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Incidence and Survivability of Acute Lymphocytic Leukemia Patients in the United States: Analysis of SEER Data Set from 2000-2019

Ishan Ghosh[1], Sudipto Mukherjee[2]

[1]Department of Biology, Rockhurst University, Kansas City, Missouri, USA
[2]Hematology and Medical Oncology, Cleveland Clinic, Cleveland, Ohio, USA
Email: ishanghosh@outlook.com

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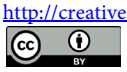

Abstract

The main goal of this research is to assess the impact of race, age at diagnosis, sex, and phenotype on the incidence and survivability of acute lymphocytic leukemia (ALL) among patients in the United States. By taking these factors into account, the study aims to explore how existing cancer registry data can aid in the early detection and effective treatment of ALL in patients. Our hypothesis was that statistically significant correlations exist between race, age at which patients were diagnosed, sex, and phenotype of the ALL patients, and their rate of incidence and survivability data were evaluated using SEER*Stat statistical software from National Cancer Institute. Analysis of the incidence data revealed that a higher prevalence of ALL was among the Caucasian population. The majority of ALL cases (59%) occurred in patients aged between 0 to 19 years at the time of diagnosis, and 56% of the affected individuals were male. The B-cell phenotype was predominantly associated with ALL cases (73%). When analyzing survivability data, it was observed that the 5-year survival rates slightly exceeded the 10-year survival rates for the respective demographics. Survivability rates of African Americans patients were the lowest compared to Caucasian, Asian, Pacific Islanders, Alaskan Native, Native Americans and others. Survivability rates progressively decreased for older patients. Moreover, this study investigated the typical treatment methods applied to ALL patients, mainly comprising chemotherapy, with occasional supplementation of radiation therapy as required. The study demonstrated the considerable efficacy of chemotherapy in enhancing patients' chances of survival, while those who remained untreated faced a less favorable prognosis from the disease. Although a significant amount of data and

information exists, this study can help doctors in the future by diagnosing patients with certain characteristics. It will further assist the health care professionals in screening potential patients and early detection of cases. This could also save the lives of elderly patients who have a higher mortality rate from this disease.

Keywords

Acute Lymphocytic Leukemia, Survivability, Incidence, Demography, SEER Data Set

1. Introduction

The research aims to address the existing gap in understanding the influence of demographic factors, including sex, race/ethnicity, age, and phenotype, on the incidence and survivability of patients diagnosed with Acute Lymphoblastic Leukemia (ALL) in the United States. Despite significant advancements in medical research and treatment options for ALL, there remains a lack of comprehensive investigation into how these demographic variables collectively impact the disease's presentation, prognosis, and outcomes. While there are studies from 1973-1999 by Kadan-Lottick *et al.*, the data is dated and does not give doctors current and relevant treatment options.

Acute lymphocytic leukemia (ALL), also known as acute lymphoblastic leukemia, is a form of blood cancer primarily found within children. ALL is a rapidly progressing disease which creates immature blood cells and only affects the white blood cells [1]. According to the estimate by the National Cancer Institute (NCI), 6,150 new cases of ALL are anticipated yearly, out of which 1,520 people are expected to succumb to the disease. Even though the disease progresses rapidly in children (0 - 16 years of age), the survival rate is significantly higher (approximately 90%) in children compared to older adults (55 - 70 years of age), which ranges between 30% to 40% [2]. The survival rate among children under the age of 19 is approximately 70% higher than those 60 years and older. The survival rate is also influenced by disease phenotype (T-cell, B-cell, or unknown) and chosen treatment options.

ALL is known to first start off in the bone marrow, the spongy tissue found inside the bones, where the blood cells form [3], of an individual which then invades into the blood quickly. Some symptoms of ALL include bone and joint pain as well as swollen lymph nodes, unintentional weight loss along with a purple skin rash [4]. Mutation of the bone marrow cells causes corruption of deoxyribonucleic acid (DNA) of such cells leading to ALL. Normally a healthy cell would stop dividing and eventually die, whereas cells with damaged or corrupted DNA do not stop growing causing abnormal blood cell production. The immature bone marrow cells eventually develop into immature white blood cells called lymphoblasts which lead to abnormal blood cell production [1].

There are many factors which influence the risk of someone developing ALL. Among those, one of the most common ones is long term or acute radiation exposure [5]. For example, those who survived the Japanese atomic bombings were at extremely high risk of developing ALL. The constant exposure to radiation has the potential to damage crucial DNA causing mutations that can potentially change the rate at which blood cells grow and die [6]. In addition, those who have previously undergone radiation therapy for another form of cancer are also at an increased risk of developing ALL.

The second major risk factor is viral infections caused by human T-cell lymphoma or leukemia virus-1 (HTLV-1), which is a retroviral infection of the T cells (a form of white blood cells) [7]. It can transmit through blood transfusions, unprotected sex, and other bodily fluids. HTLV-1 increases the risk of developing ALL by causing disruption of thousands of chromatin, which in turn affects the DNA folding causing irregularities within regulation of blood cells [7]. Although the virus is normally dormant in most infected individuals, the activation of the virus leads to the development of ALL in approximately one in every 20 patients. Although HTLV-1 has infected more than 10 million people worldwide, it only presents symptoms and manifests into ALL in 5 to 10 percent of the affected population. Furthermore, within that group a small percentage of patients develop leukemia progressive paralytic disease [8].

Treatment options depend on the stage the disease is identified in a patient which primarily consists of chemotherapy and/or radiation. Chemotherapy is administered typically in three phases: (a) induction, typically lasting for a month but intensive; (b) consolidation or intensification, intensive and normally lasting for a few months; and (c) maintenance or post-consolidation lasting up to two years. Chemotherapy is typically given in cycles so that the body can rest and recuperate. Various chemotherapy drugs that are commonly used in ALL treatments include vincristine or liposomal vincristine, daunorubicin, cytarabine, L-asparaginase, 6-mercaptopurine, and methotrexate [9]. While on chemotherapy people normally receive different combinations of these drugs, however, they never receive all of them together. The most common type of radiation therapy given to patients is external beam radiation which helps in shrinking any tumor associated with ALL. Before one goes for a stem cell transplant or a high dose of chemotherapy, they must complete a full body radiation session [10].

Chemotherapy drugs also affect the normal cells in bone marrow. This causes lower blood cell counts which can lead to high risk of infection, easy bruising, and shortness of breath. Along with chemotherapy steroids are also typically used for treatment, which commonly include prednisolone, dexamethasone, and methylprednisolone [11]. Some of the side effects of steroids and chemotherapy use are: increase of appetite, weight gain, and changes to blood sugar levels. While taking steroids and chemotherapy some patients also develop steroid induced diabetes. Along with steroids and chemotherapy, patients are typically also put on antibiotics to prevent fungal or bacterial infections as they can easily

catch an infection due to a depressed immune system. Fully recovered ALL patients have an increased chance of developing a secondary type of cancer later in their life.

