DOI:10.31557/APJCB.2025.10.4.859

RESEARCH ARTICLE

Evaluation of Gamma-Glutamyl Transferase as a Diagnostic Biomarker for Prostate Cancer in Iraqi Patients

Najlaa Abdulameer Ali AL-Dahhan[1], Hadi Hasan Hadi[2], Zahraa Hamza Abdulzahraa[3]

[1]College of Dentistry, University of Kufa, Al-Najaf, Iraq. [2]Department of Chemistry, College of Science, University of Kufa, Al-Najaf, Iraq. [3]Department of Anesthesia techniques, College of health and medical techniques / Kufa Al furat Al Awsat technical university, 31003 Alkufa lraq.

Abstract

Background: Prostate cancer remains the most prevalent malignancy and leading cause of cancer-related mortality among men worldwide. This study investigated the diagnostic potential of serum gamma-glutamyl transferase (GGT) as a novel biomarker for Prostate cancer detection compared to established markers. **Methods:** A case-control study was conducted with 80 histologically confirmed Prostate cancer patients and 80 age-matched healthy controls. Serum levels of prostate-specific antigen (PSA), malondialdehyde (MDA), paraoxonase 1 (PON1), arylesterase (ARE), and GGT were quantified using ELISA. **Results:** Significantly elevated levels of PSA, MDA, and PON1 were observed in prostate cancer patients compared to controls ($p \leq 0.001$ for all). In contrast, ARE activity was significantly reduced in patients ($p \leq 0.001$). Serum GGT levels were significantly higher in prostate cancer patients than in healthy controls, though this difference did not reach statistical significance ($p = 0.104$). The mean difference in GGT levels between prostate cancer patients and controls was 16.17 U/L (95% CI: −2.65 to 34.99), which was not statistically significant ($p = 0.104$). In contrast, PSA levels exhibited a significant mean difference of 79.67 ng/mL (95% CI: 27.87 to 131.47; $p \leq 0.001$). Multivariate analysis revealed a non-significant inverse correlation between MDA and GGT in the prostate cancer group ($r = -0.18$, $p = 0.12$). **Conclusions:** The use of serum GGT as an independent prognostic biomarker for prostate cancer has limited clinical utility due to its poor specificity and sensitivity, despite its significantly elevated levels in patients. In contrast, oxidative stress markers (MDA, PON1, ARE) and PSA have shown stronger prognostic potential, with PSA remaining the most effective single marker. The observed trends highlight the potential of oxidative stress biomarkers as complementary tools.

Keywords: Prostate cancer- GGT- oxidative stress- diagnostic biomarkers- PSA

Asian Pac J Cancer Biol, **10 (4)**, 859-864

Submission Date: 06/27/2025 Acceptance Date: 09/11/2025

Introduction

Prostate cancer is the second most common type of cancer and the leading cause of cancer-related death among men in the United States and Western countries [1, 2]. Prostate cancer may not show symptoms in its early stages, and its course is often slow, requiring only active surveillance [2]. An imbalance between oxidants and reductants in vivo indicates oxidative stress (OS),which results from the increased production of highly reactive molecules known as reactive oxygen species (ROS). This imbalance can lead to DNA damage, and consequently, cancer development [3, 4].

OS damages various cellular components, including lipids, proteins, and DNA, and has been implicated in Prostate cancer pathogenesis. ROS are produced as by-products of cellular metabolism, with superoxide anions (O_2^-) and hydrogen peroxide (H_2O_2) being major endogenous sources [5]. Carcinogens partially exert their effects by generating ROS during metabolic processes [6]. Elevated ROS levels lead to a significant reduction in antioxidant defenses, resulting in oxidative damage to proteins, lipids, and DNA, as well as disruption of cellular functions [7].

Corresponding Author:
Dr. Najlaa Abdulameer Ali AL-Dahhan
College of Dentistry, University of Kufa, Al-Najaf, Iraq.
Email: najlaa.aldahhan@uokufa.edu.iq

PSA is widely used as a Prostate cancer biomarker; however, it cannot reliably distinguish between prostate cancer and benign prostatic hyperplasia (BPH) unless cancer progresses, at which point serum PSA levels become significantly higher compared to BPH [8]. Elevated PSA levels correlate with Prostate cancer severity [9].

