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Original Article

The Effect of Delay Time and EDTA Blood Storage Temperature on Leukocyte and Platelet Counts in Cancer Patients

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ABSTRACT

Cancer is a global health problem with high morbidity and mortality rates. Hematological tests play a crucial role in monitoring cancer patients; however, the results can be influenced by preanalytical factors, such as testing delays and blood sample storage temperature. This study aims to analyze the effects of time delay and EDTA blood storage temperature on leukocyte and platelet counts in cancer patients. The study design used was a laboratory experiment with a pretest-posttest approach. The sample consisted of 25 EDTA blood samples from cancer patients at the Hematology-Oncology Clinic of the Haji Provincial General Hospital in East Java. The time variables included immediate testing, 2-hour delay, and 4-hour delay, while the storage temperature variables included 2–8 °C and 20–25 °C. Data analysis was performed using Repeated Measures ANOVA. The results showed that delay time had a significant effect on leukocyte count ($p = 0.036$) and platelet count ($p = 0.013$) in cancer patients. Conversely, storage temperature did not significantly affect either parameter ($p > 0.05$). Post hoc tests revealed a significant difference in leukocyte counts between the 2-hour and 4-hour delay groups, whereas for platelet counts, a significant difference was observed starting from the 2-hour delay compared to immediate testing. In conclusion, the delay in testing affected the white blood cell and platelet counts in EDTA blood samples from cancer patients, whereas storage temperature had no significant effect during the study period.

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INTRODUCTION

Cancer remains one of the world's leading health issues, with high rates of morbidity and mortality. In 2022, the Global Cancer Observatory (GLOBOCAN) reported that cancer caused approximately 9.7 million deaths, or 18.7% of total global deaths, and that the incidence rate in Indonesia reached 408,661 cases with 242,988 deaths. Based on these data, cancer ranks third as

a cause of death after stroke and heart disease[1]. Cancer is associated with oxidative stress. Reactive oxygen species (ROS) are generated during cellular metabolism and can increase when the balance between oxidant production and antioxidant defense is disturbed. Excess ROS can damage lipids, proteins, and nucleic acids and alter cellular function[2,3]. Research by Danesh et al[4] indicates that high ROS exposure in cancer patients reduces glutathione peroxidase (GPX) levels. GPX acts as an antioxidant enzyme that neutralizes ROS and protects blood cells from oxidative damage. Low GPX levels in cancer patients expose blood cells, including leukocytes and platelets, to oxidative stress, making them more susceptible to cellular damage. In leukocytes, increased ROS and systemic inflammation may stimulate the bone marrow to release excessive numbers of cells, including immature leukocytes, which have lower membrane stability and are more susceptible to structural changes during in vitro storage[5] . Meanwhile, persistent ROS exposure may cause chronic platelet hyperactivation, making platelets more susceptible to additional cellular stress[6].

Once blood is collected into an EDTA tube, blood cells are removed from their physiological environment and remain metabolically active. Leukocytes may undergo morphological changes during storage, including nuclear lobulation, pyknosis, vacuolization, degeneration, and membrane damage[7]. Platelets may also change in shape, aggregate, or form smaller fragments due to their adhesive and aggregative properties[2]. Although EDTA prevents coagulation by binding calcium ions, prolonged exposure may affect cellular stability and cause irreversible structural, biochemical, and functional changes[7,8]. These changes may ultimately affect the accuracy of leukocyte and platelet measurements[9] .

Storage time and temperature are important factors influencing the rate of cellular degeneration. Higher temperatures may maintain cellular metabolic and enzymatic activity, thereby accelerating morphological changes and cellular degradation, whereas refrigeration can reduce metabolic activity and slow these processes[3]. Ideally, EDTA blood should be examined immediately after collection. When immediate analysis is not possible, refrigerated storage may be used within an appropriate time limit[10]. Laboratory guidelines indicate that cellular degeneration may begin within 30 minutes after collection and that the quality of EDTA blood smears may not be guaranteed after six hours[11].

