

Article

A Study on The Assessment of Glutathione S-Transferase (GTS) Enzyme Activity and Glutathione (GSH) Concentration Levels in Women with Breast Cancer, By Age Group

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Abstract: This study examines the extent of biochemical changes relating to oxidative balance in breast cancer patients in a specific city. The study involved 50 women diagnosed with the disease, who were compared with a further 45 women without the disease, referred to as the control group. The study A methodology was adopted to measure the activity of the glutathione S-transferase enzyme and to determine the concentrations of reduced glutathione in the blood serum of both the affected and unaffected groups, using validated spectroscopic and laboratory techniques. The results were categorised by age group, and these analytical findings revealed a statistically significant increase in glutathione enzyme activity in the patient samples compared with the non-patient samples, with a trend towards an increase observed as age advanced. Finally, these findings demonstrated a difference in the antioxidant system among breast cancer patients, thereby reinforcing the diagnostic significance of glutathione and its associated enzymes in monitoring disease progression, as well as in assessing the state of oxidative stress in breast cancer patients.

Keywords: Oxidative Stress, Antioxidants, Blood Serum, Resistance to Chemotherapy, Reduced Glutathione

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1. Introduction

Cancer is a condition characterised by rapid, uncontrolled and unregulated cell proliferation and division, which occurs in cells that have lost their normal function; this leads to the formation of various masses. These masses, which develop within the tissues responsible for maintaining intracellular balance, trigger tissue changes and tumour formation due to an increase in cell proliferation. These cells, which normally meet the organ's needs, in this case take control of the disease, which in turn takes control of the immune system; this leads to the patient's inability to mount an effective immune response. The term 'benign tumours' refers to tumours characterised by a non-invasive growth pattern that is localised and confined to the site of origin[1-6]. These tumours do not usually pose a significant risk or threat to the patient's life, provided they remain localised. They can be readily distinguished and may be clearly defined, with a firm or soft, and may also cause discomfort to the patient. These tumours are also observed in the breast area, which may lead to pain noticed during women's menstrual cycles; after the menstrual cycle ends, the pain may disappear[7-10]. This tumour can appear in various parts of the body and may also be found throughout the body; it is one of tumours that are manageable, as they can be easily removed. As for malignant tumours, these also spread

to different parts of the body and lead to rapid cell proliferation; they have the ability to enter both the lymphatic and circulatory systems, which is the main reason for their spread [11-13]. Breast cancer is one of the most common cancers among women and is considered a leading cause of cancer-related deaths among women, ranking second only to lung cancer. Whilst breast cancer can affect both sexes, it is rare in men. In developing countries, this type of cancer is the leading cause of death; consequently, breast cancer is now considered one of the most widespread and worrying health issues globally. Reports based on global statistics indicate a marked increase in the incidence of this disease between 2014 and 2024. This reflects improvements in screening methods. Statistics for 2014 recorded approximately 100,000 cases of the disease, according to reports from the World Health Organisation [14-17]. It has also been found that incidence rates are significantly higher in countries with higher incomes compared to developing countries. In Iraq, however, a similar upward trend has been observed, with an incidence rate of 30 cases per 100,000 women. This rise may be attributed to several factors in Iraq, including improvements in healthcare infrastructure, increased awareness, scientific advances and changes in lifestyle. Despite these developments, breast cancer remains a major health challenge in Iraq [18-23].

2. Materials and Methods

A. Equipment and methods used

The following table lists the equipment and methods used to complete this section listed in the Table (1).

Table 1. Equipment and methods used in the study

No.	Instrument	Company	Country
1	Uv-Vis Spectrophotometer	T92+Spectrophotometer double beam	India
2	Cobas Elecsys 2012	Roche	China
3	Hipro A1	Hipro	Japan
4	Sensitive Eanalytical Balance	Sartorius BL210 SAG	Italian
5	Water bath	Daiki	China
6	pH meter 720	WTW Inolab	Korea
7	Universal 320/320R centrifuge	Hettich	U.S. A
8	Hot Plate & Stir.	HYSC	Italian
9	Incubator	GFL	Franch
10	ELISA reader	Mindry	India

B. Reagents and materials used in the study

The table below lists the names of the reagents and materials used in the diagnosis, which were purchased from various international companies