Previous studies by Kadan-Lottick *et al.* on cancer data from 1973-1999 had shown that patients of African American, Hispanic, and American Indian/Alaskan Native origin had significantly lower survival rates for ALL when compared to those of Caucasian descent although the disease was prevalent among Caucasian children [12]. In another comprehensive study done by Dores *et al.* on acute leukemia incidence and patient survivability noted that male children of Caucasian origin had the highest chances of survival. They also observed that the incidence rates almost doubled for those who had the T-cell phenotype when compared to other phenotypes [13].

Phenotypes play a crucial role in cancer incidence and survivability, especially evident in the context of ALL patients as it is the observable characteristics and traits of leukemia cells. The two primary phenotypes found in ALL patients are T-cell and B-cell. These phenotypes are specific to the leukemia cells that can be present in a patient's blood or bone marrow with each having a unique regimen of treatment. In T-cell ALL, the cancerous cells originate from abnormal T-cells (T lymphocytes) and proliferate uncontrollably, disrupting the production of healthy blood cells in the bone marrow. This type of leukemia is more prevalent in teenagers and adults than in children. Meanwhile, B-cell ALL occurs when abnormal B-cells (B lymphocytes) multiply rapidly, overcrowding the bone marrow and affecting the production of normal blood cells. B-cell ALL is the most common type of ALL and is frequently diagnosed in children.

By identifying whether a patient has T-cell or B-cell ALL, oncologists can create an effective treatment plan, as different subtypes of ALL may respond differently to various therapies. Specific laboratory tests that analyze the surface markers and antigens on the leukemia cells are used to determine the specific phenotype. With this information, oncologists can tailor treatment approaches to enhance the patient's likelihood of achieving remission and successful recovery. Understanding the impact of phenotypes on cancer incidence and survivability is a key factor in improving the outcomes for leukemia patients.

Although a significant amount of data and information already exist on ALL and effective treatment options, the objective of this study was to systematically evaluate the most recent data trends that establish relationships of sex, race/ethnicity, age, and phenotype on the incidence and survivability of ALL patients in the United States. Another objective of this study was to evaluate the effectiveness of common treatment options among various demographics. This would further facilitate practicing physicians in effectively screening potential patients by early detection, and in developing optimized treatment options thereby further reducing the mortality rate from this disease.

2. Methodology

In this study primarily the SEER*Stat statistical software version 8.4.0, a PC

Windows based statistical tool, produced by the Surveillance Research Program of the Division of Cancer Control and Population Sciences of National Cancer Institute (NCI) was used. NCI's Surveillance, Epidemiology, and End Results (SEER) Program systematically collects and catalogs cancer data across the United States which are then provided in a user-friendly manner to produce statistics on a population. SEER uses cancer statistics collected by population-based registries, which record all cases in a defined population within a specific geographical area. The distribution of cancer cases is further analyzed based on sex, race/ethnicity, age, and other demographic factors of the patients [14].

Cases of ALL were identified using the International Classification of Diseases (ICD) for Oncology, Third Edition, updated for Hematopoietic codes based on World Health Organization (WHO) Classification of Tumors of Hematopoietic and Lymphoid Tissues. However, no patient-specific identifiable or private information was accessed or utilized during the course of this study. In this study primarily two parameters: incidence and survival rate were used to measure rate of occurrence (*i.e.*, frequency) and rate of survival from ALL.

Incidence, calculated in SEER*Stat under frequency session, is the number of new cancer patients diagnosed within a population in a year. In this study, SEER 22 registry, which contained diagnosis records from 2000 through 2019, the latest year for which data were available at the time of completion of this study, was queried. This registry covered approximately 47.99% of the U.S. population (per 2010 census) covering the following regions: California excluding SF/SJM/LA, San Francisco - Oakland SMSA, Connecticut, Hawaii, Iowa, New Mexico, Seattle (Puget Sound), Utah, Atlanta (Metropolitan), San Jose - Monterey, Los Angeles, Alaska Natives, Rural Georgia, Kentucky, Louisiana, New Jersey, Greater Georgia, Idaho, New York, Massachusetts, Illinois, and Texas [15]. This data set was the largest and covered the greatest percentage of populations in the United States. Unfortunately, data from all 50 states and U.S. territories were not available due to SEER's rigorous quality control and data integrity requirements.

The registry contained one record for each of the total 15,791,422 tumors. The frequency of occurrence of ALL, its trends, and percentages were calculated against the specific variables, such as, sex, race/ethnicity, age, and other demographic factors of the patients, selected along with the time [16]. In calculating the incidence statistics only the first primary tumor and reported diagnosis of the disease was accounted for [17].

Survival in cancer statistics measures the proportion of patients alive after a given time interval subsequent to their diagnosis [18]. In this study the 5-year and 10-year survival rates were calculated using monthly intervals at 95% confidence level using the Ederer II Cumulative Expected Method [19] [20], an approach that aligns well with the net cancer survival concept [21]. The Ederer II method was able to calculate the expected survival rates for patients at post-diagnosis follow ups until the corresponding patient died or the follow up data was no longer available [15] [22].

In this study for survival statistics SEER 17 registry, which contained diagno-

sis records from 2000 through 2019, the latest year for which data were available at the time of completion of the study, was queried. This registry covered approximately 26.5% of the U.S. population (per 2010 census) covering the following regions: California excluding SF/SJM/LA, San Francisco - Oakland SMSA, Connecticut, Hawaii, Iowa, New Mexico, Seattle (Puget Sound), Utah, Atlanta (Metropolitan), San Jose - Monterey, Los Angeles, Alaska Natives, Rural Georgia, Kentucky, Louisiana, New Jersey, Greater Georgia, Idaho, New York, Massachusetts, Illinois, and Texas [15]. The registry contained one record for each of the total 8,721,474 tumors. The ALL-survival results were calculated against the specific variables, such as, sex, race/ethnicity, age, and other demographic factors of the patients, selected along with the time [16]. In calculating the survival statistics only, the first primary tumor and reported diagnosis of the disease was accounted for [22].

As specified above, the variables selected for this study included sex, race/ethnicity, and age related to the ALL patients. For sex both male and female were taken into account along with the different phenotypes, namely T-cell, B-cell, unknown lineage, and other. For race/ethnicity, the following four races were selected: White (*i.e.*, Caucasian), Black (*i.e.*, African American), Other, and Unknown. The Asian/Pacific Islander, American Indian/Alaskan Native, and Hispanic race records were included under "other" race recode [17]. The "unknown" recode included all races excluding the ones listed above. The age ranges 0 - 19, 20 - 39, 40 - 59, and >60 years of age at diagnosis were considered in this study.