Serum MDA levels, a marker of OS, may increase in various prostatic lesions and are often assessed alongside PSA [10, 11]. PON1 , ARE, and the HDL-bound enzyme system function as antioxidants. This enzyme system protects lipoproteins (LDL and HDL) from oxidation by hydrolyzing bioactive phospholipids and lipid peroxidation products,thereby preventing atherosclerosis [12, 13]. This study aimed to measure serum levels of PSA, MDA, and GGT, as well as PON1 and ARE activities, in newly diagnosed Prostate cancer patients. Additionally, we sought to evaluate the relationship between these markers and determine whether serum GGT could serve as a sensitive biomarker for Prostate cancer detection.

Materials and Methods

Study subjects

A case-control study was conducted involving 80 men diagnosed with Prostate cancer (ages 45-75 years) and 80 apparently healthy control subjects. The study was carried out at the urology clinic of Al-Sadder Teaching Hospital in Najaf City, Iraq, from March 2024 to August 2024. The study was conducted after obtaining informed consent from each patient and healthy control. Patients undergoing Prostate cancer treatment were excluded from the study. All participants had no history of liver pathology, and their plasma alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), and GGT levels were within normal ranges. None of the participants were alcohol consumers.

Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Five milliliters of venous blood were collected from each subject. Two milliliters were immediately placed in EDTA tubes and divided into two aliquots: one for MDA level determination and the other for plasma separation to measure uric acid levels. The remaining three milliliters of blood were allowed to clot, and serum was separated by centrifugation at 3,000 rpm for 15 minutes. The serum samples were stored at -20°C for subsequent analysis of PSA, ALT, AST, ALP, and total bilirubin (TB) levels. All serum markers were measured using ELISA.

Serum PON1 activity was determined using the method described by Eckerson et al. [14]. Serum ARE activity was measured using phenylacetate as a substrate according to the protocol established by Haagen and Brock [15].

Biochemical measurements

Serum AST and ALT activities were determined according to the method of Bergmeyer and Bernt [16]. Serum ALP activity was measured using the Walter and Schütt protocol [17]. Total bilirubin levels were assessed colorimetrically following the procedure by Rutkowski and DeBaare [18], while plasma uric acid levels were determined according to Bergman and Shabtay's method [19].

Serum MDA levels were evaluated using the thiobarbituric acid reactive substances (TBARS) assay. Serum GGT activity was measured following the Odorsen and Strømme method [20] using a commercial kit (Agape Diagnostic Laboratory, UK). The absorbance at 412 nm was recorded, showing a direct correlation with GGT activity in the sample.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 20.0, IBM Corp., Armonk, NY, USA). Data were expressed as mean ± standard deviation(SD). Differences between means were assessed using independent samples t-test (for continuous variables) and chi-square test (for categorical variables). A p-value < 0.05 was considered statistically significant. Pearson's correlation coefficient (r) was used to evaluate relationships between variables. The significance of correlations was tested using t-tests for correlation coefficients. Mean differences between prostate cancer patients and controls were calculated. 95% confidence intervals (95% CI) for the mean differences were determined using t-distribution.

Results

No significant differences were observed in mean age, weight, or BMI between prostate cancer patients and controls (Table 1).

Biomarker profile of prostate cancer patients indicated a significant increase in PSA levels (mean difference: +79.67 ng/ml; 95% CI: 27.87-131.47; $p \leq 0.001$), a significant increase in MDA levels (+2.98 µmol/L; 95% CI: 0.96-5.00; $p \leq 0.001$),and a significant increase in PON1 activity (+48.45 U/L; 95% CI: -70.38-167.28; $p \leq 0.001$). While ARE activity were observed a significant decrease in patients (-6.01 kU/L; 95% CI: -157.85-145.83; $p \leq 0.001$). Serum GGT levels were quantitatively higher in prostate cancer patients (mean difference: 16.17 U/L), this difference did not reach statistical significance (95% CI: -2.65-34.99, $p = 0.104$) (Tables 2 and 3).

