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Quick Response Code:

Website: https://journals.lww.com/ijhm

DOI: 10.4103/ijh.ijh_70_24

Evaluation of the level of tumor necrosis factor-alpha and lactate dehydrogenase in acute lymphoblastic leukemia patients

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Submission: 04-07-2024
Revised: 08-08-2024
Accepted: 10-08-2024
Published: 08-10-2024

Abstract:

BACKGROUND: Acute lymphoblastic leukemia (ALL) is an abnormal clonal proliferation of early hemopoietic precursor cells in bone marrow (BM). There are certain cytokines like tumor necrosis factor alpha (TNF-α) which plays a crucial role in the development and progression of malignant process, and other enzymes like lactate dehydrogenase (LDH) which has prognostic value.

OBJECTIVE: The aims of this study were to evaluate the level of serum TNF-α and LDH in ALL patients at diagnosis and post-induction chemotherapy.

PATIENTS, MATERIALS, AND METHODS: This was an observational–analytical study, which was done in Ibn-Sina Teaching Hospital in the period between May 2023 and November 2023. It included 22 newly diagnosed patients with ALL. All patients underwent complete blood count, bone marrow examination, flowcytometry, serum TNF-α and LDH at diagnosis and post induction chemotherapy.

RESULTS: In 22 patients with ALL, at diagnosis, the means of serum TNF-α (97.89 ± 52.945 ng/l), serum lactate dehydrogenase(1138.94 ± 430.10 IU/l), and percentage of blasts cells in BM (0.742 ± 0.181) in B-ALL. The means of serum TNF-α (165.33 ± 23.437 ng/l), serum lactate dehydrogenase (1633.33 ± 497.426 iu/l), and percentage of blasts cells in BM (0.816 ± 0.125) in T-ALL were statistically higher than those among the controls (s.TNF-a (18.09 ± 6.795 ng/l), s.LDH (142.59 ± 61.626 IU/l), and percentage of blasts cells in BM 0.0 ± 0.0) with P = 0.000 for all parameters mentioned, respectively. After induction phase chemotherapy in B-cell ALL , there were a significant reduction noted for serum TNF-α (29.26 ± 18.648 ng/l) and LDH levels (245.47 ± 154.592 IU/l) and a significant decrease in the percentage of blasts cells (0.07 ± 0.060).also in T-cell ALL there were a significant reduction noted for serum TNF-a (26.00 ± 11.135 ng/l) serum LDH (347.66 ± 160.300 IU/l) and percentage of blasts cells in bone marrow (0.06 ± 0.046). All of the postchemotherapy acute leukemia cases with lower TNF-α levels had complete remission (100%).

CONCLUSIONS: There were significant increases in serum TNF-α and LDH in ALL patients at diagnosis; while after induction, there was a significant reduction in their levels. Complete remission from the disease was associated with lower levels of serum TNF-α in newly diagnosed patients.

Keywords:

Acute lymphocytic leukemia, lactate dehydrogenase, tumor necrosis factor-alpha

Introduction

Leukemia is described as a group of malignant stem cell neoplasms. In acute leukemia, the immature, neoplastic leukemic "blast" cells proliferate and accumulate, but fail to mature. Infiltration of the marrow by leukemic cells finally results in cytopenias.[1,2] Tumor necrosis factor-alpha (TNF-α) is a cytokine with a wide range of functions, it is engaged in all stages of leukemogenesis, including cellular proliferation, transformation, angiogenesis,

How to cite this article: Ahmed RY, Al Hatem ZI. Evaluation of the level of tumor necrosis factor-alpha and lactate dehydrogenase in acute lymphoblastic leukemia patients. Iraqi J Hematol 2024;13:275-81.

inflammation, and extramedullary infiltration, and plays a crucial role in the development and progression of malignant illness.[3] LDH is a pyridine-linked enzyme that is normally seen in tissues. In ALL, there is a high cell turnover rate which leads to increased leukemic cell burden and increased serum LDH levels.[4] The aims of this study were to evaluate the level of serum TNF-α and LDH in ALL patients at diagnosis and post-induction chemotherapy.