3. Results

Incidence of ALL within specified demographic populations from 2000 to 2019 was summarized in **Table 1** along with further discretization of such results based on sex, race/ethnicity, age at diagnosis, and phenotypes. Distribution of the incidence results across various demographics were also presented in **Figure 1**. The 5-year and 10-year survival probabilities for ALL patients with a 95% confidence interval across various demographics within the same time frame (*i.e.*, 2000 through 2019) were summarized in **Table 2** and visual representations were provided in **Figures 2(A)-(B)**. **Table 3** through **Table 6** presented 5-year and 10-year survival probabilities for various combinations of treatment options that were commonly administered and tracked among ALL patients within the same time period. **Table 3** contained the survival probability for patients who were treated only with chemotherapy; survival probability of those patients treated with a combination of chemotherapy along with some form of radiation were summarized in **Table 4**, **Table 5(A)-(B)**; **Table 6** contained survival probabilities of patients treated with beam radiation as their primary form of treatment; and **Table 7** summarized the survival probabilities for those who did not use any treatment options (*i.e.*, either chemotherapy or radiation) or decided against receiving any treatment.

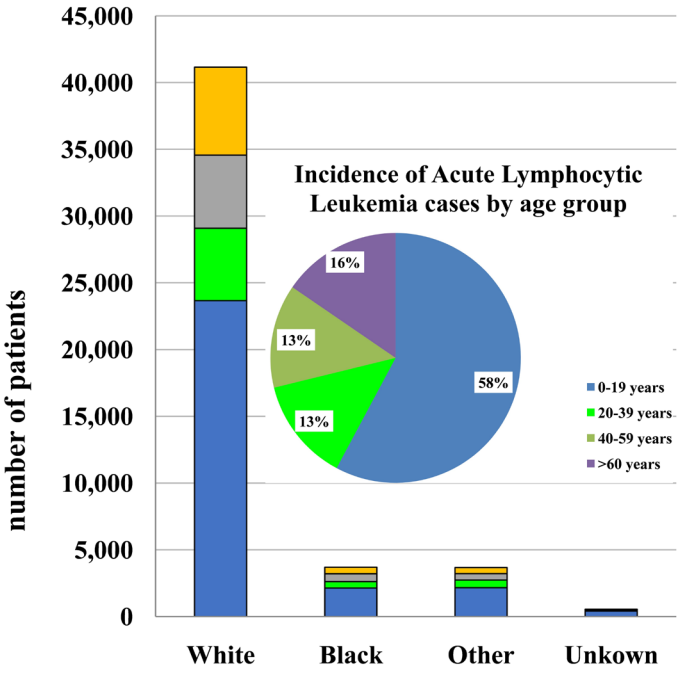

Figure 1. Incidence of Acute Lymphocytic Leukemia cases by demography (2000-2019).

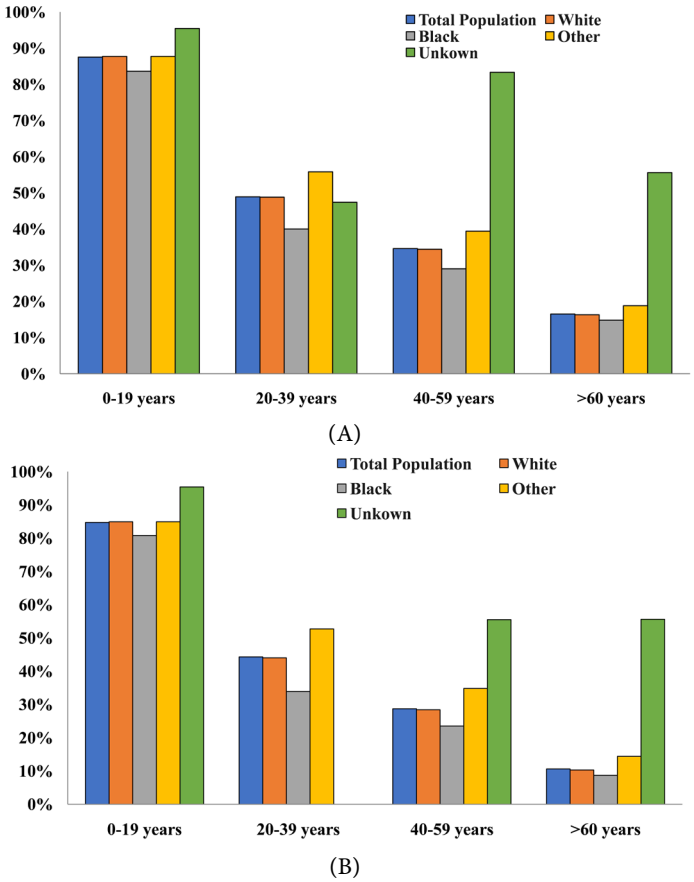

Figure 2. (A) 5-year survival probability of Acute Lymphocytic Leukemia patients by demography (2000-2019). (B) 10-year survival probability of Acute Lymphocytic Leukemia patients by demography (2000-2019).

Table 1. Characteristics of Study Population Diagnosed with Acute Lymphocytic Leukemia.

	Number|Percentage									
	Total Population		White		Black		Other		Unknown	
Sample Size	49,067	100%	41,163	84%	3693	8%	3665	7%	546	1%
Age at diagnosis										
0 - 19 years	28,363	58%	23,656	57%	2134	58%	2162	59%	411	75%
20 - 39 years	6557	13%	5427	13%	486	13%	569	16%	75	14%
40 - 59 years	6578	13%	5479	13%	585	16%	481	13%	33	6%
>60 years	7569	15%	6601	16%	488	13%	453	12%	27	5%
Diagnosis era										
2000-2009	22,666	46%	19,318	47%	1692	46%	1513	41%	143	26%
2010-2019	26,404	54%	21,848	53%	2001	54%	2152	59%	403	74%
Sex										
Male	27,572	56%	23,195	56%	2055	56%	2000	55%	322	59%
Female	21,495	44%	17,968	44%	1638	44%	1665	45%	224	41%
All phenotypes										
T-cell	4109	8%	3134	8%	589	16%	348	9%	38	7%
B-cell	33,806	69%	28,727	70%	2243	61%	2534	69%	302	55%
Unknown lineage	5495	11%	4712	11%	437	12%	294	8%	52	10%
Other	5672	12%	4602	11%	426	12%	489	13%	155	28%

It should be further noted that six of the treatment combinations tracked in the registry: (i) chemotherapy unknown if administered and radiation therapy was recommended, however, unknown if administered; (ii) chemotherapy was not administered and radiation therapy was refused by patient; (iii) chemotherapy was administered along with radiation therapy involving a combination of beam radiation with radioactive implants or isotopes; (iv) chemotherapy was administered along with treatment using radioisotopes; (v) chemotherapy was administered along with treatment using radioactive implants; and (vi) chemotherapy was administered, however, radiation therapy was refused by patient, were not included in this paper due to the limited number of patient records available for those (highest patient records, n = 11). Inclusion of those patient survival probabilities could artificially skew the results due to limited records, thereby being considered to mis-represent the treatment data trends.

4. Discussion

The objective of this study was to evaluate the cancer registry data over the past two decades to see if any correlation exists between sex, race/ethnicity, age, and phenotype of ALL patients, and the incidence and survival rate of the patients. Furthermore, this study looked into the effectiveness of common treatment options among various demographics.

