

Effect of *Toxoplasma gondii* on Some Neurotransmitter Levels in Patients with Toxoplasmosis Infection

Raja Jawad Mohamed*

Abstract

Background: The study of *Toxoplasma gondii* on some neurotransmitter levels in patients with toxoplasmosis infection is one of the challenges of sustainable development. *Toxoplasma gondii* is a parasite that can alter host behavior by affecting neurotransmitters of the host. **Aim:** To diagnose if there are differences in neurotransmitter levels in infected people by toxoplasmosis and healthy people to predict the psychological and neurological diseases. **Methods:** The study included collecting 60 samples, 30 of which were from people infected with toxoplasmosis and 30 from healthy people. These people were visitors to the Middle Euphrates Center for Neurosciences during the period from August 2024 to January 2025. The presence of antibodies to the toxoplasmosis parasite was investigated using the ELISA test and the test kit from Calbiotech. The ages of the people included in the study ranged from 20 to 69 years. Verbal and written consent was obtained from them, and the content and purpose of the study were explained to them. The study also included investigations into education. 5 ml of blood samples were withdrawn from the people included in the study, the serum was isolated from the rest of the blood components, and the concentrations of neurotransmitters were investigated using the ELISA technique and the Elabscience kit. **Results:** The results showed that the number of infected men was more than women, and that most of the infected were Gainers, and that the age group between 40 and 59 was the most affected. The results of the current study also showed that people infected with toxoplasmosis had significant differences with healthy people, as they had higher concentrations of adrenaline compared to healthy people. However, when comparing the levels of neurotransmitters between healthy men and women, there were no significant differences. However, between men and women infected with toxoplasmosis, significant differences were shown, as the dopamine concentration rate was higher in women compared to men. **Conclusion:** The results of the current study confirmed the proposed mechanism by which the toxoplasmosis parasite may induce behavioral changes in hosts via the parasite's influence on the levels of certain neurotransmitters. There was no significant effect of gender on neurotransmitter levels when compared to healthy controls, but there was an increase in dopamine levels in women when compared to those infected with the toxoplasmosis parasite. We can also conclude that some psychiatric and neurological diseases, such as schizophrenia and Parkinson's disease, may be caused by infection with the toxoplasmosis parasite.

Keywords: *Toxoplasma gondii*, neurotransmitter, dopamine, epinephrine, nor-epinephrine, toxoplasmosis

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INTRODUCTION

Toxoplasma gondii is an obligatory single-celled parasite that infects humans and animals. Humans are considered the intermediate host, while cats are the definitive host [1]. Since cats belong to the feline family, all members of the feline family are considered definitive hosts for this parasite. When infected with this parasite, the parasite manipulates the behavior of the host it infects [2]. Experiments have shown that when a group of rodents is infected with this parasite, their behavior changes. Instead

of running away from cats, we find them attracted to the scent of cats, which leads to easy preying on them. This behavior occurs due to changes in the memory of mice. When infected with this parasite, mice are exposed to memory loss due to the loss that occurs in two areas of the brain: the cortex and the amygdala [3]. The neurotransmitters located there are affected, leading to these behavioral changes. Experiments have also shown that males infected with the parasite are attracted to uninfected females, which increases the chances of the parasite's successful survival and transmission [4]. There are many previous studies that have shown these behavioral changes in rodents when infected with the toxoplasmosis parasite.

Neurotransmitters are chemicals found at the synaptic junction between neurons, where they regulate nerve signals coming to and from the brain. These chemicals are produced in the pre-synaptic region and transmit nerve impulses to the postsynaptic region between neurons. Neurotransmitters are abundant at synapses, numbering approximately 10,000 [5]. When a nerve impulse arrives, thousands of neurotransmitters at the synapse are stimulated to transmit the impulse to the postsynaptic region, where they bind to their receptors on neighboring neurons. In our current research, we examined the effect of the toxoplasmosis parasite on some neurotransmitters such as dopamine, adrenaline, and noradrenaline [6, 7].

Aim of Study

To diagnose if there are differences in neurotransmitter levels in infected people by toxoplasmosis and healthy people to predict the psychological and neurological diseases.