In routine laboratory practice, delays may occur due to equipment problems, staff shift changes, power outages, specimen transportation delays, or an imbalance between specimen volume and available personnel[12]. Maharani and Astuti[13] reported significant changes in leukocyte and platelet results following a 48-hour delay at refrigerator temperature, indicating that refrigeration may slow but does not completely prevent cellular deterioration. Similarly, Aunisajidah and Afriansyah[14] found that a two-hour delay at room temperature caused leukocyte morphological

changes, particularly cytoplasmic vacuolization, which became more pronounced with longer storage.

Considering the biological vulnerability of blood cells in cancer patients, appropriate management of delay time and storage temperature is essential for maintaining specimen quality and ensuring reliable hematology results. However, studies evaluating the combined effects of delay time and EDTA blood storage temperature on leukocyte and platelet counts specifically in cancer patients remain limited in Indonesia. Therefore, this study aims to analyze the effects of delay time and EDTA blood storage temperature on leukocyte and platelet counts in cancer patients. The findings are expected to support improved pre-analytical specimen handling and contribute to obtaining hematology results that more accurately represent patients' conditions.

METHODS

The study used a laboratory experiment with a pretest-posttest design to evaluate changes in leukocyte and platelet counts after controlled delays in testing. The independent variables were testing delay (immediate, 2 hours, and 4 hours) and storage temperature (2–8 °C and 20–25 °C). The dependent variables were leukocyte count and platelet count, treated as continuous numerical variables and reported as $\times 10^3/\mu L$. Leukocyte and platelet counts were obtained from EDTA whole blood samples using the Sysmex XN-1000 Hematology Analyzer. Leukocyte counts were measured by fluorescent flow cytometry, whereas platelet counts were determined using the impedance principle. The study was conducted at the Clinical Pathology Laboratory of Haji Provincial General Hospital, East Java, during 2026 and was approved by the Health Research Ethics Committee of Haji Provincial General Hospital.

Five patients diagnosed with cancer were included through purposive sampling, with sample selection conducted between January 22 and February 3, 2026. Inclusion criteria were a confirmed cancer diagnosis, age 18–60 years, absence of HIV/AIDS, sepsis, or pneumonia, and willingness to participate by signing informed consent. From each participant, blood was distributed into five EDTA microtubes (0.5 mL), yielding 25 EDTA blood samples in total. Tube 1 was examined immediately as the control. Tubes 2 and 3 were stored at 2–8 °C for 2 and 4 hours, respectively, while tubes 4 and 5 were stored at 20–25 °C for 2 and 4 hours, respectively.

The data were tested for normality using the Shapiro–Wilk test because the sample size was less than 50. Normally distributed data were analyzed using Repeated Measures ANOVA to assess the effects of delay time, storage temperature, and their interaction. If the normality assumption was not met, the Friedman test was planned. When a significant overall effect was identified, post hoc tests were performed were performed. Statistical significance was set at $p < 0.05$.

RESULTS

Table 1. Mean Leukocyte and Platelet Counts in Cancer Patients Based on Delay Time and Storage Temperature

Parameter	Storage Temperature	Time		
		Immediate	2-hour delay	4-hour delay
Leukocyte Count $(10^3/\mu L)$	2 – 8 °C	11.64	11.65	11.91
	20 – 25 °C		11.63	11.72
Platelet Count $(10^3/\mu L)$	2 – 8 °C	248.4	257.6	261.2
	20 – 25 °C		263.4	269.6
Parameter	Storage Temperature	**Immediate**	**2-hour delay**	**4-hour delay**
Leukocyte Count $(10^3/\mu L)$	2 – 8 °C	11.64	11.65	11.91
	20 – 25 °C		11.63	11.72
Platelet Count $(10^3/\mu L)$	2 – 8 °C	248.4	257.6	261.2
	20 – 25 °C		263.4	269.6

The mean leukocyte and platelet counts in EDTA blood samples from cancer patients examined immediately, after a 2-hour delay, and after a 4-hour delay at storage temperatures of 2–8 °C and 20–25 °C are presented in Table 1. The mean leukocyte count showed a tendency to increase with longer delay times under both storage temperature conditions. Similarly, the mean platelet count tended to increase as the storage time increased under both temperature conditions.

