GPx1 in studied groups.



Fig(3): Level of Cu in studied groups**.**



Fig(4): Level of Zn in studied groups**.**



Fig(5): Level of Se in studied groups.

Discussion

Given that the active form of vitamin D has antioxidant qualities, reduces cellular oxidative damage, and increases endogenous antioxidant enzyme systems, the elevation seen in both AML and MM may be explained as an adaptive response to the increased oxidative stress typical of thesehematologic malignancies.[29]Additionally, disease-related changes in vitamin D metabolism may be the cause of the observed variations in serum vitamin D3 levels between patients with hematological malignancies

and healthy controls. The active form of vitamin D has immunomodulatory and anticancer qualities in addition to its well-known function in preserving calcium and phosphorus homeostasis. It might help control cell division, induce apoptosis, and promotecellular differentiation all biological processes that contribute to the emergence and spread of hematological malignancies.[30][31] Additionally, prior research has indicated that hematological malignancies may interfere with vitamin D metabolic pathways by altering the expression of enzymes involved in vitamin D activation and catabolism as well as vitamin D receptor (VDR) signaling. Therefore, rather than representing typical fluctuations in vitamin D level, the discrepancies seen between patients and healthy controls may represent disease-associated dysregulation of vitamin D metabolism.[32][33][34] This disparity could be the result of methodological variances between the two studies as well as variations in patient characteristics, disease stage, and treatment status. It should be mentioned that a number of factors, including renal function, parathyroid hormone status, and the activity of the enzyme Cytochrome P450 Family 27 Subfamily B Member 1 (CYP27B1), control the amount of this active vitamin D metabolite .

Serum GPx1 protein levels are elevated in MM patients. This result is in line with a well-established pattern seen in a number of cancers, especially hematologic cancers that have biological characteristics in common with MM. Research on AML and malignant pleural mesothelioma patients has shown that GPX1 expression is significantly higher in tumor tissue than in surrounding normal tissue.[35][36]. According to information from The Cancer Genome Atlas (TCGA), patients with ALL have higher levels of GPX1.[37]. These findings align with the current study's findings.

However, other research evaluating GPX1 enzyme activity, including Cole and Cort's study, does not support our conclusions.[38] Additionally, compared to healthy individuals, patients with CML in this study showed significantly reduced serum GPX1 protein levels, which is indirectly compatible with the findings of.[39], who reported reduced GPX1 enzyme activity in CML. In contrast,[40] revealed elevated GPX1 expression in BCR::ABL1-T315I mutant CML cells, where GPX1 supported cell survival under metabolic stress and preserved mitochondrial function. Differences in the study population and technique may be the cause of the disparity between their results and the current investigation. While the current study encompassed CML patients with various clinical features and used ELISA to quantify serum GPX1 protein levels, their study only examined drug-resistant CML patients carrying the T315I mutation and assessed GPX1 gene expression. Furthermore, since protein levels do not always correspond to enzymatic activity, the current study's lower GPX1 levels could be a sign of antioxidant defense system depletion and GPX1 dysregulation brought on by ongoing oxidative stress, which could differ depending on the stage of the disease and the state of treatment. Recent evaluations that link GPX1 dysregulation to CML development and treatment response provide credence to this interpretation.[41] . The elevated serum Cu in MM and AML may be attributed to the tumor-associated inflammatory response, which enhances synthesis of the copper-carrier protein ceruloplasmin, alongside increased oxidative stress and the elevated Cu requirements of rapidly proliferating malignant cells to support angiogenesis and tumor growth.[42][43]