As noted in Table 1, SEER 22 cancer registry data between 2000 and 2019 contained a total of 49,068 new ALL patient diagnosis records of which 56% were male and 44% were female indicating the disease is slightly more prevalent among males than among females. Out of the total number of patients, 41,163 were white, 3693 were black, 3665 were of other origin (including Asian/Pacific

Islander, American Indian/Alaskan Native, and Hispanic), and for 546 the race/ethnicity was unknown. In terms of percentages this equated to approximately 84% white, 8% black, 7% other, and 1% of unknown origins indicating ALL is most prevalent among Caucasian population. As we looked into the age of these patients, 58% were 0 to 19 years old, 13% were 20 to 39 years old, 13% 40 to 59 years old, and 15% were above 60 years of age. Across all races, more than 50% of the patients diagnosed were between 0 to 19 years of age, further confirming that the disease disproportionately affects children and younger adults. As we looked into the phenotypes, patients with T-cell phenotypes represented 8% of the diagnosed cases, while B-cell phenotype accounted for 69% of ALL patients followed by 11% patients with unknown lineage, and 12% patients with other phenotypes. As we looked across the various races, the distribution of cases across various phenotypes almost remained identical. This is consistent with the prior research that documented ALL patients with B-cell phenotype tend to have an increased amount of immature white blood cells [9].

Net cancer-specific survival is the probability of surviving a specific type of cancer that does not take into consideration other causes of death [23]. In this study relative survival was used as the measure of survival probability following the Ederer II method. This method is widely used in the field of epidemiology to compare disease rates across various populations while keeping into account the age differences. Unlike the Pohar Perme method, Ederer II has a greater precision in estimating long term survival rates. The Ederer II method helps to identify actual differences in disease occurrence that are not related to age [24]. Relative survival is a type of net survival that "is defined as the ratio of the proportion of observed survivors in a cohort of cancer patients to the proportion of expected survivors in a comparable set of cancer free individuals" [25]. Following this approach in this study 5-year and 10-year survival probability of ALL patients was calculated across the various demographics to see if sex, race/ethnicity, age at diagnosis, and phenotypes play any role.

As summarized in **Table 2**, SEER 17 cancer registry data between 2000 and 2019 contained a total of 25,652 ALL patient records that were available for calculating the 5-year and 10-year survival probabilities. Overall, 5-year survival probability for ALL patients was calculated to be 67.5%, while the 10-year survival probability was noted to be 64%, indicating the patients had an overall good prognosis. The data indicated that 10-year relative survival probability among ALL patients was slightly lower than the corresponding 5-year survival probability of the respective races. Among these ALL patients, 5-year survival probability for male patients was 67.3% compared to 67.8% for females; whereas 10-year survival probability for male patients was 63.4% compared to 64.7% for females. The data indicated female patients in general might have slightly better survival probability than their male counterparts, although the data did not indicate that it was significantly different. As we looked across the races, it was noted that the 5-year survival probabilities were 67.4% for white, 63.8% for black, 69.6% for other, and 87.2% for patients of unknown origins; whereas the

Table 2. Survival Probabilities Among the Study Population Diagnosed with Acute Lymphocytic Leukemia.

	Survival Probability (95% Confidence Interval)									
	Total Population		White		Black		Other		Unknown	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
					5-Year Survival					
Sample Size	25,652	67.5%	21,143	67.4%	1791	63.8%	2455	69.6%	263	87.2%
Age at diagnosis										
0 - 19 years	15,971	87.5%	12,973	87.7%	1122	83.6%	1496	87.7%	200	95.4%
20 - 39 years	3611	48.9%	2949	48.8%	232	40.0%	391	55.8%	39	47.4%
40 - 59 years	3271	34.6%	2700	34.4%	248	29.0%	308	39.4%	15	83.3%
>60 years	2979	16.5%	2521	16.3%	189	14.8%	260	18.8%	9	55.6%
Diagnosis era										
2000-2009	12,047	65.4%	10,091	65.6%	840	61.1%	1059	66.7%	57	80.9%
2010-2019	13,605	69.6%	11,052	69.3%	951	66.2%	1396	72.0%	206	91.1%
Sex										
Male	14,522	67.3%	12,053	67.0%	986	64.8%	1329	70.4%	154	85.5%
Female	11,130	67.8%	9090	67.9%	805	62.5%	1126	68.7%	109	89.5%
All phenotypes										
T-cell	2221	65.5%	1,660	67.6%	305	57.2%	242	60.8%	14	77.9%
B-cell	18,068	68.1%	15,080	67.8%	1114	66.5%	1728	69.9%	146	89.0%
Unknown lineage	2534	62.7%	2157	62.6%	179	53.9%	177	72.1%	21	80.0%
Other	2829	69.9%	2246	68.6%	193	66.7%	308	83.3%	82	--
					10-Year Survival					
Sample Size	25,652	64.0%	21,143	63.8%	1791	60.2%	2455	66.5%	263	86.1%
Age at diagnosis										
0 - 19 years	15,971	84.7%	12,973	84.9%	1122	80.8%	1496	84.9%	200	95.4%
20 - 39 years	3611	44.3%	2949	44.0%	232	33.9%	391	52.7%	39	--
40 - 59 years	3271	28.7%	2700	28.4%	248	23.5%	308	34.8%	15	55.5%
>60 years	2979	10.6%	2521	10.3%	189	8.7%	260	14.4%	9	55.6%
Diagnosis era										
2000-2009	12,047	62.0%	10,091	62.1%	840	57.7%	1059	63.3%	57	80.9%
2010-2019	--	--	--	--	--	--	--	--	--	--
Sex										
Male	14,522	63.4%	12,053	63.1%	986	60.8%	1329	66.8%	154	83.7%
Female	11,130	64.7%	9090	64.7%	805	59.4%	1126	66.1%	109	89.5%
All phenotypes										
T-cell	2221	63.3%	1660	65.5%	305	55.6%	242	57.1%	14	77.9%
B-cell	18,068	64.3%	15,080	63.9%	1114	62.3%	1728	67.1%	146	87.5%
Unknown lineage	2534	59.6%	2157	59.5%	179	51.1%	177	67.4%	21	80.0%
Other	2829	67.5%	2246	65.5%	193	66.7%	308	83.3%	82	--

10-year survival probabilities for the above-mentioned races were 63.8%, 60.2%, 66.5%, and 86.1%, respectively. The data indicated that although across all races

the survival probabilities for ALL patients were greater than 60%, however, patients of African American origin had the lowest survival probabilities followed by white, other, and those of unknown ethnicity.

Considering the age of diagnosis for ALL patients, it was noted the 5-year survival probability was greatest for 0 to 19 years age group across all races, which progressively decreased for older age groups and was only 14% for those of 60 years or older. This trend was also consistent for 10-year survival probability of ALL patients with 0-to-19-year age group the highest (80%), which decreased as age of patients became higher with only 10% for those of 60 years or older. The data further confirmed, although overall ALL has a good prognosis, however, it has a significant negative impact on survivability for older patients.