Table 2. Results of the Shapiro-Wilk Test for Normality of Leukocyte and Platelet Data

Parameter	Storage Temperature	Time	p-value	Notes
Leukocyte Count	2 – 8 °C	Immediate	0.093	Normally distributed
		2-hour delay	0.082	
		4-hour delay	0.097	
	20 – 25 °C	Immediate	0.093	
		2-hour delay	0.090	
		4-hour delay	0.090	
Platelet Count	2 – 8 °C	Immediate	0.289	
		2-hour delay	0.286	
		4-hour delay	0.301	
	20 – 25 °C	Immediate	0.289	
		2-hour delay	0.272	
		4-hour delay	0.225	

The results of the Shapiro-Wilk normality test for leukocyte and platelet parameters are presented in Table 2. Based on these data, all p-values were >0.05 therefore, the data were considered normally distributed, and the leukocyte and platelet count data were subsequently analyzed using parametric Repeated Measures ANOVA.

Table 3. Results of the RM Anova Test for Leukocyte and Platelet Parameters

Parameter	Effect	p-value	Note
Leukocyte Count	Time	0.036	There is an effect
	Temperature	0.990	There is no effect
	Time* Temperature	0.333	There is no effect
Platelet Count	Time	0.013	There is an effect
	Temperature	0.969	There is no effect
	Time* Temperature	0.712	There is no effect

The results of the Repeated Measures ANOVA for leukocyte and platelet parameters are presented in Table 3. For leukocyte count, the analysis showed a significant effect of storage time ($p = 0.036$), whereas storage temperature ($p = 0.990$) and the interaction between time and temperature ($p = 0.333$) were not significant. Similarly, for platelet count, storage time had a significant effect ($p = 0.013$), while storage temperature ($p = 0.969$) and the interaction between time and temperature ($p = 0.712$) were not significant. These findings indicate that changes in leukocyte and platelet counts were significantly associated with storage time but not with storage temperature or their interaction. Therefore, post hoc analysis was performed to identify specific time points with significant differences.

Table 4. Results of Pos Hoc Test on Leukocyte and Platelet Parameters

First Time	Comparison Time	p-value	Note
Leucocyte Parameters			
Immediate leukocyte count	Leukocyte count after a 2-hour delay	1.000	There is no significant difference
Leukocyte count after a 2-hour delay	Leukocyte count after a 4-hour delay	0.033	There is significant difference
Immediate leukocyte count	Leukocyte count after a 4-hour delay	0.075	There is no significant difference
Platelet Parameters			
Immediate platelet count	Platelet count after a 2-hour delay	0.021	There is significant difference
Platelet count after a 2-hour delay	Platelet count after a 4-hour delay	0.278	There is no significant difference
Immediate platelet count	Platelet count after a 4-hour delay	0.021	There is significant difference

The results of the post hoc analysis for leukocyte and platelet parameters are presented in Table 4. For leukocyte count, the comparison between immediate testing and a 2-hour delay showed no significant difference ($p = 1.000$). However, a significant difference was observed between the 2-hour and 4-hour delays ($p = 0.033$), while the comparison between immediate testing and a 4-hour delay was not significant ($p = 0.075$). These findings indicate that the significant change in leukocyte count was observed between the 2-hour and 4-hour delay periods.

For platelet count, a significant difference was observed between immediate testing and a 2-hour delay (p = 0.021). In contrast, the comparison between the 2-hour and 4-hour delays showed no significant difference (p = 0.278). The comparison between immediate testing and a 4-hour delay was also statistically significant (p = 0.021). These findings indicate that a significant change in platelet count occurred within the first 2 hours of testing delay.

