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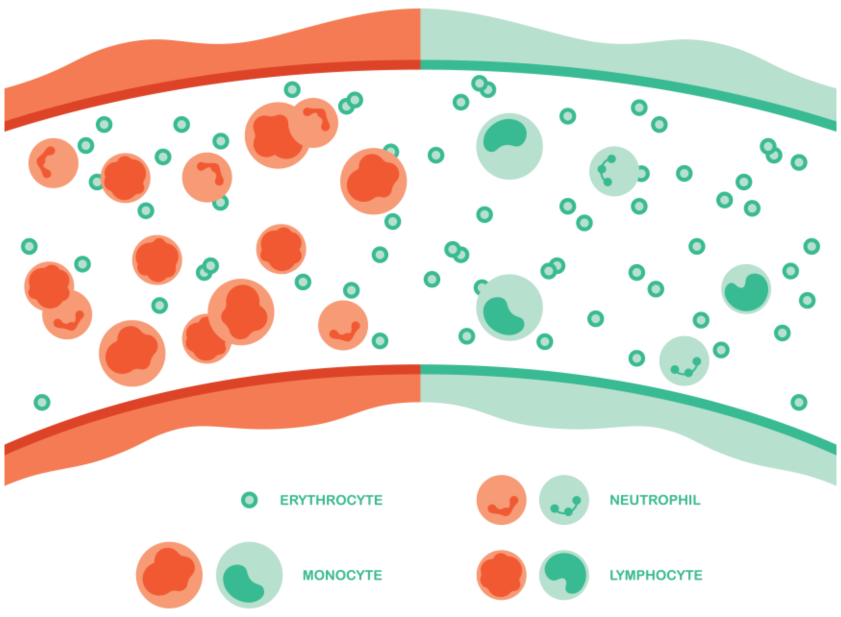
Innovation Think Tank
Proactively drive innovation to improve human life

LEUKEMIA

FACTS AND FIGURES

SIGNS AND SYMPTOMS[1]

FEVER OR CHILLS
PERSISTENT FATIGUE
EASY BLEEDING OR BRUISING
TINY RED SPOTS ON THE SKIN
SWOLLEN LYMPH NODES
ENLARGED LIVER OR SPLEEN
BONE PAIN
NIGHT SWEATS
UNINTENTIONAL WEIGHT LOSS



Leukemia statistics around the world, 2020[2]

- 474,519 new cases
- 311,594 deaths
- 1,340,506 5-year prevalence

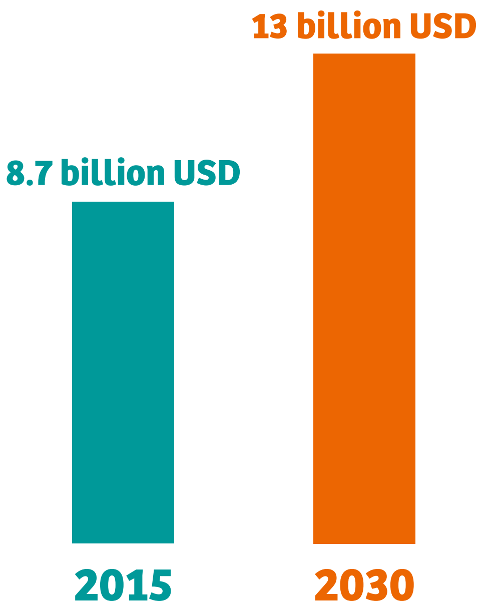
COVID-19

Leukemia patients are at a higher risk of severe illness due to COVID–19[3]

In the **US**, **5-year** survival rate for all types of **leukemia** is **~65%**[4]

RISK FACTORS[1]

- Family history of leukemia
- Myelodysplastic syndromes
- Genetic disorders e.g., Down's syndrome
- Previous cancer treatment
- Exposure to certain chemicals e.g., benzene
- Smoking