Patients, Materials, and Methods

This was an observational–analytical study, which was done in Ibn-Sina Teaching Hospital in the period between May 2023 and November 2023. It included 22 newly diagnosed patients with ALL. with age ranged between 2 and 75 years. Diagnosis was confirmed by complete blood count (CBC), blood film, bone marrow (BM) aspiration, and flow cytometry. Twenty-two healthy volunteers recruited as a control group. Their age range from 2–75 years.

A full history was taken from all patients regarding the following: patient's name, age, and sex; date of diagnosis; clinical symptoms; past medical history; past surgical history; family history of any hereditary disease; and drug history. A general and systemic physical examination was done on all patients. The patients underwent hematological and biochemical investigations, including CBC, BM aspirate and flow cytometry, TNF-α, and LDH levels estimation at diagnosis and after induction chemotherapy (21–28 days after starting chemotherapy).

Exclusion criteria

1. Patients previously diagnosed with ALL (patients on maintenance therapy or relapsed cases)
2. Patients with hemolysis (because of high LDH level).

In the start of the study, four male cases died after starting induction and the other two males escaped follow-up before the assessment of induction.

Investigations

Complete blood count

An automated hematology analyzer (Sysmex/XN-350) is used to perform a CBC, including white blood cell count (WBC), hemoglobin (Hb), and platelet count (PLT) indices, on all patients and control with EDTA blood samples.

Peripheral blood (PB) and BM smears were examined for establishing the diagnosis and assessing the remission after induction therapy (by examining the PB and BM and found no blast in PB and <5% blast in BM and neutrophil count above 1×10^9/l, PLT above 100×10^9/l).[5,6] flow cytometry findings data were taken from their files.

Tumor necrosis factor-alpha level assay

Serum TNF-α assay done by a sandwich enzyme immunoassay performed by using a 40-microliter serum sample by using the immunoassay analyzer and the Human TNF-α enzyme-linked immunosorbent assay (ELISA) kit by (YLbiont = name of the kit, China), the test done according to the instructions kit by semi-automated devise chromate.

Test principle

This kit uses an ELISA based on the biotin double antibody sandwich technology to assay Human TNF-α. TNF-α is added to wells precoated with TNF-α monoclonal antibody and incubated. Subsequently, biotin-labeled anti-TNF-α antibodies are added to form an immune complex with streptavidin-HRP. Unbound enzymes are removed after incubation and washing. Substrate solutions A and B are then added, resulting in a color change from blue to yellow due to the acidic reaction. The color intensity of the solution is positively correlated with the concentration of human TNF-α.

The normal value of serum TNF-α which is provided in the kit for serum sample:

Assay range: (3 ng/L→900 ng/L)

There is no global reference for TNF-a; each laboratory should have had its reference value, the normal range in this study according to the control group was: The assay range was 3 ng/l–900 ng/l. The normal range in this study, according to the control group was (20.6271–21.4478 ng/l):

Serum LDH was measured using the fully automated Architect c4000 Biochemistry Analyzer (Abbott Diagnostics, USA.[7]

Reaction principle:

Substrate and coenzyme: The assay involves a reaction where LDH catalyzes the conversion of lactate to pyruvate, with the simultaneous conversion of NAD+ (Nicotinamide adenine dinucleotide) to NADH. Detection: The formation of NADH (which is measurable) can be detected photometrically. NADH absorbs light at a different wavelength than NAD+, so the increase in absorbance can be measured using the analyzer. Automated analysis: The Architect c4000 uses a series of optical sensors and automated systems to measure the absorbance changes caused by the enzymatic reaction. It then calculates the LDH concentration based on these absorbance changes.