Table 2. Reagents and materials used in the study

No.	Chemical and Kits	Company	Country
1	Immunoglobulin G (Kit) IgG	Hipro	Germany
2	Immunoglobulin M (Kit) IgM	Hipro	Japan
3	Vitamin A (Kit)	ELK Biotechnology	Spain
4	Vitamin E (Kit)	ELK Biotechnology	Spain
5	Vitamin C (Kit)	ELK Biotechnology	China

6	Total Protein (Kit)	Biolabo	India
7	Potassium dihydrogen orthophosphate (KH_2PO_4)	Alpha Chemika	Germany
8	Di-potassium hydrogen orthophosphate (K_2HPO_4)	Alpha Chemika	Japan
9	1-Chloro-2,4-dinitrobenzene (CDNB)	Sigma-Aldrich	Spain
10	Glutathione (GSH)	Sigma-Aldrich	Spain
11	2,4,6-Tripyridyl-S-triazine (TPTZ) ($\text{C}_{18}\text{H}_{12}\text{N}_6$)	Fluka Chemical	Spain
12	Sodium acetate anhydrous ($\text{C}_2\text{H}_3\text{O}_2\text{Na}$)	HI MEDIA	Spain
13	Ferric chloride hexahydrate ($\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$)	Thomas Baker	Spain
14	Ferrous sulfate heptahydrate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$)	Thomas Baker	Spain
15	Acetic acid (CH_3COOH)	Loba Chemie	China
16	Hydrochloric acid (HCl)	Thomas Baker	China
17	Sodium acetate trihydrate ($\text{C}_2\text{H}_3\text{NaO}_2 \cdot 3\text{H}_2\text{O}$)	Thomas Baker	China
18	Sephadex G-75	Thomas Baker	China
19	Ammonium Sulfate ($(\text{NH}_4)_2\text{SO}_4$)	Loba Chemie	China
20	Bovine Serum Albumin	Biolabo	China
21	Pepsin	Scharlau	China
22	Papain	Scharlau	China
23	Tryptophan	Scharlau	China

C. Samples used

Test samples

A total of 44 blood samples were collected from healthy women aged between 23 and 60 during the period from March 2025 to July 2026, all of whom resided in the same area

Patients Samples

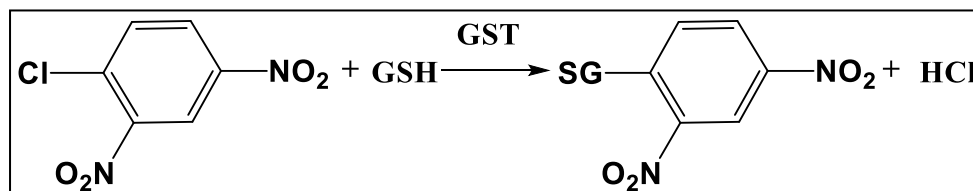
The patient group consisted of 50 female individuals diagnosed with breast cancer, residing in Kirkuk from the oncology and hematology center in Kirkuk between September 2024 and February 2025. The ages of the patients ranged from 20 to 64 years. Clinical information was collected, including data on chemotherapy, radiotherapy, and the use of medications such as hormonal treatments, daily medications, and monthly medications. Data on mastectomy procedures were also recorded. This dataset serves as a foundation for analyzing the impact of treatments, medications, and clinical history on the biochemical and hematological parameters of breast cancer patients in Kirkuk. Blood samples in this study were collected by drawing 5 mL of venous blood using a 5 mL disposable syringe. The samples were divided based on the type of analysis. A volume of 2.5 mL was placed in tightly sealed plastic test tubes containing the anticoagulant ethylene diamine tetraacetic acid (EDTA) for the measurement of hematological parameters. The remaining blood was transferred into tightly sealed plastic test tubes without anticoagulants and left at a temperature of 25°C to allow clotting. The serum was then separated using a centrifuge at a speed of 3000 rpm. Subsequently, the serum was aspirated using a micropipette to obtain the blood serum. Afterwards, the serum is divided into four equal parts using sterilized micropipette and transferred into small, tightly sealed Eppendorf tubes or PCR tubes (1.5 mL capacity). Finally, the tubes are stored in a specialized deep freezer at a temperature of -20°C until the required biochemical tests are performed.

D. Chemical measurements and tests

Testing the level of the enzyme glutathione S-transferase (GST) in serum

Basic procedure for conducting the tests

GST enzyme activity is enhanced by the aromatic and electronic properties of the compound under investigation. The activity of the dinitrobenzene dehydrogenase enzyme is measured via a substitution reaction between the thiol group and chlorine, resulting in the formation of the ethyl ether dinitrophenyl compound. The enzyme activity is then recorded by measuring the compound's absorbance at a wavelength of approximately 350 nanometres.