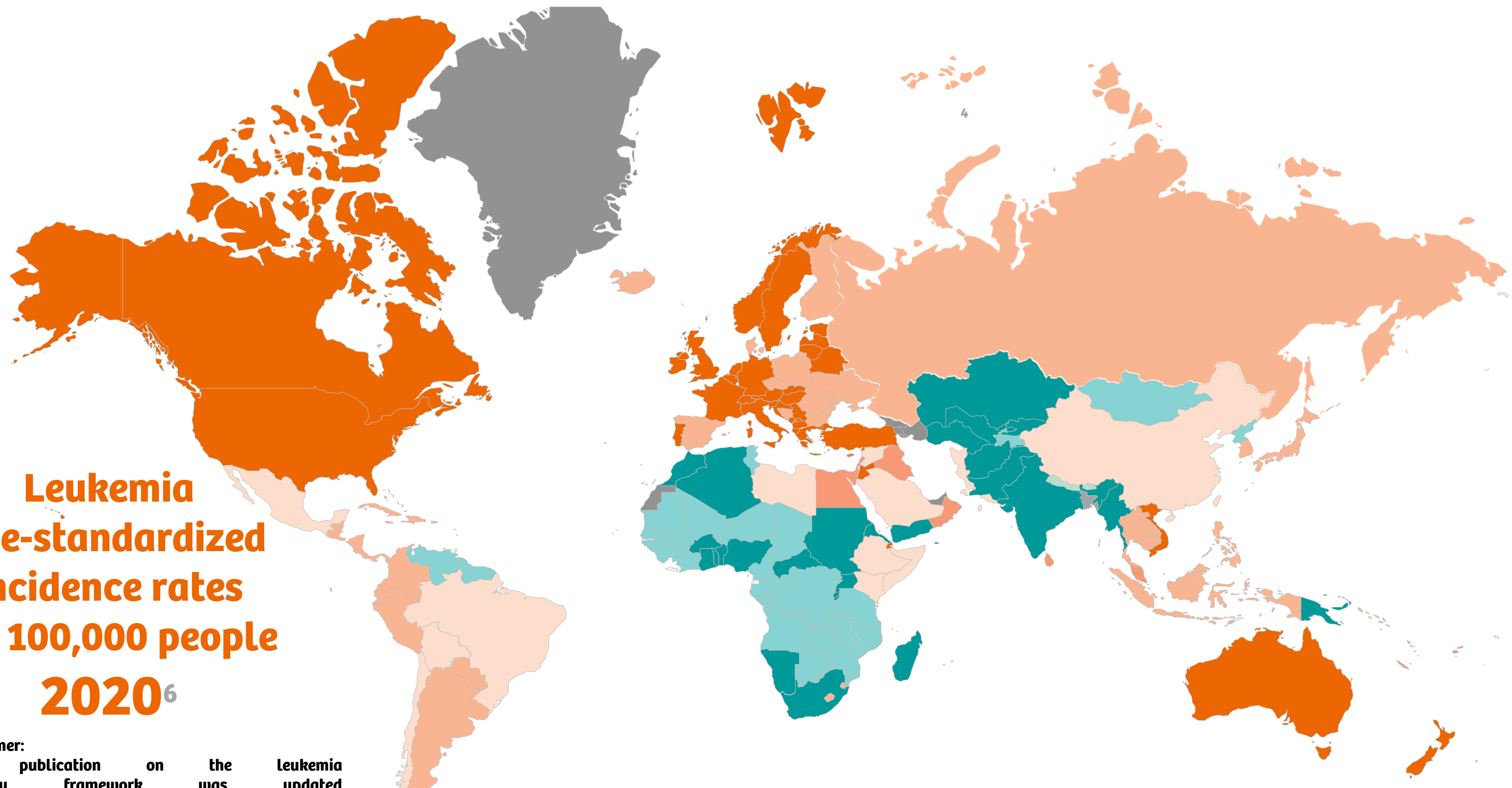


Total national cost of treating **leukemia** in the **US** is expected to increase by **49%** by 2030[5]

MAJOR TYPES OF LEUKEMIA[1]

Acute lymphocytic leukemia (ALL)
Acute myeloid leukemia (AML)
Chronic lymphocytic leukemia (CLL)
Chronic myeloid leukemia (CML)

Leukemia Age-standardized incidence rates per 100,000 people 2020[6]



Disclaimer:
This publication on the leukemia pathway framework was updated on 21.10.2022. It cannot be taken as a recommendation for the readers, especially not as a guideline for treatment, and it is not a medical document. There is no guarantee for completeness or global correctness, the various pain points, solutions, and statistical data are examples only. Sources are multiple, such as public statistics, expert opinions, open innovation workshops, research, own data and many more (see references).
The products and features mentioned may not be available in all countries and their future availability cannot be guaranteed. Some products mentioned are planned and under development.

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6. World Health Organization. (n.d). *Estimated age-standardized incidence rates (World) in 2020, leukaemia*. Cancer Today. Retrieved July 29, 2022, from https://gco.iarc.fr/today

Website: https://www.siemens-healthineers.com/careers/innovation-think-tank

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LEUKEMIA

Disease pathway analysis with painpoints and solution examples

Innovation Think Tank
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An extensive research-based analysis from 40+ scientific articles and journals in combination with hospital workflow experience allowed the identification of painpoints and solutions.

These solutions were proposed based on AI, IoMT, AR/VR, biosensors, nanorobotics and smart wearable technologies.