Ethical consideration

This study was approved by the Ministry of Health/ Nineveh Health Department, Ethical Committee No. of paper approval (15946/April 9, 2023). The study

was explained to all enrollers and verbal consents were obtained from all patients and control.

Statistical analysis

The data collected during the study were summarized in sheets of Microsoft Excel 2010. The statistical analysis was performed using IBM-SPSS 26 (IBM Company, Armonk, New York). The categorical data were expressed in frequencies and proportions, while the numerical data were expressed in means and standard deviations. The one-way ANOVA was used to calculate the difference between more than two groups with a *post hoc* test to determine the real significance. A paired *t*-test was used to assess the difference between the pre- and postinduction groups, while a *t*-test for independent two means was used for unpaired data. Pearson correlation coefficients were estimated. The association between the proportions of the variables was evaluated using the Fisher exact test, which estimated the difference between the expected and observed values when the expected value for any cell was <5. $P \leq 0.05$ was considered as significant.

Results

The study included 22 patients with ALL (9 males and 13 females, number of B-ALL 19 patients, T-ALL total number was three patients) and 22 age- and sex-matched healthy controls. The mean age of cases was 16.28 ± 17.872 years, and the mean age of control was 20.36 ± 21.682 years.

The distribution of the studied sample according to sex showed that 40.9% were male and 59.1% were female, with a male-to-female ratio of 1:1.44.

The comparison of hematological parameters, TNF-a and LDH levels in B-ALL and T-ALL cases at the time of diagnosis and with control were shown in Table 1 which reveals that the means of Hb, platelets, in T-cell ALL and B-cell ALL were statistically lower than those among the controls with a ($P = 0.000$). The means of TNF, LDH, and %Blast in PB, %Blast in BM in B-ALL and T-ALL were statistically higher than those among the controls with a (P value 0.000). The mean age and WBC showed no statistically significant differences between the cases and the control group.

The comparison of hematological parameters, TNF and LDH levels in B-ALL and T-ALL cases after induction chemotherapy are shown in Table 2, which revealed that means of Hb and WBC among the T-ALL and B-ALL were statistically lower than those among the controls with a ($P = 0.000$). The mean of LDH among the T-ALL and B-ALL were significantly higher than that among the controls ($P = 0.008$). The mean levels of platelets and TNF showed no statistically significant differences compared to the control group. The percentage of blasts in the peripheral blood smear and bone marrow among B-ALL cases was higher than in the controls ($P = 0.023$ and 0.0, respectively).

In the preinduction state, a positive and direct correlation was observed between the TNF-α level and the percentage of blasts in the peripheral blood smear ($r = 0.285$) and in the bone marrow ($r = 0.369$), with statistically significant associations ($P = 0.041$ and $P = 0.039$, respectively).

No statistically significant correlations were found with the remaining study parameters, including WBC, platelets, and hemoglobin, as shown in Table 3.

In the preinduction phase, LDH levels showed no statistically significant differences with the hematological parameters except for the percentage of the blasts in the BM, which showed a positive direct correlation ($r = 0.520$) with a statistically significant association ($P = 0.013$), as shown in Table 4.

In the postinduction phase, the TNF level showed a direct and positive correlation with the percentage of blasts in the peripheral blood smear ($r = 0.649$) and in the bone marrow ($r = 0.712$), both with statistically significant associations ($P = 0.001$ and $P = 0.000$, respectively). Additionally, LDH levels were directly and positively correlated with the percentage of blasts in the peripheral blood smear ($r = 0.630$) and in the bone marrow ($r = 0.562$), also showing statistically significant associations ($P = 0.002$ and $P = 0.006$, respectively). However, the correlations with WBC, Hb, and platelets were not statistically significant, as shown in Table 5.