E. The solutions used in the study

A buffer solution with a pH of 6.20 was prepared by preparing several solutions, one of which was a phosphate acid solution: 1.5 g of KH_2PO_4 was dissolved in a flask containing 35 ml of distilled water, and the volume was made up to 95 ml. As for the other solution, a phosphate buffer solution was prepared by dissolving 2 g of KH_2PO_4 in 35 ml of distilled water, and the volume was also made up to 95 ml. The third solution was a buffer solution with a molarity of 30, prepared by dissolving 0.9 g of GSH was dissolved in 35 ml of ethanol, the volume of which was made up to 95 ml.

Table 3. CDNB protocol

No.	Materials	Blank	Sample
1	Phosphate buffer (pH 6.20)	2.5 mL	2.4 mL
2	Sample	-	110 μL
3	Distilled water	110 μL	-
4	CDNB solution	110 μL	110 μL
The mixture is incubated for 3.5 minutes.			
5	Standard solution (GSH)		110 μL
The components are mixed thoroughly, and the absorbance is measured after the first minute and every minute thereafter at a wavelength of 350 nm.			

F. Calculations

The following formula is used to calculate the activity of the GST enzyme[24]:

$$\text{GST activity (U/L)} = \frac{\Delta A \times V_t \times 1000}{E_o \times V_s \times d}$$

Where:

ΔA : Change in absorbance (absorbance at the tenth minute- absorbance at the first minute), V_t : Total reaction volume(3.5 mL), V_s : Volume of the sample (110 μL), E_o : Molar absorption coefficient(with a value of 9.6 mmol^{-1}), d : Cuvette path length (1 cm).

3. Results and Discussion

A. Assessment of glutathione S-transferase enzyme activity

Measurement of glutathione S-transferase enzyme activity

The activity of this enzyme was measured in the serum of breast cancer patients and compared with control groups; the results showed a statistically significant difference in the probability level

Assessment of glutathione S-transferase enzyme activity in the serum of breast cancer patients compared with the control group: $p \leq 0.06$ for serum enzyme activity, and higher activity was also observed in the patients at (50 ± 9 units/litre); Figure (1) shows the values and the results are recorded in Table (4).

Table 4. GST enzyme activity in the sera of patients with breast cancer and the Control Group

Parameters	Controls (n=45)	Patients (n=50)	p-value
GST (U/L)	28 ± 9	50 ± 25	$P < 0.06$

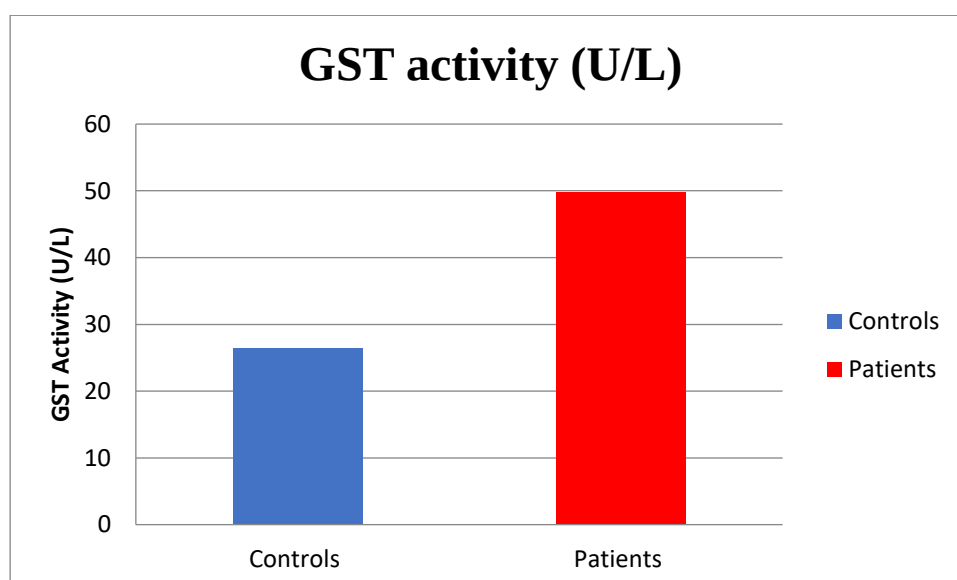


Figure 1. An illustration of the measurement of GST enzyme activity in the control group and in women with breast cancer

B. Age group and GST enzyme activity levels in the control group and patients

Table 5 shows the specific variation in GST enzyme activity for each age group, in which a clear statistical difference ($p < 0.05$) was observed across the three age groups when compared with the control group. Figure (2) also illustrates the enzyme activity results, showing an increase in activity with advancing age in patients; these differences are not statistically significant.