THROUGH THIS CAREPLAN WE HIGHLIGHT DATA FROM A COLLECTION OF

113 painpoints

85 solutions

15 connected to different stakeholders

Solution categories

★	Existing in healthcare sector
📝	Ongoing research in healthcare
💡	Futuristic solution (may or may not be implemented)

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1 PRENATAL

Scenario:
Pregnant woman at the doctor's office

STAKEHOLDERS

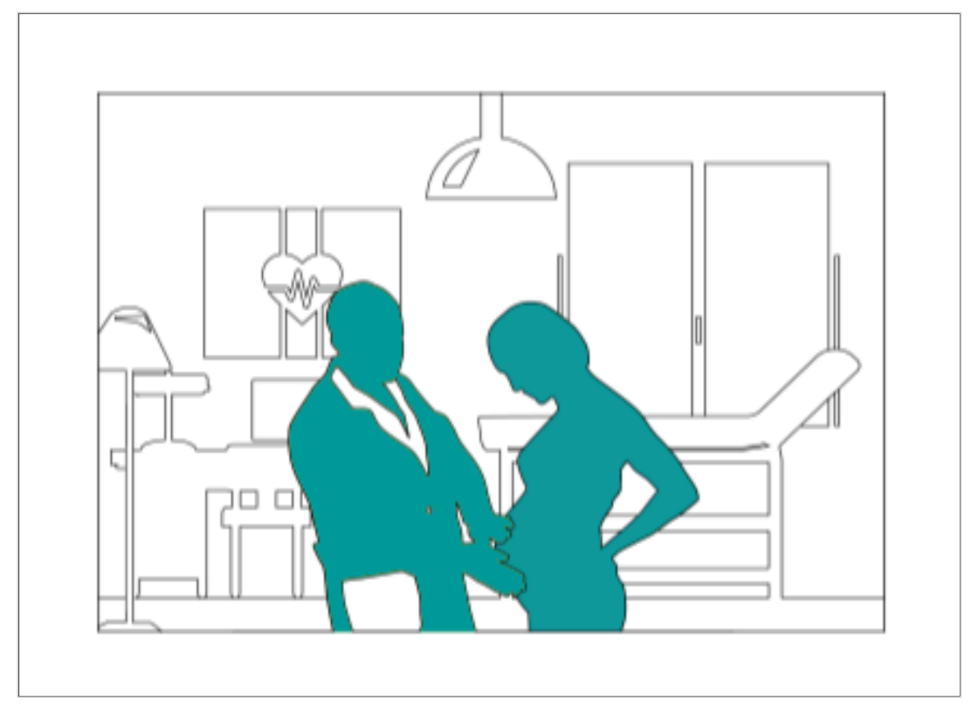
Pregnant woman Receives care services from providers and is motivated to ensure positive health of her unborn child.

Family Supports the pregnant woman and is concerned about the wellbeing of the mother and the fetus.

OB/GYN Provides care relating to gynecological and obstetric problems to the patient.

General physician Supports the patient with general health issues.

Neonatologist Doctor for newborn babies who treats neonatal issues.



A pregnant woman is going for a regular check-up. She is concerned for the health of her baby but also struggles to admit her hardship to sustain alcohol abstinence to her doctor.

1 PAINPOINT
Alcohol consumption during pregnancy might be connected to a higher risk for the child to develop acute lymphocytic leukemia (ALL) or acute myeloid leukemia (AML).[1]

SOLUTION
Digitalization

★ **Behaviour assessment and consulting tool**
Creating a digital questionnaire and implementing it into regular check-ups for pregnant women would help in identifying risky behavior like regular alcohol consumption. The tool can also be used to give information on treatment and referral programs to help with the problem.[2]

2 PAINPOINT
Use of certain medications like antidepressants, antihistamines, amphetamines, and mind-altering drugs by either parent before or during pregnancy can raise the risk of ALL in the child.[3,4]

SOLUTION
Process innovation & Digitalization

💡 **Electronic health record tracking along with prenatal education**
Ensuring that both parents are informed of the potential effects of drug use on the occurrence of ALL in the child, regardless of how insignificant the medication may seem to the parents (e.g., antihistamines), coupled with an electronic health record tracking system to log all medications taken by both parents at all times.