As we looked into the phenotypes, patients under the other phenotype category had the highest 5-year survival probability of 69.9% and followed by B-cell phenotype at 68.1%, T-cell phenotype at 65.5%, and were least for patients of unknown lineage at 62.7%. The black patients of unknown lineage showed the lowest survival probability of 53.9%. Although this phenotype-based survivability data trend was consistent among white and black patient populations, however, patients with race listed as other or unknown did not quite follow a similar pattern. The patients for whom the race was listed as unknown with a B-cell phenotype had the highest survival probability of 89.0%. A similar trend was noted for 10-year survival probability among ALL patients with others at 67.5%, patients with B-cell phenotype at 64.3%, T-cell phenotype at 63.3%, and those with unknown lineage at 59.6%. The black patients of unknown lineage showed the lowest 10-year survival probability of 51.1%.

Based on treatment data from the SEER 17 cancer registry, the treatment regimen for ALL patients primarily fell into two categories: chemotherapy and radiation therapy, which were administered to patients either by itself or in conjunction. Evaluation of treatment data further showed out of the 25,652 treatment records for ALL patients in SEER 17 registry, 81% (20,793 patients) were treated with chemotherapy alone, followed by 12% (3096 patients) were treated with a combination of chemotherapy and beam radiation, and 6% (1637 patients) received no treatment. These numbers accounted for 99% of the recorded patients, the remainder of which received either chemotherapy in conjunction with various types of radiation therapy other than bean radiation or for which the accurate treatment data were not available.

Table 3 contained 5-year and 10-year survival probability data for 20,793 ALL patients who only received chemotherapy and no radiation treatment. Among these ALL patients, 5-year survival probability for male patients was 70.2% compared to 71.4% for females; whereas 10-year survival probability for male patients was 66.6% compared to 66.8% for females. The data indicated the female patients might have slightly better survival probability than their male counterparts, although the data did not indicate that survival probabilities were significantly different. The 5-year survival probability for white patients was 70.6%, compared to 67.5% for black, 73.0% for other, and 88.3% for those of

Table 3. Survival Probabilities Among the Study Population Diagnosed with Acute Lymphocytic Leukemia.Treatment: Chemotherapy = "Yes", Radiation = "None/Unknown".

	Survival Probability in % (95% Confidence Interval)									
	Test Population		White		Black		Other		Unkown	
	n	%	n	%	n	%	n	%	n	%
					5-Year Survival					
All Cases	20,793	70.7%	17,148	70.6%	1459	67.0%	1985	73.0%	201	88.3%
Age at diagnosis										
0 - 19 years	13,920	88.8%	11,459	89.0%	967	85.6%	1333	89.0%	161	95.5%
20 - 39 years	2549	46.4%	2089	46.0%	174	37.4%	260	56.3%	26	48.7%
40 - 59 years	2348	30.9%	1937	30.7%	190	26.8%	212	36.2%	9	75.2%
>60 years	1976	17.4%	1663	17.1%	128	18.4%	180	18.2%	5	40.0%
Sex										
Male	11,642	70.2%	9667	70.0%	801	68.4%	1056	72.8%	118	84.7%
Female	9151	71.4%	7481	71.5%	658	65.2%	929	73.3%	83	92.9%
All phenotypes										
T-cell	1344	62.0%	998	63.9%	200	56.0%	136	56.5%	10	78.8%
B-cell	15,131	71.4%	12,608	71.1%	956	70.6%	1452	73.7%	115	90.8%
Unknown lineage	1940	68.9%	1650	69.4%	133	54.8%	141	75.1%	16	73.9%
Other	2378	70.3%	1892	68.4%	170	67.4%	256	85.2%	60	--
					10-Year Survival					
All Cases	20,793	67.5%	17,148	67.3%	1459	63.2%	1985	70.5%	201	88.3%
Age at diagnosis										
0 - 19 years	13,920	86.1%	11,459	86.3%	967	82.5%	1333	86.3%	161	95.5%
20 - 39 years	2549	41.7%	2089	41.2%	174	31.2%	260	53.9%	26	--
40 - 59 years	2348	26.1%	1937	25.4%	190	23.1%	212	34.1%	9	75.2%
>60 years	1976	11.3%	1663	11.0%	128	8.1%	180	15.0%	5	--
Sex										
Male	11,642	66.6%	9667	66.3%	801	64.3%	1056	70.0%	118	84.7%
Female	9151	68.6%	7481	68.7%	658	62.0%	929	71.0%	83	92.9%
All phenotypes										
T-cell	1344	60.3%	998	62.3%	200	53.1%	136	55.1%	10	78.8%
B-cell	15,131	68.0%	12,608	67.6%	956	66.4%	1452	71.2%	115	90.8%
Unknown lineage	1940	66.0%	1650	66.6%	133	52.5%	141	71.4%	16	73.9%
Other	2378	70.3%	1892	68.4%	170	67.4%	256	85.2%	60	--

unknown origins. The 10-year survival probability for the races was 67.3%, 63.2%, 70.5%, and 88.3%, respectively. The data further showed that the survival probability among ALL patients receiving chemotherapy were least for the African American population consistent with overall survival probability trends presented in Table 2.

As noted in Table 3, the 5-year and 10-year survival probabilities across all races were highest among those between 0 to 19 years of age, which progressively declined among older patients with those 60 years or older recording the lowest survival probability even with chemotherapy treatment. For patients between 0 to 19 years of age, the 5-year survival probability was 88.8% and the 10-year survival probability was 86.1% indicating chemotherapy was a very effective

treatment for younger patients delivering an excellent prognosis from the disease. As we looked into the phenotypes and survivability data for ALL patients treated with chemotherapy, we noticed patients with B-cell phenotype had the highest overall 5-year survival probability of 71.4% and patients with "other" phenotype had the highest overall survival probability of 70.3% across the races. Conversely, ALL patients with T-cell phenotype had the lowest overall 5-year and 10-year survival probabilities of 62.0% and 60.3%, respectively not considering the race-specific survivability's, which varied slightly for different phenotypes.

Table 4. Survival Probabilities Among the Study Population Diagnosed with Acute Lymphocytic Leukemia. Treatment: Chemotherapy = "Yes", Radiation = "Beam radiation".