No significant correlation was found between MDA and GGT ($r = -0.18$; $p = 0.12$). MDA showed a positive correlation with PSA, PON1, and ARE, but a non-significant negative correlation with GGT ($r = -0.46$; $p = 0.740$). No significant correlation was observed between PSA and GGT ($r = 0.05$; $p = 0.867$). In controls: All correlations between MDA and other markers were negative (Table 4).

Discussion

Prostate cancer remains the second most prevalent malignancy among men globally and the fifth leading cause of cancer-related mortality [2, 9]. Our analysis revealed no statistically significant differences in mean BMI, age, or weight between prostate cancer patients

Table 1. Demographic Characteristics and Clinical Parameters Across Study Groups

Parameters	Patients (n=80) (mean ± SD)	Control (n=80) (mean ± SD)	P-value
Age (yr)	65.60±6.11	63.28±6.30	NS
Weight (kg)	73.88±4.51	71.53±4.47	NS
BMI (kg/m^2)	24.65±2.21	22.86±1.65	NS
Height (m)	1.59±00.06	1.68±0.05	<0.05
TB(mg/dl)	1.43 ±0.72	0.43 ±0.30	<0.05
Uric acid (mg/dl)	2.27 ±0.73	3.74 ±0.79	<0.05

NS, Non Significant; TB:Total Bilirubin; Significant if ($p<0.05$).

Table 2. Serum Levels of MDA, PON1, ARE, PSA, and GGT in Prostate Cancer Patients and Controls

Parameters	Patients (n=80) (mean ± SE)	Control (n=80) (mean ± SE)	P-value
MDA (µmol/l)	3.07±1.03	0.09±0.10	$P \leq 0.001$
PON1 (U/L)	123.66±40.22	75.21±45.33	$P \leq 0.001$
ARE (kU/L)	150.22±52.32	156.23±57.11	$P \leq 0.001$
PSA (ng/ml)	80.35±26.43	0.68±0.44	$P \leq 0.001$
GGT(U/L)	43.83±7.12	27.66±6.44	0.104

and healthy controls (Table 1), indicating that these variables did not confound the biomarker outcomes. Prostate carcinogenesis is driven by progressive genetic alterations under OS, wherein an imbalance between the production of ROS and the cellular repair capacity initiates pathological cascades [21, 22]. ROS-mediated lipid peroxidation compromises membrane integrity, increases tissue permeability, and propagates oxidative damage [23].

Serum levels of PSA, MDA, and PON1 were significantly elevated in prostate cancer patients compared to controls (all $p \leq 0.001$), while ARE activity was markedly reduced ($p \leq 0.001$). In contrast, GGT levels showed a non-significant increase ($p = 0.104$) (Table 2). MDA, a stable end-product of lipid peroxidation, serves as a surrogate marker for ROS activity. Its significant elevation in patients ($p \leq 0.001$) aligns with prior studies linking OS to prostate cancer pathogenesis [22, 24-26]. ROS-induced oxidation of polyunsaturated fatty acids leads to the formation of lipid peroxides and MDA-protein adducts, which can inactivate vital cellular components. Similar OS-induced MDA elevations have been reported in hepatic [27], colorectal [28], and lung [29] cancers, underscoring its broad involvement in carcinogenesis [30, 31]. These findings support the rationale for developing therapeutic strategies targeting oxidative damage in prostate cancer [32].

The significant elevation of PSA ($p \leq 0.001$) reaffirms its established role as a diagnostic biomarker. Its association with decreased antioxidant levels [33, 34] suggests that PSA may also reflect OS severity, potentially enhancing its sensitivity in prostate cancer detection. ROS-induced

Table 3. Mean Differences and 95% CI of Studied Parameters between Prostate Cancer Patients and Controls

Parameter	Mean Difference	95% CI(Confidence Interval)	Statistical Significance (p-value)
MDA (µmol/L)	2.98	(0.96, 5.00)	$P \leq 0.001$
PON1 (U/L)	48.45	(-70.38, 167.28)	$P \leq 0.001$
ARE (kU/L)	-6.01	(-157.85, 145.83)	$P \leq 0.001$
PSA (ng/mL)	79.67	(27.87, 131.47)	$P \leq 0.001$
GGT (U/L)	16.17	(-2.65, 34.99)	0.104