MATERIALS AND METHODS

Samples Collection

The study included collecting 60 samples, 30 of which were from people infected with toxoplasmosis and 30 from healthy people. These people were visitors to the Middle Euphrates Center for Neurosciences during the period from August 2024 to January 2025. The presence of antibodies to the toxoplasmosis parasite was investigated using the ELISA test and the test kit from Calbiotech. The ages of the people included in the study ranged from 20 to 69 years. Verbal and written consent was obtained from them, and the content and purpose of the study were explained to them. The study also included investigations into education. 5 ml of blood samples were withdrawn from the people included in the study, the serum was isolated from the rest of the blood components, and the concentrations of neurotransmitters were investigated using the ELISA technique and the Elabscience kit.

Statistical Analysis

The results were expressed using the arithmetic mean (average) and standard deviation ($M \pm SD$) for both the experimental and control groups. Statistical analysis was performed using the Chi-square test (X^2) and one-tailed t-test at a 5% probability level. The correlation coefficient (R) was calculated to determine the correlation between the criteria using Microsoft Excel 2013.

Ethical Approval

Samples were collected based on patient consent for testing and investigation, in accordance with the standards of the Iraqi Ministry of Health. Written and verbal consent was obtained prior to sample collection from patients and healthy individuals.

RESULTS

The current study included 60 samples, 30 of which were infected with toxoplasmosis and 30 of which were healthy. The number of males was 44 and the number of females was 16 as shown in Table 1.

Table 1. Distribution of specimens according to sex group.

Sex	No.60	Percentage (%)
Female	16	(26.66%)
Male	44	(73.33%)

The average age of total participant was between 20 to 69 (Table 2).

Table 2. Distribution of specimens according to age group.

Mean of age	No. 60	Percentage (%)
20–29	4	(6.66%)
30–39	10	(16.66%)
40–49	16	(26.66%)
50–59	16	(26.66%)
60–69	14	(23.33%)

Most patients are gainers (43.33%), followed by employees (26.66%) and housewives (23.33%) as shown in Table 3.

Table 3. Distribution of specimens according to education.

Education	No.60	Percentage (%)
Student	4	(6.66%)
Employee	16	(26.66%)
Gainer	26	(43.33%)
Housewife	14	(23.33%)

The study Table 4 showed that the infection rate with the *T. gondii* parasite (the presence of IgG antibodies to the Toxoplasma parasite in the serum) was significantly higher ($P < 0.05$) in infected people (100%) than in healthy people (10%) using the Chi square (χ^2) statistical analysis.

Table 4. Percentage of IgG antibodies to *Toxoplasma gondii* in infected and healthy individuals.

Group	IGg positive	IGg negative	probability
Patients	30 (100%)	0 (0%)	P-value using chi-square test (χ^2) P = 0.01317 P < 0.05
Control	3 (10%)	27 (90%)	

When comparing serum levels of neurotransmitters between the groups of people with toxoplasmosis and those without, it was found that there were significant differences in neurotransmitters Adrenaline between the two groups, but there are no significant differences in Dopamine and NorAdrenaline between the two groups as shown in Table 5.

Table 5. Serum levels of neurotransmitters (dopamine, epinephrine, and norepinephrine) in people with chronic toxoplasmosis and those uninfected.

Standards	People infected with toxoplasmosis	Uninfected People	P value
Dopamine pg/ml	1443.126 ± 328.921	1501.006 ± 232.800	0.17155
Adrenaline pg/ml	265.8141 ± 189.790	169.2037 ± 101.314	*0.0329
Noradrenaline pg/ml	3.878 ± 2.605	3.451 ± 1.956	0.282

Note: *Significant differences below the 0.05 significance level.

Table 6 shows the effect of gender on the mean concentrations of dopamine, adrenaline, and noradrenaline in individuals without cataracts. Statistical analysis using the t-test showed no statistically significant differences ($P > 0.05$) for all parameters between males and females.

Table 6. Serum levels of neurotransmitters (dopamine, adrenaline, and noradrenaline) in healthy individuals according to gender.

Standards	Concentration rate ± standard deviation M ± SD		P value
	Male 21	Female 9	
Dopamine pg/ml	1493.215 ± 252.963	1515.934 ± 189.409	0.3930
Adrenaline pg/ml	210.16 ± 161.797	185.938 ± 99.698	0.2558
Noradrenaline pg/ml	3.659 ± 2.375	3.439 ± 1.675	0.3475

The results in Table 7 showed a significant difference in the dopamine concentration rate between males and females with toxoplasmosis, as its concentration in males was lower than in females, but there were no significant differences in the concentration of both adrenaline and noradrenaline between the sexes ($P > 0.05$) in people with toxoplasmosis.