2 PREVENTION

Scenario:
Patient is at home resting

STAKEHOLDERS

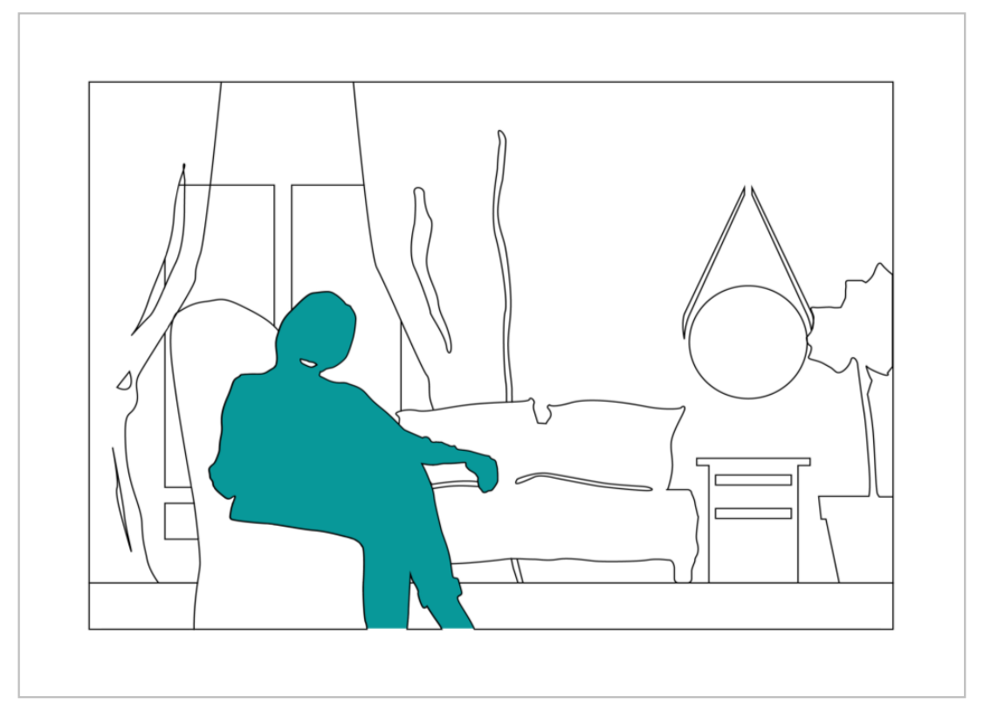
Patient Wants to live a healthy life, however, struggles with stress and a smoking habit.

Family Encourages the patient to follow a healthy lifestyle.

General physician Monitors patient health and gives clinical advice on how to prevent cancer.

Medical device companies Design wearable devices and innovative technologies that help stick to a healthy lifestyle.

Ministry of Health Ensures public access to healthcare and enforces set healthcare guidelines.



The patient wishes to engage in preventive measures to ensure a long and healthy life. However, she also struggles with stress and a smoking addiction.

1 PAINPOINT
Smoking significantly increases the risk of developing some types of leukemias, especially ALL and AML.[5]

SOLUTION
Sensing

★ **VR-assisted smoking interventions**
Behavioral therapies such as virtual reality approach-avoidance tasks or gamified interventions can help patients to successfully reduce or even stop smoking.[6]

SOLUTION
Digitalization

★ **Wearables for smoking cessation**
A small wearable device that detects the specific movement pattern of smoking, asks the user to confirm, and then offers personalized interventions to stop smoking.[7]

2 PAINPOINT
Obese individuals have a significantly higher risk for hematological malignancies.[8]

SOLUTION
Sensing & Digitalization

★ **Wearables and apps**
Wearables like smart watches can count the patient's daily steps and monitor general physical activity. In combination with a smartphone app that collects and analyzes the data to give motivating feedback and customized diet plan, it can help a patient to stay active.[9]

3 PAINPOINT
Treating other types of cancers with chemotherapy or exposure to high-energy radiation, especially in children, increases the risk of developing second primary leukemia.[10]

SOLUTION
Digitalization & Sensing

💡 **Risk prediction algorithm and remote blood analysis**
By using mathematical algorithms, the risk of developing a second primary leukemia based on the chemotherapy and radiation received by a patient earlier in life, can be calculated. If the risk is high, the patient can be provided smart sensor devices performing routine blood work remotely and sending results to a clinician for further regular analyses.

4 PAINPOINT
Exposure to chemicals such as fertilizers and pesticides can increase the risk for various hematological cancers such as chronic lymphocytic leukemia (CLL), ALL or AML.[11,12]

SOLUTION
Sensing

★ **Smart protective gear**
Smart personal protective equipment like helmets, goggles, suits or gloves not only provide protection against certain chemicals, but also help to make the work more comfortable. E.g., using 3D gesture detection technology, smart gesture controlled intelligent workwear allows the operation of devices without touching them.[13]

5 PAINPOINT
Certain genetic mutations or congenital disorders such as Down's syndrome increase a person's risk of developing leukemia, especially acute leukemias like AML and ALL.[14]

SOLUTION
Process innovation

★ **Screening guidelines for leukemia**
Formulating guidelines that recommend periodic screening for early detection of leukemia in children with Down's syndrome by regular medical checkups for signs and symptoms evaluation, blood tests and genetic testing.[15,16]

6 PAINPOINT
In most people, leukemia can easily be detected in early stages by regular physical exams and routine blood work. However, in limited access areas, hospitals to perform these routine procedures might be scarce.