Table 4. Correlation between Biochemical Parameters in the Study Groups

Parameters	Patients (n=80)		Control (n=80)	
	r	p-value	r	p-value
MDA Vs GGT	-0.46	0.74	-0.02	0.876
MDA Vs PSA	0.08	0.756	-0.33	0.36
MDA Vs PON1	0.07	0.627	-0.31	0.338
MDA Vs ARE	0.06	0.622	-0.22	0.276
PSA Vs GGT	0.05	0.867	0.21	0.442

DNA damage, as evidenced by elevated levels of 8-hydroxy-2'-deoxyguanosine (8-OHdG) in smokers and patients with renal failure [2, 24, 25, 30, 35], further emphasizes the role of oxidative insults in carcinogenesis.

The significant reduction in PON1 activity ($p \leq 0.001$) [13, 36-38] may reflect its consumption during ROS neutralization or its structural denaturation by superoxide anions. Likewise, diminished ARE activity ($p \leq 0.001$) [39-41] correlates with the severity of OS and may be exacerbated by HDL dysfunction. This inverse relationship between PON1/ARE and oxidative damage highlights their importance in the body's antioxidant defense mechanisms. Despite a higher mean GGT level observed in patients (mean difference: 16.17 U/L; 95% CI: −2.65 to 34.99; $p = 0.104$), the lack of statistical significance and the weak correlation with MDA ($r = −0.46$, $p = 0.740$) [22, 24, 33, 42, 43] limit its applicability as an independent biomarker. Conversely, the strong discriminatory capacity of PSA (mean difference: 79.67 ng/mL; 95% CI: 27.87 to 131.47; $p \leq 0.001$) reaffirms its clinical relevance (Tables 3 & 4). While OS biomarkers (MDA, PON1, ARE) and PSA demonstrate substantial diagnostic potential, the nonspecific nature of GGT restricts its clinical utility.These results are consistent with previous studies [2, 24, 33, 42, 44]. Collectively, these results position OS markers (MDA, PON1, ARE) as potentially valuable adjuncts to PSA in prostate cancer diagnostics, while underscoring GGT's restricted standalone diagnostic value. The notable reduction in ARE activity particularly merits further investigation into its pathophysiological role in carcinogenesis. These results establish OS markers as promising additions to PSA, although further large-scale studies are needed to improve their clinical applications, particularly in Iraqi populations, to establish optimal biomarker combinations.

In conclusion, while serum PSA remains the gold standard for prostate cancer detection, OS markers (MDA, PON1, ARE) show promise as complementary biomarkers for early-stage identification. Although serum GGT levels are elevated in patients, its poor specificity and sensitivity limit its diagnostic utility as a standalone marker. Our findings suggest that PSA combined with OS markers may improve diagnostic accuracy.

Acknowledgments

Statement of Transparency and Principals

- Author declares no conflict of interest
- Study was approved by Research Ethic Committee of author affiliated Institute.
- Study's data is available upon a reasonable request.
- All authors have contributed to implementation of this research.