DISCUSSION

Leukocyte counts in cancer patients based on delay time and storage temperature

The mean leukocyte count increased with longer testing delays under both storage conditions, with a greater increase at 2–8°C (2.32%) than at 20–25°C (0.69%). The observed increase in mean leukocyte count does not represent leukocyte production after blood collection but rather reflects changes in the measured leukocyte concentration during in vitro storage. Cancer patients may exhibit increased systemic inflammation and altered immune activity, which can affect leukocyte characteristics and their response to in vitro conditions. Inflammatory mediators such as granulocyte colony-stimulating factor (G-CSF), granulocyte-macrophage colony-stimulating factor (GM-CSF), and interleukin-6 (IL-6) may contribute to changes in leukocyte activity and cellular characteristics in cancer patients[5]. In addition, cancer cells and inflammatory processes may increase the production of reactive oxygen species (ROS), potentially inducing oxidative stress in circulating blood cells. This is supported by findings of elevated cellular and mitochondrial ROS levels in peripheral blood mononuclear cells of patients with gastrointestinal cancers, suggesting an association between cancer-related oxidative stress, mitochondrial dysfunction, and immune cell alterations [15,16]. Reduced antioxidant capacity, including decreased glutathione peroxidase (GPX) activity, may further increase the susceptibility of cells to oxidative damage. These conditions may increase the biological vulnerability of leukocytes to pre-analytical factors such as prolonged storage and changes in storage conditions[4].

During storage, leukocytes remain metabolically active and continue to undergo cellular metabolism. The first mechanism is cellular in nature. After blood is collected, blood cells experience oxygen deprivation, leading to a decrease in oxidative phosphorylation and reduced production of adenosine triphosphate (ATP). The decrease in ATP causes a reduction in ion pump activity, leading to an increased influx of sodium (Na^+), calcium (Ca^{2+}), and water (H_2O) into the cells, which causes the cells to swell (cell swelling)[17]. The second mechanism is chemical in nature, resulting from exposure to EDTA. EDTA functions as a chelating agent by binding calcium ions. Calcium plays a crucial role in maintaining cell membrane integrity, thus prolonged exposure to EDTA can increase leukocyte membrane permeability. Consequently, extracellular fluid more easily enters the cell, exacerbating the cell swelling phenomenon that has already occurred through cellular biochemical mechanisms[18].

The phenomenon of leukocyte swelling caused by these two mechanisms directly affects the physical characteristics of the cells detected by the hematology analyzer. For leukocyte count analysis, this study utilized the Sysmex XN-1000 instrument, which operates on the principle of fluorescent flow cytometry to identify cells based on three laser signals: forward scatter (cell size), side scatter (internal complexity and cell structure), and fluorescent signal (DNA/RNA content)[19]. Fluorescent dyes such as Stromatolyser-4DS can penetrate the cell membrane and bind to nucleic acids (DNA/RNA) in the nucleus and cytoplasm; thus, cells with high activity or low maturity levels will exhibit a stronger fluorescent signal due to their high nucleic acid content. Under delayed conditions, enlarged cells not only increase cell size (forward scatter) but also increase fluorescence signal intensity because cancer patients are dominated by immature cells. The combination of these changes causes a shift in cell position within the scattergram, so that cells previously below the detection limit begin to be counted as leukocytes, resulting in a falsely high leukocyte count[19].

In addition to an increase, the number of leukocytes also decreases after a 2-hour delay at a temperature of 20–25 °C. After blood is drawn, leukocytes continue to metabolize, but due to reduced oxygen supply, they switch to anaerobic metabolism (glycolysis). Under anaerobic conditions, pyruvic acid produced by glycolysis is converted into lactic acid to regenerate NAD+ from NADH allowing glycolysis to continue and maintain cellular energy production[20]. This aligns with the findings of Zavorsky et al[21], who demonstrated that blood samples stored at 22–24 °C exhibit a progressive increase in lactate concentration at an average rate of 0.008 mmol/L/minute. An increase in lactate concentration of ≥ 0.4 mmol/L occurred after 45 minutes at 22–24 °C, with 5% of all blood samples showing significant changes within ≤ 20 minutes. During storage at 20–25 °C, the accumulation of reactive oxygen species (ROS) and the decrease in blood pH due to lactate production in EDTA tubes cause oxidative stress that can damage the integrity of leukocyte membranes. This triggers the spontaneous activation of lysosomal enzymes. Consequently, autolysis and cellular structural degradation occur. Leukocytes begin to lose their normal cell shape, and cell size also changes, making them no longer optimally recognizable by hematology analyzers[22].