SOLUTION
Process innovation

★ **Mobile medical units**
Mobile units of health professionals can bring routine check-ups and bloodwork services even to remote areas with limited access to health care. In some areas they use cars, motor bikes or even camels.[17]

3 SYMPTOMS

Scenario:
Patients faints on the street

STAKEHOLDERS

Patient Experiences frequent fever and is prone to getting infections.

Family Notices symptoms in the patient and advises consultation.

General physician Provides care relating to general medical problems.

Haemato oncologist Provides care relating to haemato oncological issues.

Hospital administration Redefines hospital workflows and ensures high-quality care across all patient services.

Patient faints on the street from a combination of exhaustion, dehydration, and low red blood cell count.

1 PAINPOINT
Patients might not give much importance to unspecific symptoms of leukemia like fatigue due to anemia, low-grade fever, or the tendency to bruise easily.

SOLUTION
Digitalization

★ **Awareness campaigns**
Organizing awareness campaigns using modern communication technologies can significantly increase the public knowledge about early leukemia symptoms. They can be targeted to specific at-risk groups.[18]

2 PAINPOINT
Even if patients are concerned about unspecific symptoms, they might be unable to go for a check-up due to a lack of health care providers in the area.

SOLUTION
Digitalization

★ **Telemedicine**
Telemedicine such as real-time, synchronous video-conferencing enables geographically isolated patients to connect with health experts from afar and receive basic health care services.[19]

3 PAINPOINT
Patients might not be aware of the possible implications of tiny red spots on the skin (petechiae), a common symptom of leukemia.

SOLUTION
Digitalization & Automation

📝 **AI supported diagnostic app**
AI supported diagnostic apps can enable patients to receive realistic sets of possible conditions by taking photos of the affected area of their skin with a smartphone and answering a respective in-app questionnaire. The app can then recommend to visit a doctor for further examination.[20]

4 PAINPOINT
Patient may suffer from unintentional weight loss, which often goes unnoticed or is overlooked.

SOLUTION
Digitalization

💡 **Weight tracking**
Patients can be made aware of the potential health implications of unintentional weight loss by a clinician, following which they are advised to regularly, e.g., weekly, track their weight and report it via an app. It is a cheap and effective method with little to no false positives, since in most cases unwanted weight loss is connected to pathological processes of benign or malignant origin.[21]

4 DIAGNOSIS

Scenario:
Patient visits the hospital

STAKEHOLDERS

Patient Wishes to receive the right diagnostic tests to receive the right treatment.

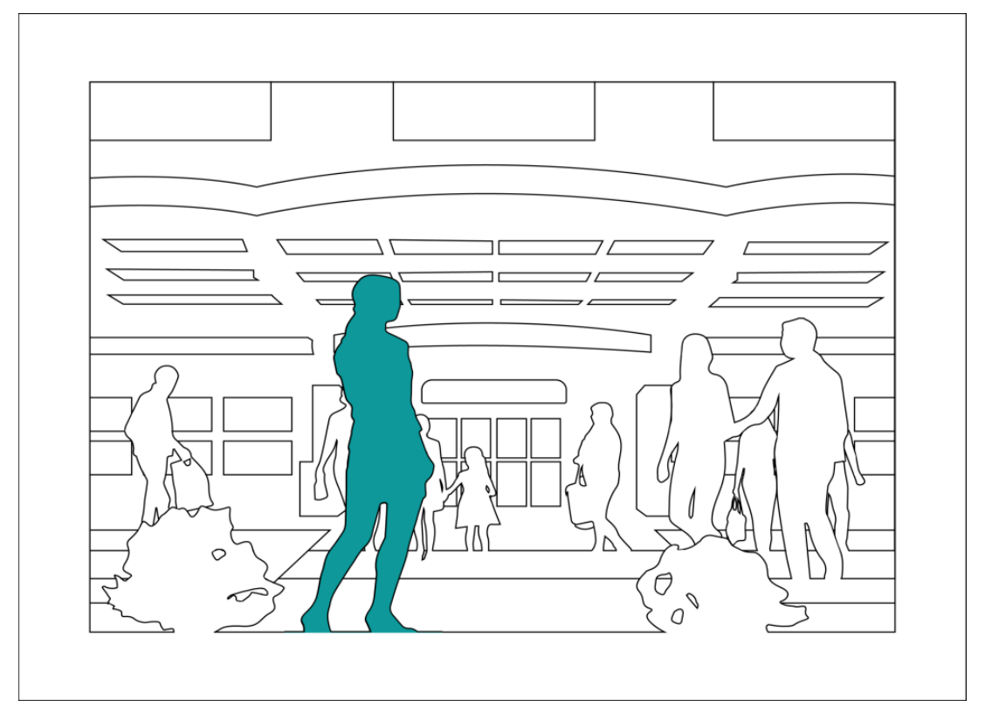
Family Supports patient throughout the lengthy process of diagnosis and treatment.