References

1. Kawakami K, Fujita Y, Matsuda Y, Arai T, Horie K, Kameyama K, Kato T, et al. Gamma-glutamyltransferase activity in exosomes as a potential marker for prostate cancer. BMC cancer. 2017 05 05;17(1):316. https://doi.org/10.1186/s12885-017-3301-x
2. Rawla P. Epidemiology of Prostate Cancer. World Journal of Oncology. 2019 04;10(2):63-89. https://doi.org/10.14740/wjon1191
3. Finkel T. Signal transduction by reactive oxygen species. The Journal of Cell Biology. 2011 07 11;194(1):7-15. https://doi.org/10.1083/jcb.201102095
4. Shazia Q, Mohammad ZH, Rahman T, Shekhar HU. Correlation of oxidative stress with serum trace element levels and antioxidant enzyme status in Beta thalassemia major patients: a review of the literature. Anemia. 2012;2012:270923. https://doi.org/10.1155/2012/270923
5. Elahi MM, Kong YX, Matata BM. Oxidative stress as a mediator of cardiovascular disease. Oxidative Medicine and Cellular Longevity. 2009;2(5):259-269. https://doi.org/10.4161/oxim.2.5.9441
6. Birben E, Sahiner UM, Sackesen C, Erzurum S, Kalayci O. Oxidative stress and antioxidant defense. The World Allergy Organization Journal. 2012 01;5(1):9-19. https://doi.org/10.1097/WOX.0b013e3182439613
7. Udensi UK, Tchounwou PB. Dual effect of oxidative stress on leukemia cancer induction and treatment. Journal of experimental & clinical cancer research: CR. 2014 Dec 18;33:106. https://doi.org/10.1186/s13046-014-0106-5
8. Catalona WJ, Richie JP, Ahmann FR, Hudson MA, Scardino PT, Flanigan RC, DeKernion JB, et al. Comparison of digital rectal examination and serum prostate specific antigen in the early detection of prostate cancer: results of a multicenter clinical trial of 6,630 men. The Journal of Urology. 1994 05;151(5):1283-1290. https://doi.org/10.1016/s0022-5347(17)35233-3
9. Almushatat ASK, Talwar D, McArdle PA, Williamson C, Sattar N, O'Reilly DSJ, Underwood MA, McMillan DC. Vitamin antioxidants, lipid peroxidation and the systemic inflammatory response in patients with prostate cancer. International Journal of Cancer. 2006 02 15;118(4):1051-1053. https://doi.org/10.1002/ijc.21451
10. Srivastava DSL, Mittal RD. Free radical injury and antioxidant status in patients with benign prostate hyperplasia and prostate cancer. Indian journal of clinical biochemistry: IJCB. 2005 07;20(2):162-165. https://doi.org/10.1007/BF02867419
11. Setyaningsih Y, Husodo AH, Astuti I. Detection of Urinary 8-hydroxydeoxyguanosine (8-OHdG) Levels as a Biomarker of Oxidative DNA Damage among Home Industry Workers Exposed to Chromium. Procedia Environmental Sciences. 2015 01 01;23:290-296. https://doi.org/10.1016/j.proenv.2015.01.043
12. Eren E, Yilmaz N, Aydin O. High Density Lipoprotein and it's Dysfunction. The Open Biochemistry Journal. 2012 07 27;6:78-93. https://doi.org/10.2174/1874091X01206010078
13. Watson AD, Berliner JA, Hama SY, La Du BN, Faull KF, Fogelman AM, Navab M. Protective effect of high density lipoprotein associated paraoxonase. Inhibition of the biological activity of minimally oxidized low density lipoprotein. The Journal of Clinical Investigation. 1995 Dec;96(6):2882-2891. https://doi.org/10.1172/JCI118359
14. Eckerson HW, Romson J, Wyte C, La Du BN. The human serum paraoxonase polymorphism: identification of phenotypes by their response to salts. American Journal of