When compared to the control group, the level of Se considerablydropped in the ALL group and dramatically increased in the MM group. Patients with multiple myeloma had higher serum selenium levels than healthy controls, which is in line with the results of.[44], who also found that newly diagnosed multiple myeloma patients had higher selenium concentrations. This increase could be a physiological compensating reaction to the elevated oxidative stress linked to the illness. The production of selenoproteins, or GPXs, which are vital for defending cells against oxidative damage and preserving cellular redox equilibrium, depends on selenium, an essential trace element. Therefore, in response to ongoing oxidative stress in multiple myeloma, elevated selenium levels may represent an adaptive mechanism meant to fortify the antioxidant defense system.[45] . However, when compared to healthy controls, it dropped in patients with ALL, which is in line with the findings of. and additionally backed by.[46]. In addition to its crucial function in the synthesis of selenoproteins, particularly glutathione peroxidase, one of the main elements of the cellular antioxidant defense system, this decrease may be explained by increased Se consumption brought on by the oxidative stress linked to the illness. Se deficiency, accordingly, would be expected to impair both the expression and enzymatic activity of this enzyme, thereby weakening antioxidant defenses,

exacerbating oxidative stress, and potentially contributing to the progression of malignancells.[47]

Conclusion

The present study demonstrates that hematological malignancies—specifically CML, AML, ALL, and MM—are characterized by distinct and disease-specific alterations in antioxidant status and essential trace element profiles. The observed elevations in serum active vitamin D3 across all patient groups, alongside significant variations in GPx1 levels, suggest complex cellular responses to cancer-induced oxidative stress and potential alterations in systemic vitamin D metabolism. Furthermore, the specific marked increases of GPx1, copper, and selenium in multiple myeloma and acute myeloid leukemia highlight potential physiological compensatory mechanisms to mitigate ROS production and support tumor-related metabolic demands. In contrast, the reduction of GPx1 and selenium in CML and ALL points toward the depletion of the endogenous antioxidant defense system under prolonged oxidative strain. Although serum zinc concentrations showed no statistically significant differences across the studied patient cohorts, the overall dysregulation of trace elements like copper and selenium highlights their critical involvement in the pathophysiology of hematological cancers. These altered biomarker patterns demonstrate that oxidative stress and antioxidant modulation vary substantially depending on the lineage and specific malignancy type. Collectively, these findings emphasize the relevance of serum GPx1, active vitamin D3, copper, and selenium as potential systemic indicators of oxidative imbalance in patients with hematological malignancies. Monitoring these trace elements and enzymatic antioxidants could offer valuable clinical insights into disease progression, host defense response, and therapeutic stratification. Further large-scale longitudinal investigations are recommended to validate these biological associations, clarify the underlying molecular mechanisms, and determine the potential utility of targeted antioxidant- or element-modulating interventions in hematological oncology.

References

[1] K. Anilkumar, V. Manoj, and T. Sagi, “A survey on image segmentation of blood and bone marrow smear images with emphasis to automated detection of leukemia,” *Biocybernetics and Biomedical Engineering*, vol. 40, no. 4, pp. 1406–1420, 2020.

[2] A. Chennamadhavuni, V. Iyengar, S. K. R. Mukkamalla, and A. Shimanovsky, “Leukemia,” in *StatPearls*. Treasure Island, FL, USA: StatPearls Publishing, 2023.

[3] B. Ye, Y. Sheng, M. Zhang, Y. Hu, and H. Huang, “Early detection and intervention of clonal hematopoiesis for preventing hematological malignancies,” *Cancer Letters*, vol. 538, Art. no. 215691, 2022.

[4] A. Stengel, C. Baer, W. Walter, M. Meggendorfer, W. Kern, T. Haferlach, and C. Haferlach, “Mutational patterns and their correlation to CHIP-related mutations and age in hematological malignancies,” *Blood Advances*, vol. 5, no. 21, pp. 4426–4434, 2021.

[5] A. A. Mo‘minjonov and M. S. Abduljon o‘g‘li, “Leukemia – types, clinical appearances, diagnosis and treatment,” vol. 2, no. 4, 2024.

[6] J. Shen, Z. Lu, J. Wang, T. Zhang, J. Yang, Y. Li, G. Liu, and X. Zhang, “Advances of nanoparticles for leukemia treatment,” *ACS Biomaterials Science & Engineering*, vol. 6, no. 12, pp. 6478–6489, 2020.