Haemato oncologist Provides care relating to haemato oncological issues.

Laboratory personnel Help conduct laboratory tests and provide results that can aid in diagnosis.

Hospital administration Redefines hospital workflows and ensures high-quality care across all patient services.

Medical device companies Design innovative technologies that help to ensure fast and accurate diagnosis.



Patient is visiting a hospital to receive adequate diagnosis.

1 PAINPOINT
Morphological analysis of blood slides by hematologists is complex, time-consuming, costly, and requires considerable training and experience.[22]

SOLUTION
Digitalization & Automation

📝 **Intelligent decision support system**
Supported by machine learning, such systems use different approaches of image processing – e.g., performing segmentations of cell nucleus and cytoplasm of leukocytes – to successfully identify the type of leukemia, leading to faster and more effective diagnosis and treatment.[23,24]

2 PAINPOINT
A lack of standardization and subjective data interpretation can limit the validity of flow cytometry, which plays a central role in diagnosing acute leukemia.[25,26]

SOLUTION
Digitalization & Automation

📝 **Automated flow cytometry analysis**
An AI-based framework backed by a large-scale dataset can be incorporated in routine flow cytometry. This can help in automated classification and analysis of the data, thereby optimizing classification accuracy.[27,28]

3 PAINPOINT
AML diagnosis is a time and resource consuming process since it relies on integrating multiple test results such as cytomorphology, cytochemistry, immunophenotyping, cytogenetics and molecular genetics.

SOLUTION
Clinical innovation

★ **Next Generation Sequencing (NGS)**
Using NGS allows the characterization of the molecular genetic landscape of AML. Thereby, not only classification and prognostication of the disease can be done but also conclusions regarding the most effective treatment can be drawn.[29]

4 PAINPOINT
Delayed diagnosis of leukemia may lead to a negative patient outcome, thereby impacting the survival rate and quality of life.

SOLUTION
Clinical innovation

📝 **AI-based leukemia detection**
AI can be used for early diagnosis of leukemia, where the system is trained to recognize the leukemia patterns in blood images which serve as an input to the testing model. Based on the previously trained algorithm, it indicates whether the patient is suffering from leukemia or is going to suffer from it in the coming years.[30,31]

5 TREATMENT

Scenario:
Patient receives chemotherapy at the hospital

STAKEHOLDERS

Patient Gets treated for leukemia and receives health care services from providers.

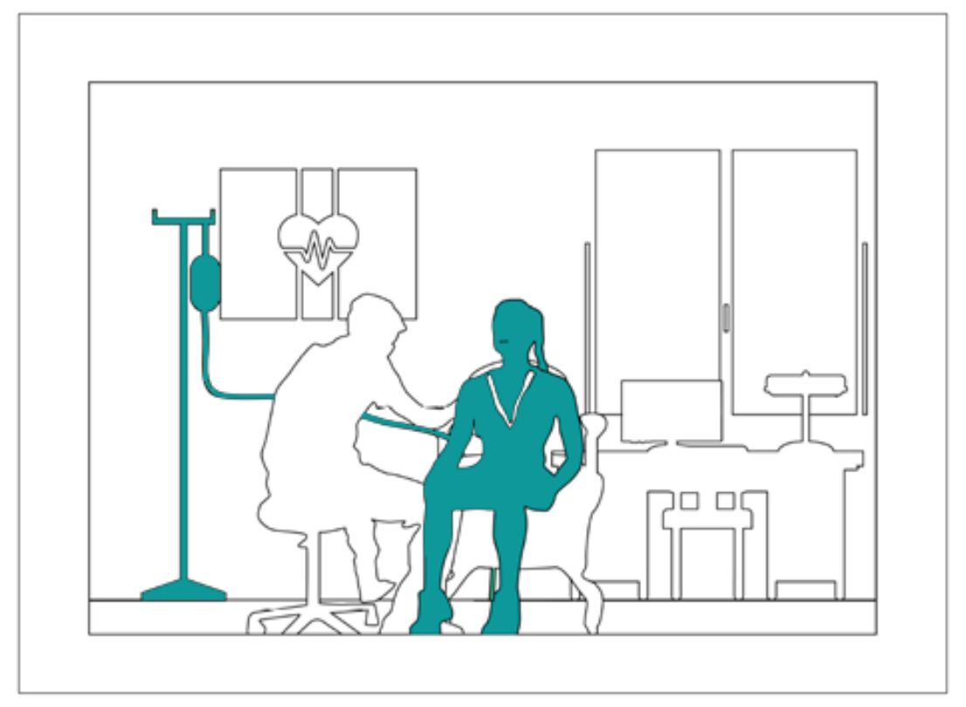
Haemato oncologist Provides care relating to haemato oncological issues.