Human Genetics. 1983 03;35(2):214-227.
15. Haagen L, Brock A. A new automated method for phenotyping arylesterase (EC 3.1.1.2) based upon inhibition of enzymatic hydrolysis of 4-nitrophenyl acetate by phenyl acetate. European Journal of Clinical Chemistry and Clinical Biochemistry: Journal of the Forum of European Clinical Chemistry Societies. 1992 07;30(7):391-395. https://doi.org/10.1515/cclm.1992.30.7.391
16. Bergmeyer HU, Bernt E. Methods of enzymatic analysis. 2nd ed. New York: Academic Press. 1974;:p. 735.
17. Walter K, Schütt C. In: Bergmeyer HU, editor. Methods of enzymatic analysis. 2nd ed. Vol 2. New York: Academic Press. 1974;:p. 860-4.
18. Rutkowski RB, DEBaare L. An ultramicro colorimetric method for determination of total and direct serum bilirubin. Clinical Chemistry. 1966 07;12(7):432-438.
19. Bergmann F, Dikstein S. Studies on uric acid and related compounds. I. Quantitative determination of uric acid in biological fluids. The Journal of Biological Chemistry. 1954 Nov;211(1):149-153.
20. Theodorsen L, Stromme JH. Gamma-Glutamyl-3-carboxy-14-nitroanilide: the substrate of choice for routine determinations of gamma-glutamyl-transferase activity in serum?. Clinica Chimica Acta; International Journal of Clinical Chemistry. 1976 Oct 15;72(2):205-210. https://doi.org/10.1016/0009-8981(76)90074-7
21. Dizdaroglu M, Jaruga P. Mechanisms of free radical-induced damage to DNA. Free Radical Research. 2012 04;46(4):382-419. https://doi.org/10.3109/10715762.2011.653969
22. Udensi UK, Tchounwou PB. Oxidative stress in prostate hyperplasia and carcinogenesis. Journal of experimental & clinical cancer research: CR. 2016 09 08;35(1):139. https://doi.org/10.1186/s13046-016-0418-8
23. Girotti AW. Mechanisms of lipid peroxidation. Journal of Free Radicals in Biology & Medicine. 1985;1(2):87-95. https://doi.org/10.1016/0748-5514(85)90011-x
24. Oh B, Figtree G, Costa D, Eade T, Hruby G, Lim S, Elfiky A, et al. Oxidative stress in prostate cancer patients: A systematic review of case control studies. Prostate International. 2016 09;4(3):71-87. https://doi.org/10.1016/j.prnil.2016.05.002
25. Najlaa AA, Anwar JA, Ammar JH. Role of lipid peroxidation and antioxidants as biomarkers for prostate cancer. Int J Pharm Res. 2020;Special Issue 1:1667-72.
26. Strasak AM, Rapp K, Brant LJ, Hilbe W, Gregory M, Oberaigner W, Ruttmann E, et al. Association of gamma-glutamyltransferase and risk of cancer incidence in men: a prospective study. Cancer Research. 2008 05 15;68(10):3970-3977. https://doi.org/10.1158/0008-5472.CAN-07-6686
27. Suman J, Renu S, Suman S, Physiology VAMDOB, Hospital GMC. Activities Of Some Antioxidant Enzymes And Lipid Peroxidation In Liver Cancer Patients. International Journal of Current Research and Review
28. Jiao L, Taylor PR, Weinstein SJ, Graubard BI, Virtamo J, Albanes D, Stolzenberg-Solomon RZ. Advanced glycation end products, soluble receptor for advanced glycation end products, and risk of colorectal cancer. Cancer Epidemiology, Biomarkers & Prevention: A Publication of the American Association for Cancer Research, Cosponsored by the American Society of Preventive Oncology. 2011 07;20(7):1430-1438. https://doi.org/10.1158/1055-9965.EPI-11-0066
29. Kaynar H, Meral M, Turhan H, Keles M, Celik G, Akcay F. Glutathione peroxidase, glutathione-S-transferase, catalase, xanthine oxidase, Cu-Zn superoxide dismutase activities, total glutathione, nitric oxide, and malondialdehyde levels in erythrocytes of patients with small cell and non-small cell lung cancer. Cancer Letters. 2005 09 28;227(2):133-139. https://doi.org/10.1016/j.canlet.2004.12.005
30. Aryal M, Pandeya A, Bas BK, Lamsal M, Majhi S, Pandit R, Agrawal CS, Gautam N, Baral N. Oxidative stress in patients with benign prostate hyperplasia. JNMA; journal of the Nepal Medical Association. 2007;46(167):103-106.