Table 7. Serum levels of neurotransmitters (dopamine, adrenaline, and noradrenaline) in infected individuals according to gender.

Standards	Concentration rate \pm standard deviation M \pm SD		P value
	Male 23	Female 7	
Dopamine pg/ml	1335.145 \pm 363.19	1539.792 \pm 234.454	0.0369*
Adrenaline pg/ml	163.837 \pm 114.139	167.696 \pm 88.879	0.4902
Noradrenaline pg/ml	1.0012 \pm 0.4702	1.092 \pm 0.325	0.0856

Note: *Significant differences below the 0.05 significance level

DISCUSSION

Many people are unaware of how toxoplasmosis, which they may consider a secondary disease, has a significant impact on neurotransmitters. Studies have shown that most psychological and neurological illnesses in humans are caused by infection with the chronic toxoplasmosis parasite [8]. This parasite manipulates the behavior of its host, enabling it to successfully carry out its life cycle. Numerous studies have shown that mice infected with the toxoplasmosis parasite are attracted to cats and no longer fear them [9]. This change in infected mice is due to the parasite manipulating the host's genes. Among these genes are those that encode the enzymes responsible for producing neurotransmitters, the most important of which is the gene for the enzyme tyrosine hydroxylase, which produces dopamine [10]. Numerous studies have also demonstrated that schizophrenia, epilepsy, depression, and paralysis occur in people with chronic toxoplasmosis [11]. There have also been studies documenting cases of people attempting suicide and traffic accidents in people infected with toxoplasmosis. A 2011 study confirmed that people with toxoplasmosis experience psychological and behavioral changes, finding a direct correlation between the number of dopamine cells infected with *Toxoplasma gondii* in the brain and the amount of dopamine produced [12]. Since dopamine acts as a precursor to both adrenaline and noradrenaline, it has a direct effect on both. Therefore, a decrease in dopamine will lead to a decrease in adrenaline and noradrenaline. Noradrenaline is found in plasma and is derived from sympathetic nerves, which play an important role in the activity of the sympathetic nervous system [13].

In current study show that there are increasing in IgG levels in patients infected with toxoplasmosis. Inflammatory cytokines are secreted in response to psychological and physical stress, particularly in the central nervous system and peripheral blood. These cytokines alter neurotransmitter levels, leading to behavioral changes [14, 15]. Studies have shown that prolonged exposure to inflammatory mediators affects their production, impairing the functional capacity of the substantia nigra and locus coeruleus regions of the rat brain. As a result of this response, the enzyme that regulates dopamine and norepinephrine levels is impaired, leading to a decrease in this enzyme, resulting in decreased gene expression in the brainstem and midbrain regions [16, 17]. In 2009, a study conducted by Delibaş et al. showed that there was an increase in the production of IgM and IgG antibodies in mice infected with the *T. gondii* parasite, which exposed these mice to psychological stress, as the increase in IgG antibodies affects the level of cytokines and reduces them [18].

The results of the current study showed no significant difference in dopamine and norepinephrine levels between the group of individuals infected with the toxoplasmosis parasite and the control group, although there was a slight increase in their concentrations in the infected group compared to the control group. Serum epinephrine levels in the chronically infected group in this study were significantly higher than in the control group (i.e., there was a significant increase). The changes recorded in some neurotransmitters during this study may result from neuronal injury or the immune response to the parasitic infection [19–21]. A 2010 study on mice infected with the toxoplasmosis parasite showed the

presence of parasitic cysts only in neurons, while astrocytes were free of them in the brains of mice during chronic infection using FITC-Dolichos biflorans staining and confocal fluorescence microscopy [22]. Another study indicated that neurons are the main target cells when the parasite infects the central nervous system in the chronic stage, and that the presence of bradyzoite stages of the toxoplasmosis parasite is located in the neurons of the brain [23].