[7] R. L. Siegel, T. B. Kratzer, A. N. Giaquinto, H. Sung, and A. Jemal, “Cancer statistics, 2025,” *CA: A Cancer Journal for Clinicians*, vol. 75, no. 1, pp. 10–45, 2025.

[8] N. Shuja, “Unobtrusive health hazard,” *Developmental Medico-Life-Sciences*, vol. 1, no. 2, 2024.

[9] P. Khumploy, *Anti-oxidant and Anti-inflammatory Compounds from Magnolia lilifera (L.) Baill. Flower and Dendrobium signatum Rchb.f.*, Master’s thesis, Chulalongkorn Univ., Bangkok, Thailand, 2020.

[10] A. K. Zaid and S. A. Sayer, “Association abnormal levels of serum interleukin-33, interleukin-23 with oxidant-antioxidants status in patients with acute liver failure,” *University of Thi-Qar Journal of Science*, vol. 9, no. 2, pp. 94–99, 2022.

[11] J. Liu, Y. Li, S. Chen, Y. Lin, H. Lai, B. Chen, and T. Chen, “Biomedical application of

reactive oxygen species-responsive nanocarriers in cancer, inflammation, and neurodegenerative diseases," *Frontiers in Chemistry*, vol. 8, Art. no. 838, 2020.
[12] A. H. Rahmani, "Illustration," BioRender, 2026. [Online]. Available: BioRender canvas. Accessed: Feb. 22, 2026.
[13] W. D. Marak, "Exploring the potential impact of herbal antioxidants on human cardiovascular diseases," *Sciences of Phytochemistry*, vol. 2, no. 2, pp. 70–90, 2023.
[14] H. J. Forman and H. Zhang, "Targeting oxidative stress in disease: Promise and limitations of antioxidant therapy," *Nature Reviews Drug Discovery*, vol. 20, no. 9, pp. 689–709, 2021.
[15] J. Pei, X. Pan, G. Wei, and Y. Hua, "Research progress of glutathione peroxidase family (GPX) in redoxidation," *Frontiers in Pharmacology*, vol. 14, Art. no. 1147414, 2023.
[16] H. K. Krishnamurthy, I. Rajavelu, M. Pereira, V. Jayaraman, T. Wang, K. Bei, and J. N. Rajasekaran, "Inside the genome: Understanding genetic influences on oxidative stress," *Frontiers in Genetics*, vol. 15, Art. no. 1375352, 2024.
[17] C. Carlberg, "The physiology of vitamin D—far more than calcium and bone," *Frontiers in Physiology*, vol. 5, Art. no. 335, 2014.
[18] R. C. Tuckey, C. Y. Cheng, and A. T. Slominski, "The serum vitamin D metabolome: What we know and what is still to discover," *The Journal of Steroid Biochemistry and Molecular Biology*, vol. 186, pp. 4–21, 2019.
[19] S. Ayudhia, A. Zatil Izah, F. Arbi, and F. F. Yani, "Vitamin D status in children with acute leukemia," *Sari Pediatri*, vol. 24, no. 1, pp. 51–55, 2022.
[20] A. O. Jebril, S. M. Abushkuna, A. M. Bishr, O. A. Abdulrhman, S. A. Alanabrok, E. K. Kshad, A. A. Abdrahaman, and I. M. Aglan, "Trace elements in blood of leukemia patients," *Mediterranean Journal of Pharmacy and Pharmaceutical Sciences*, vol. 3, no. 4, pp. 7–12, 2023.
[21] N. A. Jaber and M. M. Alwash, "Trace elements (selenium, copper and zinc) in de novo acute leukemia: Serum levels and their relation with some clinical and laboratory parameters," *Iraqi Journal of Hematology*, vol. 12, no. 2, pp. 105–110, 2023.
[22] S. A. Hassouni, J. T. Ahmed, and S. J. Mohammed, "Effect of socio-demographic characteristics on level of zinc in serum of adults in Najaf," *University of Thi-Qar Journal of Science*, vol. 10, no. 1, Special Issue: ISCAMET, pp. 25–30, 2023.
[23] L. Jing, L. Li, J. Zhao, J. Zhao, Z. Sun, and S. Peng, "Zinc-induced metallothionein overexpression prevents doxorubicin toxicity in cardiomyocytes by regulating the peroxiredoxins," *Xenobiotica*, vol. 46, no. 8, pp. 715–725, 2016.
[24] M. Kang, L. Zhao, M. Ren, M. Deng, and C. Li, "Reduced metallothionein expression induced by zinc deficiency results in apoptosis in hepatic stellate cell line LX-2," *International Journal of Clinical and Experimental Medicine*, vol. 8, no. 11, pp. 20603–20609, 2015.
[25] S. Valadbeigi, S. Javadian, M. Ebrahimi-Rad, S. Khatami, and R. Saghiri, "Assessment of trace elements in serum of acute lymphoblastic and myeloid leukemia patients," *Experimental Oncology*, vol. 41, no. 1, pp. 69–71, 2019.
[26] J. Milenković, B. Djordjević, D. Stojanović, O. Dunjić, and V. Petrovski, "Blue moonlighting in the immune response: Roles of copper and ceruloplasmin in the pathogenesis of inflammation and immune-mediated diseases," *Acta Medica Medianae*, vol. 61, no. 2, pp. 60–71, 2022.
[27] J. S. Jabbar and M. A. Auda, "Study the relationship between selenium, vitamin B6, B12 and hyperhomocysteine in patients with cardiovascular disease in Thi-Qar Governorate," *University of Thi-Qar Journal of Science*, vol. 10, no. 1, pp. 95–100, 2023.
[28] J. Wang *et al.*, "The progress in the relationship between trace elements and acute lymphoblastic leukemia," *Frontiers in Cell and Developmental Biology*, 2023.
[29] A. N. Kul, B. Ozturk Kurt, H. Yildiz, *et al.*, "Comparison of trace elements in peripheral blood and bone marrow of newly diagnosed multiple myeloma patients," *Clinical and Experimental Medicine*, vol. 24, no. 1, Art. no. 78, 2024.
[30] D. D. Bikle and S. Christakos, "New aspects of vitamin D metabolism and action—