All of the postchemotherapy acute leukemia cases with low (normal) TNF-α levels had complete remission (100%), while more than half of the postchemotherapy acute leukemia cases with high TNF-α levels had incomplete remission (66.7%). This association was found to be statistically significant ($P < 0.002$) with the postinduction remission status in the ALL cases. The comparison of LDH levels with the postinduction remission status in the ALL cases showed that the majority of patients (68.4%) with low LDH postinduction showed remission, while one-third (31.6%) showed no remission but this association was not significant with $P = 0.527$, as shown in Table 6.

Discussion

Acute lymphoblastic leukemia is the most common malignancy of childhood and accounts for about 20% of adult cancer with good response to treatment. Hence,

Table 1: Hematological parameters, tumor necrosis factor, and lactate dehydrogenase levels in B-acute lymphocytic leukemia, T-acute lymphocytic leukemia cases, and control at the time of diagnosis

Parameters (at diagnosis)	Control, mean±SD	B-ALL, mean±SD	T-ALL, mean±SD	*P**
Age (year)	20.36±21.682	15.16±18.884	23.33±7.637	0.569
Hb (g/dL)	13.22±1.066^{A}	7.65±1.967^{B}	9.50±6.518^{B}	0.000
WBC × 10^9/L	7.50±1.896	22.92±58.959	63.81±54.287	0.080
PLT × 10^9/L	233.63±85.776^{A}	92.68±92.242^{B}	90.33±71.500^{B}	0.000
Blast in PB %	-	0.155±0.238^{B}	0.426±0.359^{C}	0.000
Blast in BM %	-	0.742±0.181^{B}	0.816±0.125^{B}	0.000
TNF-α (ng/L)	18.09±6.795^{A}	97.89±52.945^{B}	165.33±23.437^{C}	0.000
LDH (IU/L)	142.59±61.626^{A}	1138.94±430.101^{B}	1633.33±497.426^{C}	0.000

*One-way ANOVA with *post hoc* test; similar letters mean no significant difference while different letters mean a significant difference. TNF-α=Tumor necrosis factor-alpha, LDH=Lactate dehydrogenase, B-ALL=B-acute lymphocytic leukemia, WBC=White blood cell, PLT=Platelet count, Hb=Hemoglobin, PB=Peripheral blood, BM=Bone marrow, SD=Standard deviation

Table 2: Hematological parameters, tumor necrosis factor, and lactate dehydrogenase levels in B-acute lymphocytic leukemia and T-acute lymphocytic leukemia cases after induction chemotherapy

Parameters (postinduction)	Control, mean±SD	B-ALL, mean±SD	T-ALL, mean±SD	*P**
Hb (g/dL)	13.22±1.066^{A}	10.74±1.900^{B}	8.90±0.781^{B}	0.000
WBC × 10^9/L	7.50±1.896^{A}	4.97±1.889^{B}	4.48±3.016^{B}	0.000
PLT × 10^9/L	233.63±85.776	176.84±78.497	228.66±147.649	0.059
Blast in PB %	-	0.01±0.018^{B}	0.00±0.000^{A,B}	0.023
Blast in BM %	-	0.07±0.060^{B}	0.06±0.046^{B}	0.000
TNF (ng/L)	18.09±6.795	29.26±18.648	26.00±11.135	0.069
LDH (IU/L)	142.59±61.626^{A}	245.47±154.592^{B}	347.66±160.300^{B}	0.008

*One-way ANOVA with *post hoc* test; similar letters mean no significant difference while different letters mean significant difference. TNF=Tumor necrosis factor, LDH=Lactate dehydrogenase, B-ALL=B-acute lymphocytic leukemia, WBC=White blood cell, PLT=Platelet count, Hb=Hemoglobin, PB=Peripheral blood, BM=Bone marrow, SD=Standard deviation

Table 3: Pearson correlation of tumor necrosis factor levels with other parameters at preinduction

TNF in preinduction with study parameters	*r*	Asymptotic SE[a]	Approximate *t*[b]	*P**
WBC × 10^9/L	0.001	0.161	0.005	0.996[c]
Hb (g/dL)	0.042	0.187	0.187	0.853[c]
PLT × 10^9/L	−0.240	0.261	−1.107	0.281[c]
Blast in PB %	0.285	0.169	3.921	0.041[c]
Blast in BM %	0.369	0.201	4.034	0.039[c]