	Survival Probability in % (95% Confidence Interval)									
	Test Population		White		Black		Other		Unkown	
	n	%	n	%	n	%	n	%	n	%
	5-Year Survival									
All Cases	3,096	65.8%	2555	65.9%	195	63.3%	332	66.2%	14	81.5%
Age at diagnosis										
0 - 19 years	1418	78.6%	1167	78.9%	114	72.7%	131	80.3%	6	100.0%
20 - 39 years	875	59.1%	710	59.3%	45	56.5%	114	59.2%	6	--
40 - 59 years	677	50.8%	568	50.5%	32	43.4%	75	55.6%	2	100.0%
>60 years	126	34.2%	110	35.9%	4	0.0%	12	32.1%	0	--
Sex										
Male	1952	66.0%	1626	65.8%	111	60.2%	206	70.3%	9	70.0%
Female	1144	65.5%	929	66.0%	84	67.2%	126	59.6%	5	100.0%
All phenotypes										
T-cell	702	77.4%	536	78.9%	77	70.0%	87	74.5%	2	100.0%
B-cell	1909	61.3%	1623	61.7%	90	55.6%	189	60.4%	7	83.3%
Unknown lineage	225	64.7%	188	62.5%	15	73.3%	21	76.2%	1	100.0%
Other	260	80.8%	208	80.8%	13	--	35	--	4	--
	10-Year Survival									
All Cases	3096	60.9%	2555	60.9%	195	60.1%	332	60.7%	14	81.5%
Age at diagnosis										
0 - 19 years	1418	75.1%	1167	75.1%	114	71.7%	131	77.0%	6	100.0%
20 - 39 years	875	54.5%	710	54.8%	45	50.3%	114	54.4%	6	--
40 - 59 years	677	41.8%	568	42.2%	32	27.9%	75	43.6%	2	--
>60 years	126	22.5%	110	22.9%	4	0.0%	12	32.1%	0	--
Sex										
Male	1952	60.7%	1626	60.6%	111	56.2%	206	64.3%	9	70.0%
Female	1144	61.1%	929	61.4%	84	65.1%	126	54.9%	5	--
All phenotypes										
T-cell	702	75.0%	536	76.5%	77	70.0%	87	69.2%	2	100.0%
B-cell	1909	55.4%	1623	55.6%	90	50.1%	189	55.3%	7	--
Unknown lineage	225	60.0%	188	58.5%	15	66.7%	21	66.7%	1	100.0%
Other	260	64.7%	208	64.6%	13	--	35	--	4	--

The second most cancer-specific treatment data from SEER 17 registry was for those who received a combination of chemotherapy along with beam radiation in treating ALL, which were summarized in Table 4. Out of a total of 3,096 patients the 5-year survival probability for male patients was 66.0% compared to 65.5% for females; whereas 10-year survival probability for male patients was 60.7% compared to 61.1% for females. Consistent with data trends from Table 2 and Table 3, this data also indicates female patients in general might have slightly better survival probability than their male counterparts, although the data does not indicate that it was significantly different. Considering the race-specific survivability data, the 5-year survival probability for white patients was 65.9% compared to 63.3% for black, 66.2% for other, and 81.5% for unknown origins; whereas the 10-year survival probability for the races were 60.9%, 60.1%, 60.7%, and 81.5%, respectively. The data indicated that patients represented under the "unknown origin" race category had the highest survival probabilities among patients who received a combination of chemotherapy and beam radiation which were significantly different than those belonging to other races.

Continent with data trends shown in Table 2 and Table 3, the average 5-year and 10-year survival probabilities were highest among the 0-to-19-year age group at 78.6% and 75.1% respectively, which progressively decreased among older patients with those over 60 years age group showing the lowest 5- and 10-year survival probabilities of 34.2% and 22.5%, respectively. This trend was consistent when race-specific survival probabilities were compared among various age groups. The data further indicated that the treatment was quite effective for younger patients compared to older ones, however, it was less effective in terms of survival probabilities when compared to those treated with chemotherapy alone (Table 3). Taking into consideration the phenotypes of the treated patients, it was noted that on average patients with "other" phenotype had the highest 5-year survival probability followed by T-cell, unknown lineage, and B-cell phenotypes. However, the same was not true for the 10-year survival probabilities which were highest for T-cell phenotype followed by other, unknown lineage, and B-cell phenotypes. As race-specific survival probabilities were compared against phenotypes of treated patients, the data appeared to be consistent with the overall (*i.e.*, average) trend.

Survival probabilities of ALL patients treated with chemotherapy in conjunction with either radiation using "NOS method or source not specified", or radiation "Recommended, unknown if administered" were summarized in Table 5(A)-(B), respectively. Survival probability data for patients treated only with beam radiation was summarized in Table 6. However, since the number of patient records were less than 50 (*i.e.*, $n < 50$), no treatment-specific survival probability inferences were made for these treatment options. Not only the limited data set was indicative of the fact that not many patients over a 20-year period within the studied population received such treatment, but also it was considered to have the potential to adversely impact the data trends leading to a likely erroneous interpretation.

Table 5. (A) Survival Probabilities Among the Study Population Diagnosed with Acute Lymphocytic Leukemia. Treatment: Chemotherapy = "Yes", Radiation = "NOS method or source not specified". (B) Survival Probabilities Among the Study Population Diagnosed with Acute Lymphocytic Leukemia. Treatment: Chemotherapy = "Yes", Radiation = "Recommended, unknown if administered".

(A)										
	Survival Probability in % (95% Confidence Interval)									
	Test Population		White		Black		Other		Unkown	
	n	%	n	%	n	%	n	%	n	%
	5-Year Survival									
All Cases	41	70.7%	33	75.8%	4	75.0%	4	25.0%	0	--
Age at diagnosis										
0 - 19 years	22	90.9%	18	94.4%	2	100.0%	2	50.0%	0	--
20 - 39 years	8	87.5%	8	87.5%	0	--	0	--	0	--
40 - 59 years	9	22.2%	6	16.7%	2	--	1	0.0%	0	--
>60 years	2	0.0%	1	0.0%	0	--	1	0.0%	0	--
Sex										
Male	24	74.9%	19	78.9%	2	100.0%	3	33.3%	0	--
Female	17	64.7%	14	71.4%	2	50.0%	1	0.0%	0	--
All phenotypes										
T-cell	12	91.7%	9	88.9%	2	100.0%	1	100.0%	0	--
B-cell	24	58.2%	20	65.0%	2	--	2	0.0%	0	--
Unknown lineage	5	80.0%	4	100.0%	0	--	1	0.0%	0	--
Other	0	--	0	--	0	--	0	--	0	--
	10-Year Survival									
All Cases	41	64.8%	33	68.5%	4	75.0%	4	25.0%	0	--
Age at diagnosis										
0 - 19 years	22	80.7%	18	81.7%	2	100.0%	2	50.0%	0	--
20 - 39 years	8	87.5%	8	87.5%	0	--	0	--	0	--
40 - 59 years	9	22.2%	6	16.7%	2	--	1	0.0%	0	--
>60 years	2	0.0%	1	0.0%	0	--	1	0.0%	0	--
Sex										
Male	24	69.9%	19	72.9%	2	100.0%	3	33.3%	0	--
Female	17	56.6%	14	61.2%	2	--	1	0.0%	0	--
All phenotypes										
T-cell	12	91.7%	9	88.9%	2	100.0%	1	100.0%	0	--
B-cell	24	46.6%	20	52.0%	2	--	2	0.0%	0	--
Unknown lineage	5	80.0%	4	100.0%	0	--	1	0.0%	0	--
Other	0	--	0	--	0	--	0	--	0	--
(B)										
	Survival Probability in % (95% Confidence Interval)									
	Test Population		White		Black		Other		Unkown	
	n	%	n	%	n	%	n	%	n	%
	5-Year Survival									
All Cases	34	52.9%	28	53.6%	2	--	3	66.7%	1	0.0%
Age at diagnosis										
0 - 19 years	16	68.8%	12	66.7%	2	--	2	100.0%	0	--
20 - 39 years	5	--	4	--	0	--	0	--	1	0.0%
40 - 59 years	11	36.4%	10	40.0%	0	--	1	0.0%	0	--
>60 years	2	50.0%	2	50.0%	0	--	0	--	0	--