Addressing the skin as source and target," *Nature Reviews Endocrinology*, vol. 16, no. 4, pp. 234–252, 2020.

[31] K. K. Deeb, D. L. Trump, and C. S. Johnson, "Vitamin D signalling pathways in cancer: Potential for anticancer therapeutics," *Nature Reviews Cancer*, vol. 7, no. 9, pp. 684–700, 2007.

[32] D. Feldman, A. V. Krishnan, S. Swami, E. Giovannucci, and B. J. Feldman, "The role of vitamin D in reducing cancer risk and progression," *Nature Reviews Cancer*, vol. 14, no. 5, pp. 342–357, 2014.

[33] J. C. Fleet, M. DeSmet, R. Johnson, and Y. Li, "Vitamin D and cancer: A review of molecular mechanisms," *Biochemical Journal*, vol. 474, no. 17, pp. 289–315, 2017.

[34] P. Sobhi, M. Bahrami, F. Mahdizadeh, *et al.*, "Vitamin D and potential effects on cancers: A review," *Molecular Biology Reports*, vol. 51, no. 1, Art. no. 190, 2024.

[35] N. Zhang *et al.*, "Key genes of vitamin D metabolism and their roles in the risk and prognosis of cancer," *Cancer Cell International*, vol. 25, Art. no. 231, 2025.