Platelet counts in cancer patients based on delay time and storage temperature

The mean platelet count increased progressively with longer testing delays under both storage conditions, with a greater increase observed at 20–25 °C than at 2–8 °C. from 3.70% to 8.54%. The increase in platelet count observed in this study resulted from the interaction between internal factors related to the pathological condition of cancer patients and external factors caused by delays in testing EDTA blood samples. Cancer patients have high levels of blast cells in their

bloodstream. Blast cells are immature cells with more fragile cell membranes. During the delay, blast cells are more prone to cytoplasmic fragmentation into small particles due to prolonged exposure to EDTA, which reduces cell membrane stability. These fragmentation products are known as pseudoplatelets, which are fragments of relatively small size, ranging from 2 to 30–40 fL, resembling the size of true platelets[23].

The impedance principle of hematology analyzers has limitations, one of them is that they cannot specifically distinguish platelets from other particles within the same size range because these devices detect cells solely based on the size of particles passing through the detection gap, without the ability to identify specific cell types. The cell size detectable as platelets on a hematology analyzer ranges from 20 fL to 60 fL. Therefore, pseudoplatelets formed from blast cell fragmentation may be counted as platelets, leading to a false increase in platelet count[24].

Platelets stored at a temperature of 20–25 °C continue to undergo metabolic activity, leading to lactate accumulation and a decrease in pH. When the pH drops below 6.0–6.2, platelet viability decreases, cell size increases, and disintegration may occur[25]. Platelets are a blood component susceptible to changes due to variations in environmental conditions, particularly temperature and storage duration. Delayed testing can cause platelets to undergo spontaneous activation. Additionally, changes in pH and agitation can trigger the release of platelet granules, causing a change in shape from discoid to spherical[22]. These changes cause the GPIIb/IIIa complex on the platelet surface to undergo a conformational change, thereby exposing the binding sites for fibrinogen or vWF, which triggers aggregation and the formation of aggregates[25].

Depending on their size, these platelet aggregates are then identified by the hematology analyzer as large single platelets or as small leukocytes, making cell counting difficult. This results in a false decrease in platelet count and a false increase in leukocyte count[24]. Meanwhile, at 2–8 °C, platelet metabolism can be inhibited, allowing their stability to be maintained for up to 6 hours[26]. These findings are consistent with the results of this study, which show that platelet counts stored at 2–8 °C are more stable than those stored at 20–25 °C.

The effect of delay time and EDTA blood storage temperature on leukocyte and platelet counts in cancer patients

Statistical analysis using the Repeated Measures ANOVA test showed that the time effect had a significant impact on changes in leukocyte and platelet counts in cancer patients, whereas the temperature effect did not show a significant impact. The results of the post hoc test for the leukocyte parameter indicated that the time groups that significantly influenced changes in leukocyte counts were the 2-hour and 4-hour delay groups. Meanwhile, for the platelet parameter, the time-group pairs that had a significant effect were the immediate examination group with a 2-hour delay and a 4-hour delay. This means that changes in leukocyte count can occur after a delay

of more than 2 hours, and changes in platelet count begin to occur as early as a 2-hour delay. These findings are consistent with those of Alam et al[22], who reported that the duration of blood sample storage affects changes in leukocyte and platelet counts. These changes are caused by biological degradation and cell damage resulting from prolonged exposure to room temperature.

In cancer patients, systemic inflammation causes an increase in leukocyte counts as immature cells are released from the bone marrow to fight cancer cells[5]. In addition, cancer cells and surrounding immune cells also produce high levels of IL-6 as part of the chronic inflammatory response. IL-6 then stimulates the liver to increase production of thrombopoietin (TPO), the primary hormone regulating thrombopoiesis in the bone marrow. Elevated TPO levels stimulate the proliferation and differentiation of megakaryocytes, thereby accelerating platelet formation and resulting in high platelet counts[27]. These abnormal biological conditions also affect the characteristics of cancer patients' blood cells, making them less stable and more sensitive to environmental changes during storage. When blood is collected in vacuum tubes containing the anticoagulant EDTA, it is no longer in its physiological state. The anticoagulant EDTA prevents blood clotting by binding calcium ions, keeping the blood liquid during storage and testing. The use of EDTA is crucial in hematological testing because it helps maintain blood stability, allowing various parameters such as leukocytes and platelets to be accurately measured[22]. However, long-term storage of blood samples can lead to artifactual changes in cell morphology, which may result in misinterpretation of the results[7].