The toxoplasmosis parasite contains two genes that encode the enzyme tyrosine hydroxylase, which is a dopamine-specific enzyme. [24, 25]. The amount of dopamine in cultured rat PC12 cells experimentally infected with the parasite *T. gondii* is two to three times its amount in uninfected cells (control), and this amount is directly proportional to the number of parasites inside those cells. The levels of total dopamine and released potassium also witnessed a significant increase in infected cells. The study also showed a significant increase in the activity of the enzyme tyrosine hydroxylase in the extract of cells infected with different numbers of the parasite from cells. The increase in the amount of L-DOPA is affected by changes in the infection dose, which reflects the increase in the amount of dopamine [26]. There are some studies that explained the reason for the significant increase in dopamine in brain tissue infected with the parasite *Toxoplasma gondii*, which is due to the effective contribution of the parasite in encoding the enzyme hydroxylase specific to the amino acid dopamine, which begins its work and expression after the fifth day of infection, thus increasing the activity of the enzyme. There is another study that showed an increase in the concentration of dopamine and a decrease in Gene expression of the D1-like dopamine receptors DRD1 and DRD5, as well as changes in dopamine-mediated signaling pathways, was found in the striatum of mice brains after day 5 of infection with *Toxoplasma gondii*. The enzyme dopa decarboxylase completes dopamine production by converting L-3,4-dihydroxyphenylalanine to dopamine, but the toxoplasmosis parasite does not have a genome encoding this enzyme or any similar sequences, according to the National Center for Biotechnology Information in Maryland, USA [27, 28]. Martin et al. (2015) also found a slight increase in dopa decarboxylase expression when measuring protein and mRNA levels in cells responsible for dopamine production. This study explains why dopamine increases in neurons despite the parasite's lack of dopa decarboxylase: this is due to the presence of the host's DDC enzyme inside [29]. The parasitophorous vacuole (PV) and the parasitic cysts inside the cells in the infected brain tissue. They explained this through their observations in their study by saying that the parasite works through some signals to import this enzyme into the vacuoles in which the parasite is present inside the cells to be associated with the parasite's TH enzyme so that they work together to produce dopamine [30, 31].

Noradrenaline is one of the catecholamines in the sympathetic nervous system. It acts as an immunomodulator, filtering the immune system and is secreted in response to various stressful situations. It has receptors on the surfaces of various immune cells, acting as an inhibitor or enhancer on pigment cells [32]. There is no significant relationship between dopamine, adrenaline, and noradrenaline levels in the plasma of depressed patients, and depression is a common symptom in toxoplasmosis patients. There is a relationship between neurotransmitters and sex hormones [33]. Dopamine levels and their effectiveness can be inferred by analyzing endocrine secretions and plasma prolactin levels. Dopamine inhibits prolactin secretion in the hypothalamus, and an increase in blood prolactin levels indicates a decrease in dopamine activity in the brain [34]. In a study conducted on males and females [35], they found that concentrations of both serotonin and dopamine were higher in females with toxoplasmosis than in males. Their study showed that both serotonin and dopamine concentrations were higher in the brains of females than males. The reason for the lower dopamine levels in male patients compared to females in the current study may be due to the direct link between dopamine and the disease on the one hand, and the sensitivity and symptoms of the disease with gender on the other. Furthermore, estrogen in women provides natural neuroprotection, so women are not as affected as males [35]. In the results of the current study, there was a significant increase in the concentration of adrenaline in people with IgG antibodies to *Toxoplasma* (i.e., people with toxoplasmosis) compared to the control group [36]. Adrenaline releases the hormone prolactin, so women with high levels of prolactin are more resistant to toxoplasmosis. 80% of adrenaline is secreted by the adrenal gland, and the rest is produced by brain cells. The reason for the increase in adrenaline

levels in people with toxoplasmosis may be because of the parasite on the endocrine glands, including the adrenal gland, as the adrenal gland is greatly affected in mammals, such as dolphins, where parasite stages were found in the adrenal cortex. Parasite also affects hormones produced by the endocrine glands such as testosterone, prolactin, and progesterone [37, 38]. Other studies have shown that there are many factors that affect testosterone production in people with toxoplasmosis, in addition to the effect of the parasite on causing behavioral changes [39]. Finally, there are studies and experiments. Changes in catecholamine levels, which are associated with nervous system disorders, have been shown in people with toxoplasmosis.

CONCLUSION

The results of the current study confirmed the proposed mechanism by which the toxoplasmosis parasite may induce behavioral changes in hosts via the parasite's influence on the levels of certain neurotransmitters. There was no significant effect of gender on neurotransmitter levels when compared to healthy controls, but there was an increase in dopamine levels in women when compared to those infected with the toxoplasmosis parasite. We can also conclude that some psychiatric and neurological diseases, such as schizophrenia and Parkinson's disease, may be caused by infection with the toxoplasmosis parasite.

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