Table 5. Shows GST enzyme activity in patients and the control group, organised by age group.

Parameters	Age (years)	Controls (n=45)	Patients (n=50)	P-value
		Mean $\pm$ SD	Mean $\pm$ SD	
GST Activity (U/L)	25–35	17 ± 5.4	35 ± 18.5	$P < 0.05$
	30–45	18 ± 8.7	42 ± 29	$P < 0.05$

45-50	29±14.5	53±32	P<0.05
>50	35±18	59±36	P<0.05

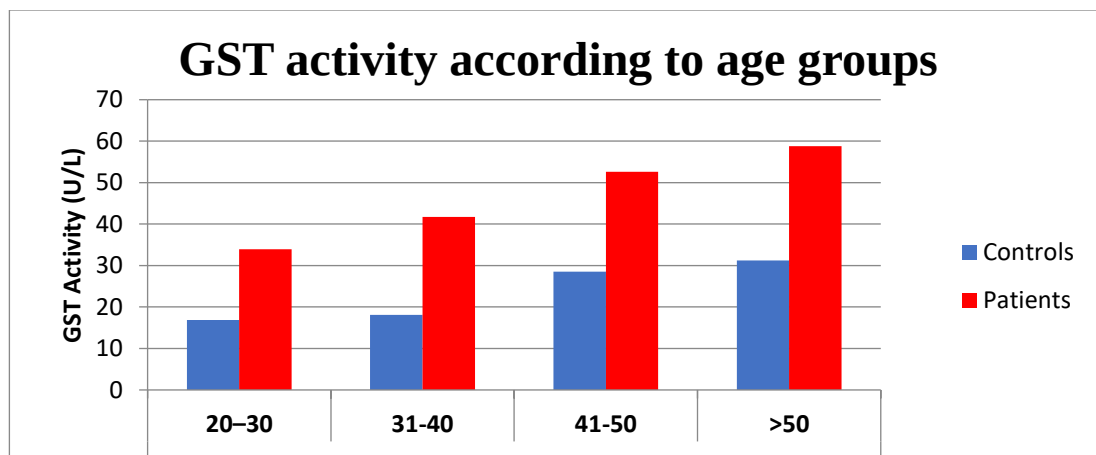


Figure 2. Illustrates a comparison of GST enzyme activity across age groups in breast cancer patients and the control group

The results of this study demonstrated a statistically significant increase in enzyme activity among patients compared with the control group at a p-value > 0.05 , with enzyme activity in patients reaching a value of 50 ± 15 units/ litre. These findings confirm the crucial role of active GST in the physiology of patients, particularly in response to oxidative stress and detoxification. The elevated levels of this enzyme in cancer patients indicate a heightened response to oxidative stress, which is increasingly associated with malignant tumours, which typically results in the uncontrolled proliferation of cancer cells in vast, uncontrolled quantities; these cells cause significant damage to lipids, nucleic acids and proteins, thereby promoting cancer development and maximising tumour growth. Studies have shown that elevated levels of GST enzymes act as a defence mechanism against oxidative damage; this, in turn, supports cell health and aids tumour growth. Furthermore, the activity of this enzyme is associated with high resistance to chemotherapy, which mitigates the anti-cancer toxicity and thus renders the treatment ineffective, [25] In a previous study, a matching process was observed in the promoter region of the GSTP1 gene, which showed a high expression in the patient's tissue samples, including high-grade tumours (grade III).

C. Measurement of reduced glutathione concentration

Glutathione concentrations were measured in the blood of breast cancer patients and compared with those of the control group; the results showed a clear reduction in the concentration of GSH in patients was estimated at (1.79 ± 0.8) , whilst the control group's value was (4.5 ± 0.9) ; $p < 0.0002$. These results are illustrated in Table (6) and Figure (3).