Continued

Sex										
Male	22	45.5%	18	44.4%	2	--	1	100.0%	1	0.0%
Female	12	66.7%	10	70.0%	0	--	2	50.0%	0	--
All phenotypes										
T-cell	14	50.0%	10	50.0%	2	--	1	100.0%	1	0.0%
B-cell	18	55.6%	16	56.3%	0	--	2	50.0%	0	--
Unknown lineage	2	50.0%	2	50.0%	0	--	0	--	0	--
Other	0	--	0	--	0	--	0	--	0	--
					10-Year Survival					
All Cases	34	47.1%	28	45.9%	2	--	3	--	1	0.0%
Age at diagnosis										
0 - 19 years	16	68.8%	12	66.7%	2	--	2	--	0	--
20 - 39 years	5	--	4	--	0	--	0	--	1	0.0%
40 - 59 years	11	24.2%	10	26.7%	0	--	1	0.0%	0	--
>60 years	2	--	2	--	0	--	0	--	0	--
Sex										
Male	22	36.4%	18	33.3%	2	--	1	--	1	0.0%
Female	12	66.7%	10	70.0%	0	--	2	--	0	--
All phenotypes										
T-cell	14	50.0%	10	50.0%	2	--	1	--	1	0.0%
B-cell	18	44.4%	16	42.2%	0	--	2	--	0	--
Unknown lineage	2	50.0%	2	50.0%	0	--	0	--	0	--
Other	0	--	0	--	0	--	0	--	0	--

Survival probability data for those who did not seek treatment or chose not to receive any treatment was summarized in Table 7, which contained 1637 such records. The overall 5-year and 10-year survival probabilities for those patients were 30.5% and 26.5%, respectively. Although the survival data was better for the patients within the 0 to 19 years age group, however, 76% of the total number of patients who did not receive any treatments was of older age group. The patient survival probability data without any treatments clearly illustrated the fact that treatment, mostly chemotherapy, was highly effective in improving the prognosis for the majority of ALL patients, while the disease was quite lethal who did not receive any treatment.

Although ALL is one of the most common forms of leukemia in children, however, looking into the 5-year and 10-year survival probability numbers over the last 20 years it was evident that younger patients in the 0 to 19 years age group if treated with chemotherapy and supplemented with radiation therapy, if needed, had the best prognosis. The success in terms of survivability could be attributed to a plethora of factors ranging from awareness among childcare specialists, socioeconomics, to sexual hormones [26]. Whereas, in older patients, since it is less common, it is sometimes mis-diagnosed, losing valuable time to arrest the progress of the disease. Also, without proper health insurance sometimes adults are denied access to potentially lifesaving medications in time lead-

ing to high morbidity from the disease. Furthermore, sometimes poor health conditions among older patients, especially those in the 60 or higher age group, are unable to withstand intensive chemotherapy due to comorbidities and organ dysfunctions [26]. Additionally, sexual hormones depending on the maturity of patients are also hypothesized to have an effect on the metabolism of anti-leukemic drugs which in turn can impact its effectiveness [26].

Even though radiation is not used as often as chemotherapy, it still has proven to be quite effective in increasing a patient's survival probabilities, especially when it is used in conjunction with chemotherapy. Radiation is commonly used when leukemia has spread to the brain, spinal fluid, or testicles [26], as it is the easiest way to reduce the risk of it spreading even further causing metastasis. Also, radiation therapy is considered as a favored treatment option before opting

Table 6. Survival Probabilities Among the Study Population Diagnosed with Acute Lymphocytic Leukemia. Treatment: Chemotherapy = "No/Unknown", Radiation = "Beam radiation".

	Survival Probability in % (95% Confidence Interval)									
	Test Population		White		Black		Other		Unkown	
	n	%	n	%	n	%	n	%	n	%
					5-Year Survival					
All Cases	25	57.2%	19	57.8%	2	50.0%	4	75.0%	0	--
Age at diagnosis										
0 - 19 years	13	74.6%	8	87.5%	2	50.0%	3	66.7%	0	--
20 - 39 years	5	25.9%	5	25.9%	0	--	0	--	0	--
40 - 59 years	5	66.7%	4	66.7%	0	--	1	--	0	--
>60 years	2	0.0%	2	0.0%	0	--	0	--	0	--
Sex										
Male	14	58.5%	12	54.8%	1	100.0%	1	--	0	--
Female	11	54.5%	7	64.3%	1	0.0%	3	66.7%	0	--
All phenotypes										
T-cell	4	50.0%	3	33.3%	0	--	1	100.0%	0	--
B-cell	12	56.3%	10	68.6%	1	0.0%	1	0.0%	0	--
Unknown lineage	4	75.0%	3	66.7%	1	100.0%	0	--	0	--
Other	5	0.0%	3	0.0%	0	--	2	--	0	--
					10-Year Survival					
All Cases	25	46.8%	19	51.4%	2	50.0%	4	0.0%	0	--
Age at diagnosis										
0 - 19 years	13	65.3%	8	87.5%	2	50.0%	3	0.0%	0	--
20 - 39 years	5	25.9%	5	25.9%	0	--	0	--	0	--
40 - 59 years	5	33.3%	4	33.3%	0	--	1	--	0	--
>60 years	2	0.0%	2	0.0%	0	--	0	--	0	--
Sex										
Male	14	50.2%	12	45.7%	1	100.0%	1	--	0	--
Female	11	40.9%	7	64.3%	1	0.0%	3	0.0%	0	--
All phenotypes										
T-cell	4	25.0%	3	33.3%	0	--	1	0.0%	0	--
B-cell	12	46.9%	10	57.1%	1	0.0%	1	0.0%	0	--
Unknown lineage	4	75.0%	3	66.7%	1	100.0%	0	--	0	--
Other	5	0.0%	3	0.0%	0	--	2	--	0	--

Table 7. Survival Probabilities Among the Study Population Diagnosed with Acute Lymphocytic Leukemia. Treatment: Chemotherapy = "No/Unknown", Radiation = "None/Unknown".