In this study, the increase in leukocyte count in cancer patients was not only caused by systemic inflammation but was also influenced by cellular changes during the delay in testing. A delay in testing can lead to cell swelling, a phenomenon in which leukocytes swell in vitro, causing the hematology analyzer to interpret the altered cell size as an increase in leukocyte count. Meanwhile, the increase in platelet count during the delay in testing may be influenced by blast cell fragmentation that occurs during the delay. Therefore, the increased leukocyte and platelet counts do not reflect the actual clinical condition but are merely artifacts resulting from the delay in EDTA blood testing.

Testing of EDTA blood samples is recommended to be performed immediately after blood collection, however if it must be delayed, the samples may be stored at refrigerator temperature while adhering to the acceptable time limits for delay[10]. Ministry of Health Regulation No. 43 of 2013 recommends that testing be performed no later than 2 hours after sample collection at room temperature to maintain the stability of leukocyte and platelet counts. Therefore, EDTA blood samples from cancer patients should be tested as soon as possible and no later than 2 hours after blood collection, as clinical decisions are highly dependent on the accuracy of the test results.

Based on the results of this study, the delay in testing had a significant effect on leukocyte and platelet counts in cancer patients. Significant changes began to appear after a 2-hour delay and became more pronounced after a 4-hour delay compared to immediate testing. This indicates that the longer the delay, the greater the potential for changes in cell counts. Conversely, the storage temperature of EDTA blood, whether at 2–8 °C or 20–25 °C, did not show a significant effect on leukocyte and platelet counts in cancer patients. Nevertheless, storage at 2–8 °C is still recommended over storage at 20–25 °C if there is a possibility of a delay in testing.

This study has several limitations. First, only five patients were included, which limits the generalizability of the findings. Second, the study was conducted at a single hospital and did not classify patients according to cancer type, disease stage, or treatment regimen, which may introduce biological heterogeneity. Third, peripheral blood smear examination was not performed to confirm morphological changes or platelet fragments. Future studies should use larger, multicenter samples, stratify participants by relevant clinical characteristics, and combine automated counts with peripheral smear confirmation.

CONCLUSION

The average leukocyte and platelet counts in cancer patients tended to increase as the delay in testing lengthened. An increase in leukocyte count became clearly evident after a 4-hour delay, while platelet counts had already begun to rise after a 2-hour delay and continued to increase until the 4-hour delay. Changes in the average leukocyte and platelet counts occur at both 2–8 °C and 20–25 °C. However, the increase in platelet count is greater at 20–25 °C compared to 2–8 °C. Meanwhile, changes in leukocyte counts are relatively small between storage temperatures. Delay time had a significant effect on changes in leukocyte and platelet counts in cancer patients, whereas storage temperature did not. Nevertheless, storage at 20–25 °C tended to produce greater changes than at 2–8 °C.

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AUTHOR CONTRIBUTIONS

All authors contributed to the conceptualization and design of the study, data collection, data analysis and interpretation, and the preparation and revision of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the publication of this article.