*Pearson's correlation test, [a]Not assuming the null hypothesis, [b]Using the asymptotic standard error assuming the null hypothesis, [c]Based on normal approximation. SE=Standard error, TNF=Tumor necrosis factor, WBC=White blood cell, PLT=Platelet count, Hb=Hemoglobin, PB=Peripheral blood, BM=Bone marrow

Table 4: Pearson correlation of lactate dehydrogenase levels with other parameters at preinduction

LDH in preinduction with study parameters	*r*	Asymptotic SE[a]	Approximate *t*[b]	*P**
WBC × 10^9/L	0.071	0.181	0.320	0.753[c]
Hb (g/dL)	0.374	0.208	1.802	0.087[c]
PLT × 10^9/L	−0.043	0.181	−0.192	0.849[c]
Blast in PB (%)	0.167	0.204	0.756	0.458[c]
Blast in BM (%)	0.520	0.144	2.725	0.013[c]

*Significance <0.05. [a]Not assuming the null hypothesis, [b]Using the asymptotic SE assuming the null hypothesis, [c]Based on normal approximation. LDH=Lactate dehydrogenase, WBC=White blood cell, PLT=Platelet count, Hb=Hemoglobin, PB=Peripheral blood, BM=Bone marrow, SE=Standard error

proper assessment of the hematological parameters with serum TNF-α and other parameters like LDH may aid the future treatment and prognosis of ALL cases.

Table 5: Pearson correlation of tumor necrosis factor and lactate dehydrogenase levels with other parameters at postinduction

Postinduction with study parameters	*r*	Asymptotic SE[a]	Approximate *t*[b]	*P**
TNF				
WBC × 10^9/L	0.025	0.236	0.111	0.913[c]
Hb (g/dL)	0.013	0.143	0.056	0.956[c]
Platelet × 10^9/L	−0.098	0.167	−0.441	0.664[c]
Blast in PBS %	0.649	0.095	3.817	0.001[c]
Blast in BM %	0.712	0.036	4.533	0.000[c]
LDH				
WBC × 10^9/L	−0.379	0.139	−1.829	0.082[c]
Hb (g/dL)	−0.028	0.189	−0.124	0.902[c]
Platelet × 10^9/L	−0.297	0.160	−1.389	0.180[c]
Blast in PBS %	0.630	0.187	3.627	0.002[c]
Blast in BM %	0.562	0.168	3.040	0.006[c]

*Pearson's correlation test, [a]Not assuming the null hypothesis, [b]Using the asymptotic SE assuming the null hypothesis, [c]Based on normal approximation. SE=Standard error, LDH=Lactate dehydrogenase, WBC=White blood cell, PLT=Platelet count, Hb=Hemoglobin, PBS=Peripheral blood smear, BM=Bone marrow, TNF=Tumor necrosis factor

The mean age of ALL patients was (16.28 ± 17.872 years), while in Hamodat *et al.*,[8] the mean age for patients with ALL was (14.1 ± 1.7 years), this disparity could be due to the wide age range in the present study because it included children and adult patient.

For the hematological parameters at diagnosis, this study showed a significant difference in the means of

Table 6: Correlation of tumor necrosis factor-α and lactate dehydrogenase levels with postinduction remission status in all cases

Remission status	Total (*n*=22)	Postchemotherapy		*P**
		High TNF-α levels (n=12), *n* (%)	Normal TNF-α levels (*n*=10), *n* (%)	
TNF-α				
Remission	14	4 (33.3)	10 (100.0)	0.002
Incomplete remission	8	8 (66.7)	0	
Remission status	**Total (*n*=22)**	**High LDH levels (*n*=3), *n* (%)**	**Normal LDH levels (*n*=19), *n* (%)**	***P****
LDH levels				
Remission	14	1 (33.3)	13 (68.4)	0.527
Incomplete remission	8	2 (66.7)	6 (31.6)	