Table 6. Shows the glutathione concentration levels in the control group and in patients with breast cancer

Parameters	Controls (n=45)	Patients (n=50)	p-value
Glutathione (GSH) $\mu\text{mol/L}$	4.5 ± 0.9	1.79 ± 0.8	$p < 0.0002$

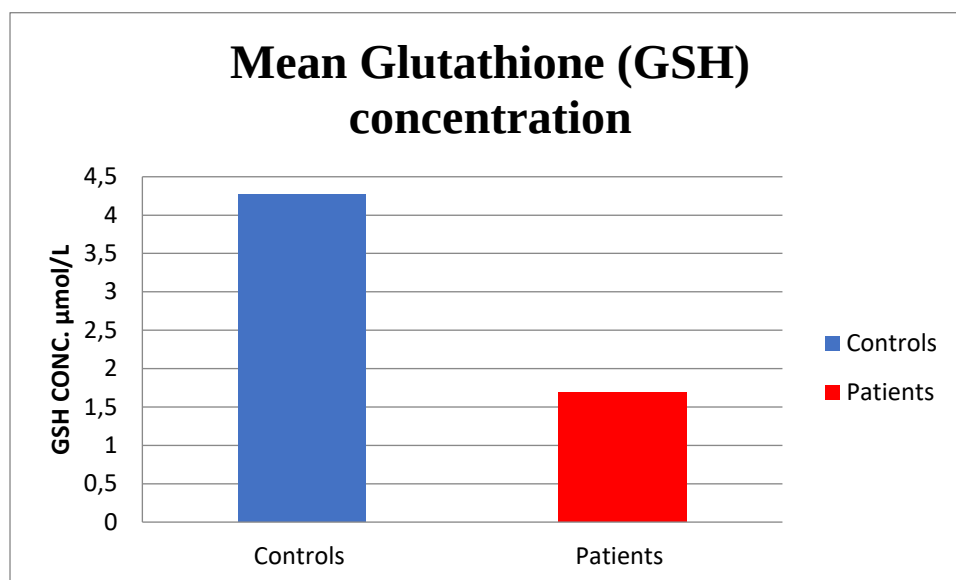


Figure 3. Shows GSH concentrations in the control group and compares them with blood samples from breast cancer patients

D. Measurement of glutathione levels in the control group and patients by age group

The results showed a decrease in glutathione levels as patients' age increased; it was found that in the 25–35 age group, a marginal ratio of (1.70–0.35) was observed when compared with the older age group, which had a value of (1.35–1). For those over 50 years of age, it was also observed that the control group in the 25–35 age group had values ranging from 4.5 to 0.9, whilst the values for those over 50 years of age ranged from 3.5 to 0.18; Table (7) and Figure (4) illustrate the recorded results.

Table 7. Shows glutathione (GSH) concentrations in the control group and breast cancer patients in the age group

Parameters	Age (years)	Controls (n=45)	Patients (n=50)	p-value
		(Mean ± SD)	(Mean ± SD)	
Glutathione µmol/L	25–35	4.5 ± 0.9	1.7 ± 0.35	P<0.05
	35–45	4.5 ± 0.95	1.50 ± 0.40	P<0.05
	45–50	3.95 ± 0.92	1.45 ± 0.85	P<0.05
	>50	3.5 ± 0.18	1.35 ± 1	P<0.05

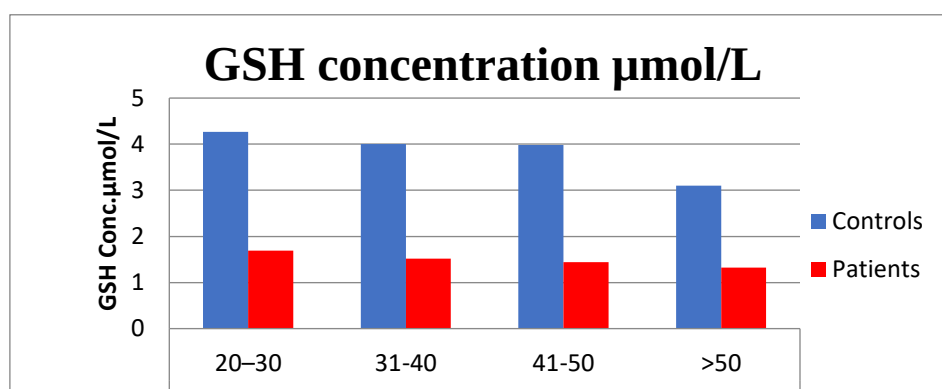


Figure 4. Glutathione concentration levels in the control group and breast cancer patients by age group