Nurse Provides and monitors patient care, as well as health and wellness information.

Ministry of Health Ensures public access to healthcare and enforces set healthcare guidelines.

Pharmacy Responsible for preparing, preserving and distributing the needed medicine.

Insurance companies Cover the patient's costs for necessary medical treatment.



Patient suffers from leukemia and is receiving chemotherapy at the hospital.

1 PAINPOINT
Delayed treatment initiation or nonadherence is observed in many CML patients due to several factors such as the high cost of tyrosine kinase inhibitor (TKI) therapy, access issues and lack of education.

SOLUTION
Process innovation

📝 **Patient adherence initiatives**
Patient adherence to medications can be improved by reducing the out-of-pocket cost burden on patients by offering subsidized treatment or expanding insurance coverage, organizing educational, behavioral, and social programs, ensuring timely access to care, and improving physician-patient interactions.[32]

2 PAINPOINT
ALL usually gets worse quickly and needs rapid treatment with intensive chemotherapy which has serious side effects and is hard to tolerate for fragile patients. There might also be a chance of relapse.[33]

SOLUTION
Clinical innovation

★ **Car-T-cell therapy**
This type of treatment uses a patient's own immune cells which are genetically modified to treat the cancer. It has short treatment times, is comparatively safer and is especially beneficial for relapse cases.[34,35]

SOLUTION
Clinical innovation

★ **Combination therapy**
Combining targeted therapies may have fewer side effects than chemotherapy alone and helps increase the chance of remission. Clinical trials are underway to test whether combination therapies can replace chemotherapy in specific cases, especially for older patients.[33,36]

3 PAINPOINT
Chemotherapy may not be enough for certain subtypes of aggressive blood cancers e.g., FLT3 mutation leukemia.[33]

SOLUTION
Clinical innovation

★ **Targeted therapies**
AML cells sometimes have gene changes that can be targeted with new drugs – such as FLT3 inhibitors. This approach might be more effective and hold less severe side effects than chemotherapy.[33]

4 PAINPOINT
Patients who require frequent blood transfusions because of anemia brought on by leukemia or chemotherapy face a constant shortage of blood donors, which was made worse by the pandemic.[37,38]

SOLUTION
Digitalization

★ **Blood donation app**
An app which engages and motivates potential and existing donors by streamlining the appointment process, rewarding donations, sending geo-targeted emergency blood alerts, enabling donors to track their blood all the way to the hospital it's being used in, and notifying them when their blood is used to save a life can make the donation process more convenient and the experience more rewarding. Due to the pandemic, a COVID-19 test could be added to the donor's appointment process for safety purposes.[39]

5 COVID-19 PAINPOINT
Due to immunodeficiency, leukemia patients are more prone to infections and may have poorer disease outcomes when infected with COVID-19, which might hinder their visits to the hospital for treatment.[40]

SOLUTION
Process innovation

★ **Protocols for preventing COVID-19 transmission**
Following aggressive non-pharmacological intervention (NPI) protocols can help prevent COVID-19 transmission. Efficient measures should be put in place to ensure that leukemia patients have the least possible contact with other patients, and strict hand-hygiene guidelines are followed.[41]