[36] A. F. Gharib, M. A. Eldeen, A. S. Khalifa, W. H. Elsawy, E. M. Eed, A. El Askary, R. A. Eid, M. A. Soltan, and N. Raafat, "Assessment of glutathione peroxidase-1 (GPX1) gene expression as a specific diagnostic and prognostic biomarker in malignant pleural mesothelioma," *Diagnostics*, vol. 11, no. 12, Art. no. 2285, 2021.

[37] J. Wei, Q. Xie, X. Liu, C. Wan, W. Wu, K. Fang, Y. Yao, P. Cheng, D. Deng, and Z. Liu, "Identification the prognostic value of glutathione peroxidases expression levels in acute myeloid leukemia," *Annals of Translational Medicine*, vol. 8, no. 11, Art. no. 678, 2020.

[38] S. Xiao, N. Xu, Q. Ding, S. Huang, Y. Zha, and H. Zhu, "LncRNA VPS9D1-AS1 promotes cell proliferation in acute lymphoblastic leukemia through modulating GPX1 expression by miR-491-5p and miR-214-3p evasion," *Bioscience Reports*, vol. 40, no. 10, Art. no. BSR20193461, 2020.

[39] T. N. K. Coca Pragnya, G. Sadashivudu, L. V. Gandhi, S. Lakshmi, and D. Raghunadharao, "Effects of imatinib therapy on serum calcium, phosphate and magnesium levels and correlation with musculoskeletal symptoms in chronic myeloid leukemia patients," *Indian Journal of Medical and Paediatric Oncology*, vol. 33, Suppl. 1, pp. S13–S18, 2012.

[40] M. Ammar, A. Boughammoura, M. B. Hmida, I. Ben Amor, N. Mnasri, B. Kacem, and N. Ben Ali, "Relationship of oxidative stress in the resistance to imatinib in Tunisian patients with chronic myeloid leukemia: A retrospective study," *Journal of Clinical Laboratory Analysis*, vol. 34, no. 2, Art. no. e23050, 2020.

[41] J.-D. Wang, J.-X. Wang, Z.-L. Li, N. Xu, L. Zhang, J.-J. Liu, R. Gao, and Z.-J. Long, "GPX1 confers resistance to metabolic stress in BCR/ABL-T315I mutant chronic myeloid leukemia cells," *Cell Death Discovery*, vol. 11, Art. no. 229, 2025.

[42] A. Allegra, G. Mirabile, S. Caserta, *et al.*, "Oxidative stress and chronic myeloid leukemia: A balance between ROS-mediated pro- and anti-apoptotic effects of tyrosine kinase inhibitors," *Antioxidants*, vol. 13, no. 4, Art. no. 461, 2024.

[43] D. Denoyer, S. Masaldan, S. La Fontaine, and M. A. Cater, "Targeting copper in cancer therapy: 'Copper That Cancer,'" *Metallomics*, vol. 7, no. 11, pp. 1459–1476, 2015.

[44] E. J. Ge, A. I. Bush, A. Casini, P. A. Cobine, J. R. Cross, G. M. DeNicola, *et al.*, "Connecting copper and cancer: From transition metal signalling to metalloplasia," *Nature Reviews Cancer*, vol. 22, no. 2, pp. 102–113, 2022.

[45] A. N. Kul, B. Ozturk Kurt, H. Yildiz, *et al.*, "Comparison of trace elements in peripheral blood and bone marrow of newly diagnosed multiple myeloma patients," *Clinical and Experimental Medicine*, vol. 24, no. 1, Art. no. 78, 2024.

[46] C. Shen, K. Zhang, J. Yang, J. Shi, C. Yang, Y. Sun, and W. Yang, "Association between metal(loid)s in serum and leukemia: A systematic review and meta-analysis," *Journal of Environmental Health Science and Engineering*, vol. 21, no. 1, pp. 201–213, 2023.

[47] F. Krannich, R. Mucke, J. Buntzel, J. Hübner, and O. Micke, "A systematic review of selenium as a complementary treatment in cancer patients," *Complementary Therapies in Medicine*, vol. 86, Art. no. 103095, 2024.