*P<0.05. Fisher's exact test. TNF-α=Tumor necrosis factor-alpha, LDH=Lactate dehydrogenase

WBC, the percentage of blast in both PB and BM in Tcell-ALL, which were statistically higher than those among the controls and those among the B-cell ALL. Similar findings were found in Jaafar and Kadhom,[9] Niaz *et al*.,[10] and Mohammed *et al*.[11] studies. The mean levels of Hb and PLT in B-cell ALL and T-cell ALL were statistically lower than those in the normal control group, which is consistent with the findings of Mustafa *et al*.[12] This decrease is attributed to the disease process, which leads to a significant increase in WBC and blast count in both the peripheral blood and bone marrow, as well as bone marrow infiltration, resulting in a marked reduction in hemoglobin and platelet levels.

In the preinduction phase, the means of TNF-α in T-cell ALL were statistically higher than those among both the controls and B-cell ALL, this was in line with another study by Verma *et al*.[13] from King George's Medical University in India, the same result was found in Drabko *et al*.[14] and Kalmanti *et al*.[15] studies. This could be due to the fact that TNF-α is a biologically active mediator (cytokine) that is secreted mainly from T-cell ALL blast cells so it is increased due to increased blast and WBC count that increases its secretion. TNF-α causes impaired apoptosis and proliferation of immature cells, but this disagrees with. However, this finding disagrees with the study by Potapnev *et al*.,[16] which found that TNF-α levels in the plasma corresponded with clinical characteristics and outcomes in patients with ALL but reported that mean TNF-α levels in these patients were not substantially different from those in healthy children ($P = 0.24$). Similarly, the study by Aref *et al*.[17] showed no significant increase in serum TNF-α levels at the time of diagnosis compared to control levels ($P > 0.05$).

This study found that serum LDH levels were higher in ALL patients than in controls during the preinduction phase, which is consistent with the findings of Elbossaty,[18] Hamodat *et al*.,[8] and Kalmanti *et al*.[15] This increase is attributed to elevated cellular LDH activity, reflecting a shift toward anaerobic metabolism and increased glycolysis in the cytoplasm of malignant cells, as well as a high cellular turnover rate and tumor burden activity.

In the present study, the comparison of the hematological parameters between B-ALL cases and control at the time of diagnosis shows that there was a statistically significant reduction in the mean of Hb and PLT; this is also comparable to Mustafa *et al*.'s[12] study, the current study also showed a statistically significant increase in the mean of the blasts percentages in PB, and BM, a similar finding was found in Jaafar and Kadhom,[9] and there was a statistically significant increase in TNF-α level, as mentioned in Verma *et al*.[13] study also showed there was an increase in LDH level, which was statistically significant, this came in line with Elbossaty[18] study.

After the induction phase, B-ALL cases showed a marked increase in mean Hb and PLT, which agrees with Hafiz and Mannan[19] and Verma *et al*.[13] studies. While the means of TNF levels and the percentage of blasts in both the peripheral blood and bone marrow during the postinduction phase were significantly lower than those in the preinduction phase, these findings are consistent with the studies by Hafiz and Mannan[19] and Verma *et al*.[13]

In the postinduction phase, regarding the T-ALL, the means of TNF-α (26.00 ± 11.135 ng/l), and the percentage of the blasts in BM (0.06 ± 0.046) were significantly lower than those in preinduction this came in line with Verma *et al*.[13] and Ahmed *et al*.[20] studies. Although the serum LDH level was also decreased significantly after induction, this is also found in the study done in Iraq by Hamodat *et al*.[8] and in Egypt by Elbossaty,[18] and Hafiz and Mannan[19] this could be due to chemotherapy that caused the elimination of the disease and corrected the hematological parameter, decreasing blast count, WBC count, and the level of serum LDH and TNF-α.