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REFERENCES

1. Kemenkes RI. *Rencana Kanker Nasional 2024-2034 : Strategi Indonesia Dalam Upaya Melawan Kanker*. 2024. Accessed September 18, 2026. https://repository.kemkes.go.id/book/1379
2. Nisa A, Noor H, Shinta D, Indanah, Yulisetyaningrum. Pengaruh Suhu Dan Waktu Penyimpanan Darah EDTA Terhadap Hasil Jumlah Trombosit Dengan Metode Otomatis. *Jurnal Analis Kesehatan*. 2025;14:142. Accessed September 18, 2026. doi:10.26630/jak.v14i1.4875
3. Ozmen SU, Ozarda Y. Stability of Hematological Analytes During 48 Hours Storage at Three Temperatures Using Cell-Dyn Hematology Analyzer. *J Med Biochem*. 2021;40(3):252-260. doi:10.5937/jomb0-27945
4. Danesh H, Ziamajidi N, Mesbah-Namin SA, Nafisi N, Abbasalipourkabir R. Association between Oxidative Stress Parameters and Hematological Indices in Breast Cancer Patients. *Int J Breast Cancer*. 2022;2022. doi:10.1155/2022/1459410
5. Xiong S, Dong L, Cheng L. Neutrophils in Cancer Carcinogenesis and Metastasis. *J Hematol Oncol*. *BioMed Central Ltd*. 2021;14(1). doi:10.1186/s13045-021-01187-y
6. Li G, Zhao D, Qin R, Zhao X, Huo Z, Li P. Associations of Three Differential White Blood Cell Counts, Platelet Counts, and Their Derived Inflammatory Indices with Cancer-Related Fatigue in Patients with Breast Cancer Undergoing Chemotherapy. *Supportive Care in Cancer*. 2024;32(7). doi:10.1007/s00520-024-08700-2
7. Choudhary S, Shankarkatkar R, Punneshetty D, Begum F, SJ S. EDTA Induced Storage Artefacts-A Study On Peripheral Blood Smears. *International Journal of Academic Medicine and Pharmacy*. Published online 2022:183-186. doi:10.47009/jamp.2022.4.5.39
8. Sinaga A, Damanik AO, Rahayu A, Sirumapea L. Optimisasi Pemeriksaan Jumlah Trombosit: Potensi Daun Seledri (Apium Graveolens Linn) sebagai Alternatif Berkelanjutan untuk Etilenediamin Tetraasetat. *Jurnal Medistra Medical Journal (MMJ), e-ISSN XXXX-XXXX*. 2023;1(2). doi:10.35451/mmj.v1i2.2092
9. Nugraha G, Ningsih NA, Sulifah T. Stabilitas Pemeriksaan Hematologi Rutin Pada Sampel Darah Yang Didiamkan Pada Suhu Ruang Menggunakan Cell-Dyn Ruby. *Surabaya : The Journal of Muhamadiyah Medical Laboratory Technologist*. 2021;1(4):21-29. doi:10.30651/jmlt.v4i1.8255
10. Gaghana C, Artini R, Risky D. Pengaruh Waktu Simpan Darah EDTA Pada Suhu 4˚C Terhadap Pemeriksaan Darah Rutin. 2025;6(1). doi:10.34063/bisf.v6i1.489
11. Samu R, Shuhaib, Revi D, Raj Rahul. Storage Dependent Cellular Changes in Blood Smears Prepared from EDTA Added Venous Blood Samples. *Acta Scientific Medical Sciences*. 2021;5(6). Accessed April 8, 2026. https://actascientific.com/ASMS/pdf/ASMS-05-0920.pdf
12. Seha N. Perbedaan Hitung Jumlah Trombosit Darah EDTA dengan Penundaan Waktu Pemeriksaan. *Jurnal Health Sains*. 2021;2. Accessed April 8, 2026. https://jurnal.healthsains.co.id/index.php/jhs/article/download/96/120