	Survival Probability in % (95% Confidence Interval)									
	Test Population		White		Black		Other		Unkown	
	n	%	n	%	n	%	n	%	n	%
					5-Year Survival					
All Cases	1637	30.5%	1,338	29.3%	128	28.7%	124	26.6%	47	85.6%
Age at diagnosis										
0 - 19 years	392	79.0%	302	79.1%	34	74.3%	23	63.6%	33	93.1%
20 - 39 years	165	31.5%	130	32.3%	13	15.4%	16	28.6%	6	50.0%
40 - 59 years	217	21.0%	171	20.3%	24	26.0%	18	14.6%	4	100.0%
>60 years	863	11.6%	735	11.1%	57	7.8%	67	17.1%	4	75.0%
Sex										
Male	849	30.9%	696	29.1%	68	29.5%	59	28.1%	26	100.0%
Female	788	30.0%	642	29.5%	60	28.2%	65	25.6%	21	50.2%
All phenotypes										
T-cell	136	34.3%	96	41.3%	24	21.2%	15	6.7%	1	100.0%
B-cell	959	29.4%	790	28.6%	64	22.6%	81	27.9%	24	79.8%
Unknown lineage	357	27.8%	309	25.5%	30	38.2%	14	39.7%	4	100.0%
Other	185	--	143	--	10	--	14	--	18	--
					10-Year Survival					
All Cases	1637	26.5%	1338	25.4%	128	26.0%	124	22.4%	47	77.4%
Age at diagnosis										
0 - 19 years	392	77.0%	302	77.4%	34	68.6%	23	63.6%	33	93.1%
20 - 39 years	165	24.2%	130	23.6%	13	--	16	28.6%	6	--
40 - 59 years	217	16.2%	171	16.0%	24	20.8%	18	14.6%	4	0.0%
>60 years	863	7.4%	735	6.8%	57	7.8%	67	11.7%	4	75.0%
Sex										
Male	849	27.4%	696	26.2%	68	27.3%	59	17.9%	26	89.5%
Female	788	25.5%	642	24.6%	60	25.1%	65	25.6%	21	--
All phenotypes										
T-cell	136	29.8%	96	35.0%	24	21.2%	15	--	1	--
B-cell	959	25.7%	790	25.1%	64	19.4%	81	25.0%	24	67.5%
Unknown lineage	357	23.9%	309	21.7%	30	34.7%	14	29.8%	4	100.0%
Other	185	--	143	--	10	--	14	--	18	--

for a bone marrow or stem cell transplant due to the increased risks involved with those procedures. It also helps in reducing the pain in the bone due to abnormal white blood cells accumulation that causes bone marrow to expand [27] [28]. A combination of both chemotherapy and radiation gives the best chances of survival probability due to the rigor of the treatment and a broad-spectrum coverage by arresting the progress of the disease and also treating it at the same time.

In recent years immunotherapies, including monoclonal antibody treatment and cell therapy, have become viable treatment options for ALL patients. Monoclonal antibodies, like Blinatumomab and Inotuzumabozogamicin, are able to attack infections present within the patient's body by attacking leukemia specific

proteins. Blinatumomab attaches to two different leukemia proteins, CD19 protein in B-cells, and CD3 protein found in T-cells. However, treatment with Blinatumomab causes severe side effects that include fever, headache, tremors, and low blood potassium levels [29]. Similarly, Inotuzumabozogamicin is typically used to treat some ALL patients with B-cell phenotype. It is typically given when after chemotherapy patients do not show much improvement and is administered in cycles compared to 28 days of nonstop chemotherapy treatment. Some common side effects of treatment with Inotuzumabozogamicin include internal bleeding, internal infection, and elevated levels of bilirubin [29].

Another immunotherapy treatment consists of CAR T-cell therapy, also known as chimeric antigen receptor therapy. It involves removal of T-cells from a patient's body and altering them to have chimeric antigen receptors on the surface, which in turn attach to the proteins found on leukemia cells. This overall process takes few weeks to complete, and in the meantime, the patient is still given chemotherapy to fight leukemia. In addition to CAR T-cell therapy, Brexucabtageneautoleucel is used in treating B-cell ALL for adult patients, and Tisagenlecleucel in B-cell ALL for children and young adults specifically when leukemia relapses or if traditional treatment is found to be ineffective. Common side effects of these drugs include increase in cytokines that may cause fever, trouble breathing, severe muscle pain, nervous system issues like headaches, seizures, lack of consciousness, and susceptibility to other infections [30].

5. Conclusions

As it was hypothesized, statistically significant correlations were found to exist between sex, race/ethnicity, age at which patients were diagnosed, and phenotype of the ALL patients, and their rate of incidence. Acute lymphocytic leukemia has historically been known to mainly affect children under the age of 19. The majority of the patients diagnosed with ALL were Caucasian males and they were between 0 to 19 years of age at the time of diagnosis. Among the patients diagnosed with ALL the B-cell phenotype was the most common.

The study also found that statistically significant correlations exist between sex, race/ethnicity, and age at which patients were diagnosed for ALL, and their rate of survivability. In general, 5-year survival rates were slightly higher than the 10-year survival rates. Five- and ten-year survival rates were the lowest among the African American patients when compared with Caucasian, Asian, Pacific Islanders, Alaskan Native, Native Americans and patients of other origins. The survivability rates progressively decreased among older patients. No statistically significant correlation was noted between ALL patient phenotypes and survival rates noted at 5 and 10 years.

Although prior studies also made similar observations in terms of incidence and survival rates for ALL patients, this study further reaffirmed those facts based on the most recent data from the past two decades. Moreover, this research investigated the treatment approaches employed for ALL patients, pri-

marily consisting of chemotherapy complemented by radiation therapy, as deemed necessary. The study demonstrated that chemotherapy had a significant positive impact on enhancing patients' chances of survival, whereas individuals who received no treatment faced unfavorable prognosis from the disease. This updated examination of ALL incidences, survival rates, and common treatment options holds valuable implications for healthcare professionals. It can aid in efficiently screening potential patients, enabling early detection, and implementing successful treatment regimens. As a result, this could potentially lead to improved survival rates, particularly among those diagnosed at an older age, who typically experience higher mortality rates from ALL compared to younger patients.

One of the main drawbacks of using the SEER 22 registry data that was used in this study for evaluating ALL incidence was that it only included approximately 47% of the U.S. population. This means over 50% of the U.S. population were not being represented in that registry, thereby under representing the rural communities and many of the sparsely populated states where access to medical diagnosis and care are not as readily available compared to the major urban centers. The same was true for the survival probability data obtained from SEER 17 cancer registry which only accounted for only 26.5% of the total U.S. population. This may have a profound effect on the incidence and survival rates that were derived from this study. Another drawback in using the current data was that the registered treatment options were limited to chemotherapy and radiation. Even though different types of radiation were mentioned, significant data was only available for beam radiation. Even though chemotherapy and beam radiation are the two most common types of therapies for ALL patients, no data on newer treatment options, such as immunotherapy, proton therapy, bone marrow transplants, were available. If these newer approaches have any beneficial use for ALL treatment, even under trial settings, the data should be tracked in the cancer registries for future consideration.

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Conflicts of Interest

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

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