During the preinduction phase, TNF-α showed a positive and direct correlation with the percentage of blasts in peripheral blood ($r = 0.285$) and in bone marrow ($r = 0.369$), with statistically significant associations ($P = 0.041$ and $P = 0.039$, respectively). While no statistically significant correlations were found with the remaining study parameters this is in line with the result of Verma

et al.[13] which does not agree with Aref *et al*.[17] who mentioned that the level of TNF-α is not significantly correlated to PB blast cell count and BM blast cell count. This is because TNF-α is secreted from immature cells (blasts), so its secretion is directly correlated with the blasts in PB and BM; when the blast increased, the TNF-α increased.

In the preinduction phase, the current study declared that LDH levels positively correlated with blast percentage in the bone marrow; this agrees with Elbossaty,[18] and Tawfique *et al*.[21] and Al-Saadoon *et al*.,[22] although these results were opposite to the result of Hafiz and Mannan[19] studies that found that there was no significant correlation between the peripheral and BM blast cell percentages with serum LDH level at day (0) before induction.

In the current study, there was no correlation between LDH and WBC, a similar finding was found by Murali *et al*. study,[23] and a different result was found by Tawfique *et al*.,[21] and Al-Saadoon *et al*.[22] studies that mention there is a strong positive correlation between initial WBC count and LDH.

In the postinduction phase, TNF-α levels showed a significant positive correlation with the percentage of blasts in both the peripheral blood and bone marrow. This finding agrees with the studies by Potapnev *et al*.[16] and Ahmed *et al*.[20] However, the correlation between TNF-α levels, blast percentage, and WBC count has been examined in only a few major studies. This could be because cytokine reflects contribution to the "peripheralization" (migration from BM to PB) of leukemic cells.

In the postinduction phase, a positive correlation of LDH with the percentage of blast in PB, and BM, This is in agreement with Hafiz and Mannan[19] and Al-Saadoon *et al*.[22] studies.

The current study showed that all the cases with low (normal) TNF-α levels had complete remission, while only (33.3%) of cases with high TNF-α levels had complete remission and the difference was statistically significant; this agrees with Tsimberidou *et al*.[24] and Verma *et al*.[13] studies but disagree with Zhonghua,[25] these results could be due to the protocol of chemotherapy that was used in recent years that led to the lowering of TNF-α more than the old protocols used in the Zhonghua study. Furthermore, the cells of lower TNF-α expression have more sensitivity to chemotherapy than those with higher TNF-α expression.

In this study, the majority of patients (68.4%) with low LDH postinduction were found to be in remission, while one-third (31.6%) showed no remission, but this association was not significant; this disagrees with Elbossaty[18] study which mentioned that all cases with low LDH show complete remission. The possible cause for this difference could be due to the short time of remission assessments, so the level of LDH did not clear from the blood or it could be due to the presence of some blasts in the BM that could not be cleared by chemotherapy yet.

Conclusions

Serum TNF-α levels were significantly higher in ALL cases than healthy controls at the time of diagnosis. After the induction phase, TNF-α levels were significantly decreased in the majority of cases. High levels of TNF-α are positively correlated with incomplete remission status. A high level of TNF-α is positively correlated with the percentage of blast in PB and BM in the preinduction and postinduction phases. Serum LDH levels were significantly higher in ALL cases than in healthy controls at the time of diagnosis. After the induction phase, serum LDH levels were significantly decreased in the majority of cases. Serum LDH level is positively correlated with the percentage of blasts in the BM in the preinduction and postinduction phases.

Acknowledgment

I dedicate my deep appreciation to the Pathology department members at the College of Medicine, University of Mosul. My special and cordial thanks to all staff in the Haematology Center in Ibn Sina and Ibn Al-Atheer Teaching Hospitals for their help and support during the study period. Special thanks to Dr. Yahya Tariq for his help in the Ibn Sina Hospital.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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