13. Maharani EA, Astuti D. Stability of Routine Hematology Sample Using The Medonic M-Series Analyzer. *Medical Laboratory Technology Journal*. 2020;6(2):108. doi:10.31964/mltj.v0i0.305
14. Aunisajidah N, Afriansyah M. Pengaruh Lama Penundaan Spesimen Darah K2EDTA Terhadap Morfologi Leukosit Pada Apusan Darah Tepi. *SEMNAS-Publikasi Hasil Penelitian dan Pengabmas Universitas Muhamadiyah Semarang*. 2022;7:734-740. Accessed April 8, 2026. https://prosiding.unimus.ac.id/index.php/semnas/article/download/1774/1779
15. Perillo B, Di Donato M, Pezone A, et al. ROS in Cancer Therapy: The Bright Side of The Moon. *Exp Mol Med*. 2020;52(2):192-203. doi:10.1038/s12276-020-0384-2
16. Nurprilinda Marliana, Pertami Sawitri DI, Janah Raudatul, Oktora Meta Z. *Patogenesis Berbagai Jenis Tumor: Tumorigenesis*. 1st ed. CV Eureka Media Aksara; 2025:1-25. ISBN 978-634-221-334-6.
17. Rahmnitarini A, Hernaningsih Y, Indrasari YN. The Stability of Sample Storage for Complete Blood Count (CBC) Toward the Blood Cell Morphology. *Bali Medical Journal*. 2019;8(2):391-395. doi:10.15562/bmj.v8i2.1369
18. Aristoteles, Puspitasari N. THE DIFFERENCE IN COUNTING THE NUMBER OF LEUKOCYTES IMMEDIATELY AND STORED FOR 6 HOURS. *Journal Health Applied Science and Technology*. 2023;1(1):16-20. doi:10.52523/jhast.v1i1.4
19. Miyajima Y, Niimi H, Ueno T, et al. Predictive Value of Cell Population Data with Sysmex XN-Series Hematology Analyzer for Culture-Proven Bacteremia. *Front Med (Lausanne)*. 2023;10. doi:10.3389/fmed.2023.1156889
20. Thachil A, Wang L, Mandal R, Wishart D, Blydt-Hansen T. An Overview of Pre-Analytical Factors Impacting Metabolomics Analyses of Blood Samples. *Metabolites*. 2024;14(9):1-24. doi:10.3390/metabo14090474
21. Zavorsky GS, Gasparyan S, Stollenwerk NS, Brooks RA. Stability of Whole Blood Lactate Specimens at Room Temperature Versus Slushed Ice Conditions. *Respir Care*. 2021;66(3):494-500. doi:10.4187/respcare.08023
22. Alam N, Putu G, Ferry A, et al. Pengaruh Waktu Penyimpanan Sampel Darah Edta Pada Suhu Ruangan Terhadap Nilai Trombosit Dan Leukosit. *Jurnal MediLab Mandala Waluya*. 2025;9(1). Accessed September 18, 2026. https://ejournal.umw.ac.id/medilab/article/view/1224/1091
23. Bobée V, Ravel-Chapuis R, Souissi M, et al. Overestimation of Automated Platelet Counts by Blast Fragments in Acute Hypercellular Leukemias: A Retrospective Study Comparing Impedance, Optical (PLT-O), Fluorescent (PLT-F), and CD41/CD61 Flow Cytometry Methods. *Int J Lab Hematol*. 2025;47(4):622-631. doi:10.1111/ijlh.14464
24. Baccini V, Geneviève F, Jacqmin H, et al. Platelet counting: Ugly traps and good advice. proposals from the french-speaking cellular hematology group (gfhc). *J Clin Med*. *MDPI*. 2020;9(3). doi:10.3390/jcm9030808
25. Rubiarti R, Nurhayati B, Durachim A, Marliana N. Differences in The Number of Thrombocytes and Thrombocyte Index at Variations of Temperature and Storage Time Using Hematology Analyzer Background. *Proceeding of the 5th International Conference on Interprofessional Health Collaboration and Community Empowerment*. Published online 2022:16-17. doi:10.34011/icihcce.v4i1.190
26. Handini F, Dewi R. Literature Review : Pengaruh Suhu Dan Waktu Penyimpanan Sampel Darah Terhadap Pemeriksaan Hitung Jumlah Trombosit Naskah Publikasi. *Repository Universitas 'Aisyiyah Yogyakarta*. Published online November 28, 2022. Accessed September 18, 2026. https://digilib.unisayogya.ac.id/6642/1/1811304012
27. Braun A, Anders HJ, Gudermann T, Mammadova-Bach E. Platelet-Cancer Interplay: Molecular Mechanisms and New Therapeutic Avenues. *Front Oncol*. *Frontiers Media S.A.* 2021;11. doi:10.3389/fonc.2021.665534