The reduced glutathione (GSH) levels observed in breast cancer patients were correlated with laboratory categories, and the study's findings were consistent with previous studies. Studies have shown that the progression of malignant disease leads to an imbalance in the redox system through increased production of reactive oxygen species (ROS), resulting in a reversal of the relative maintenance of glutathione levels, particularly in younger patients, despite the statistical weakness and age-related differences that impair antioxidant capacity. Previous studies have also shown that glutathione levels are significantly higher in breast cancer patients, particularly in tumour tissues, when compared with healthy individuals; this leads to antioxidant protection and resistance to oxidative stress by cancer cells. For example, a previous study reported that glutathione levels were found to be elevated in breast cancer tissues compared with adjacent unaffected tissues in 60 patients; this suggests that cancer cells increase glutathione production in order to maintain the redox balance, as well as to protect against reactive oxygen species.

E. Differences between glutathione concentration and GST enzyme activity

The results shown in Figure (5) and Table (8) present a comparison of glutathione concentration and GST enzyme activity in the control group and in individuals with breast cancer.

Table 8. Shows the differences between the concentration of clothiamine and the activity of the GST enzyme

Parameters	Control	Patients	p-value
	Mean $\pm$ SD	Mean $\pm$ SD	
GST U/L	25 $\pm$ 8.95	49.5 $\pm$ 15	< 0.01
GSH μ mol/L	5 $\pm$ 0.92	1.71 $\pm$ 0.8	< 0.02

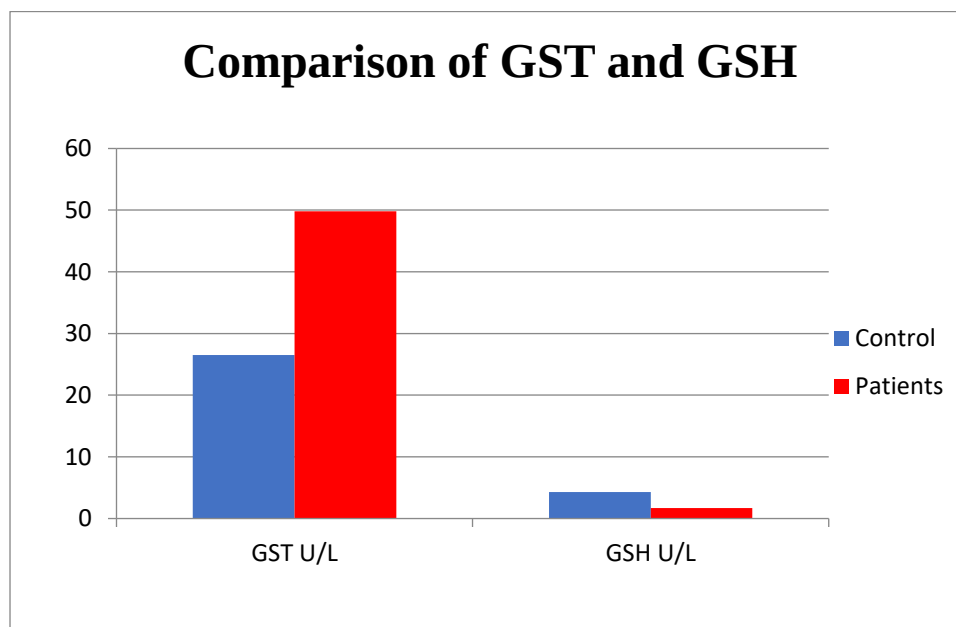


Figure 5. Illustrates the difference between GST activity and glutathione concentration in the control group and in patients with breast cancer

4. Conclusion

The results obtained indicate the presence of an imbalance in the system of biochemical oxidation and reduction processes in patients with breast cancer, which may be caused by the excessive production of reactive oxygen species; this leads to tumour

growth as well as the proliferation of cancer cells. This observed increase in the activity of the enzyme Gl, which acts as a vital defence mechanism utilised by cancer cells to protect themselves from oxidative damage, thereby enabling their continued growth. Furthermore, this direct increase in enzyme activity is linked to increased resistance of cancerous tissue to chemotherapy, as these enzymes work to eliminate the drugs and reducing their therapeutic efficacy. On the other hand, this marked decrease in serum glutathione levels is due to continuous consumption; glutathione is an essential substrate for the reactions catalyzed by glutathione enzymes, in addition to depletion in response to oxidative stress. Consequently, the decline in antioxidant levels is more pronounced in older age groups, as the natural decline in immune function and oxidative imbalance sets in; this, in turn, makes cancer cells more adaptable compared to normal tissues.

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