31. Arsova-Sarafinovska Z, Eken A, Matevska N, Erdem O, Sayal A, Savaser A, Banev S, et al. Increased oxidative/nitrosative stress and decreased antioxidant enzyme activities in prostate cancer. Clinical Biochemistry. 2009 08;42(12):1228-1235. https://doi.org/10.1016/j.clinbiochem.2009.05.009
32. Montuschi P, Collins JV, Ciabattoni G, Lazzeri N, Corradi M, Kharitonov SA, Barnes PJ. Exhaled 8-isoprostane as an in vivo biomarker of lung oxidative stress in patients with COPD and healthy smokers. American Journal of Respiratory and Critical Care Medicine. 2000 09;162(3 Pt 1):1175-1177. https://doi.org/10.1164/ajrccm.162.3.2001063
33. Akinloye O, Adaramoye O, Kareem O. Changes in antioxidant status and lipid peroxidation in Nigerian patients with prostate carcinoma. Polskie Archiwum Medycyny Wewnetrznej. 2009 09;119(9):526-532.
34. Duru R, Njoku O, Maduka I. Oxidative stress indicators in patients with prostate disorders in Enugu, South-East Nigeria. BioMed Research International. 2014;2014:313015. https://doi.org/10.1155/2014/313015
35. Kimura S, Yamauchi H, Hibino Y, Iwamoto M, Sera K, Ogino K. Evaluation of urinary 8-hydroxydeoxyguanine in healthy Japanese people. Basic & Clinical Pharmacology & Toxicology. 2006 05;98(5):496-502. https://doi.org/10.1111/j.1742-7843.2006.pto_217.x
36. Tampa M, Mitran MI, Mitran CI, Sarbu MI, Matei C, Nicolae I, Caruntu A, et al. Mediators of Inflammation - A Potential Source of Biomarkers in Oral Squamous Cell Carcinoma. Journal of Immunology Research. 2018;2018:1061780. https://doi.org/10.1155/2018/1061780
37. Aviram M, Rosenblat M, Bisgaier CL, Newton RS, Primo-Parmo SL, La Du BN. Paraoxonase inhibits high-density lipoprotein oxidation and preserves its functions. A possible peroxidative role for paraoxonase. The Journal of Clinical Investigation. 1998 04 15;101(8):1581-1590. https://doi.org/10.1172/JCI1649
38. Backos DS, Franklin CC, Reigan P. The role of glutathione in brain tumor drug resistance. Biochemical Pharmacology. 2012 04 15;83(8):1005-1012. https://doi.org/10.1016/j.bcp.2011.11.016
39. Bhattacharyya T, Nicholls SJ, Topol EJ, Zhang R, Yang X, Schmitt D, Fu X, et al. Relationship of paraoxonase 1 (PON1) gene polymorphisms and functional activity with systemic oxidative stress and cardiovascular risk. JAMA. 2008 03 19;299(11):1265-1276. https://doi.org/10.1001/jama.299.11.1265
40. Aydin O, Ellidag HY, Eren E, Ay N, Yalçınkaya S, Yilmaz N. Increased Antioxidant Quality Versus Lower Quantity of High Density Lipoprotein in Benign Prostatic Hyperplasia. Journal of Medical Biochemistry. 2015 Oct;34(4):455-459. https://doi.org/10.2478/jomb-2014-0053
41. Aldemir M. Evaluation of Oxidative Stress Status and Antioxidant Capacity in Patients with Localized Prostate Cancer and Benign Prostatic Hyperplasia. ResearchGate. 2025 08 05;. https://doi.org/10.4328/JCAM.2209
42. Al-Dahhan NAA, Al-Dahhan HAA, Hussein BJ. Elevated Bilirubin Level Increase the Risk of Gallstone Disease in Pediatric Hereditary Spherocytosis Patients: A Case Report. Systematic Reviews in Pharmacy. 2020;11(6):341-346.

https://doi.org/10.31838/srp.2020.6.54
43. Dhanju AS, Singla D, Singh P, Chhabra A, Kaur S. Study on evaluation of serum gamma-glutamyl transferase (GGT) levels in acute coronary syndrome. IJAR. 2021:39–40. http://dx.doi.org/10.36106/ijar/4109004252..
44. Kumar L, Kumar S, Agarwal S. To Find the Role of DNA Damage Marker 8-hydroxy 2-deoxy Guanosine in Patients of Prostate Cancer, Benign Prostatic Hyperplasia and its Association to Other Prognostic Factors of Prostate Cancer. Integrative Medicine in Nephrology and Andrology. 2017 06;4(2):55. https://doi.org/10.4103/jina.jina_5_17

This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License.