6 REHABILITATION

Scenario:
Patient at the rehabilitation center

STAKEHOLDERS

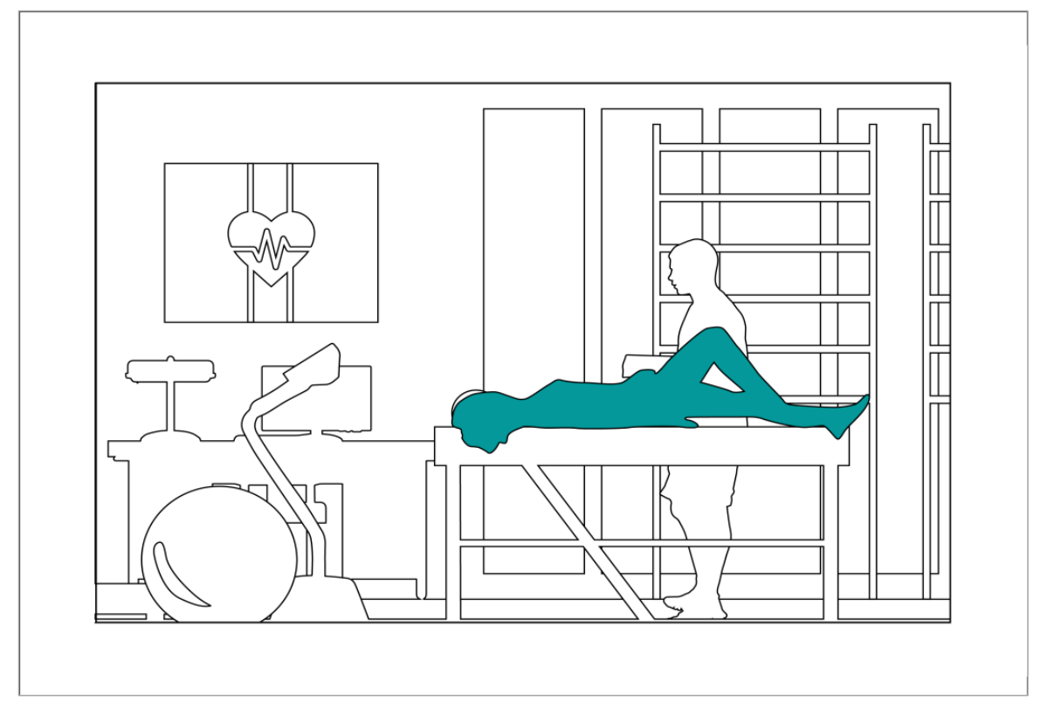
Patient Wishes to quickly get back to a normal life and engages in rehabilitation activities.

Family Supports the patient and helps her to regain strength.

General physician Does regular check-ups and blood tests, refers patient to an expert if the disease recurs.

Rehabilitation therapist Helps patients restore and enhance functional abilities through physical exercises.

Medical device companies Design innovative technologies that help the patient recover.



The patient is at the rehabilitation center and a therapist is examining her physical status.

1 PAINPOINT
A patient suffering from leukemia may experience bone pain or muscle weakness, leading to a low quality of life.[42]

SOLUTION
Process innovation

★ **Nondrug therapies**
In addition to pharmacological therapy, nondrug therapies such as exercise, massage therapy, meditation, relaxation and breathing techniques, acupuncture, or transcutaneous electrical nerve stimulation (TENS) can be effective in reducing pain and enhancing the quality of life for leukemia patients.[43]

2 PAINPOINT
People with leukemia often experience extreme fatigue that affects their ability to perform regular everyday activities.

SOLUTION
Digitalization

★ **Health monitoring apps and wearables**
Apps that monitor daily light activity (like walking) or nutrition intake can give feedback and motivation to stay on track and help to cope with severe fatigue. Monitoring sleep with wearables can additionally support healthy sleep patterns.[42]

3 PAINPOINT
Leukemia and its treatment can affect a patient's physical and mental health, leaving the patient vulnerable and depressed. Family and friends might have difficulties to support the patient appropriately.[42]

SOLUTION
Digitalization

★ **Online support groups**
When in-person support groups are not available or not wished, online support groups can be a suitable replacement. Not only can patients connect with each other to share similar experiences, but also their families find communities focused on leukemia.[44]

SOLUTION
Process innovation

★ **Music therapy**
Music therapy can be used to meet the psychological, physical, emotional, spiritual, and social needs of patients and their families. It is very effective in cancer patients; it makes them calm, eases their symptoms and helps them handle their treatment in a positive manner.[45,46]

4 COVID-19 PAINPOINT
Due to the pandemic, rehabilitation services might be difficult or even impossible to access in-person.

SOLUTION
Digitalization

★ **Physical rehabilitation apps**
Apps can play a crucial role in supporting the patient to exercise correctly at home. Physicians or therapists could develop individual training plans that are stored in the app for later access.[47]

SOLUTION
Digitalization

📝 **VR supported physiotherapy**
VR technology may bring complete therapy routines to the patient's home, using a VR headset and following exercises with the help of a virtual avatar. Further, this may aid in compliance monitoring, progress tracking and ensuring exercise safety, thereby increasing engagement and access.[48,49]

7 FOLLOW-UP

Scenario:
Patient at the hospital for follow-up

STAKEHOLDERS

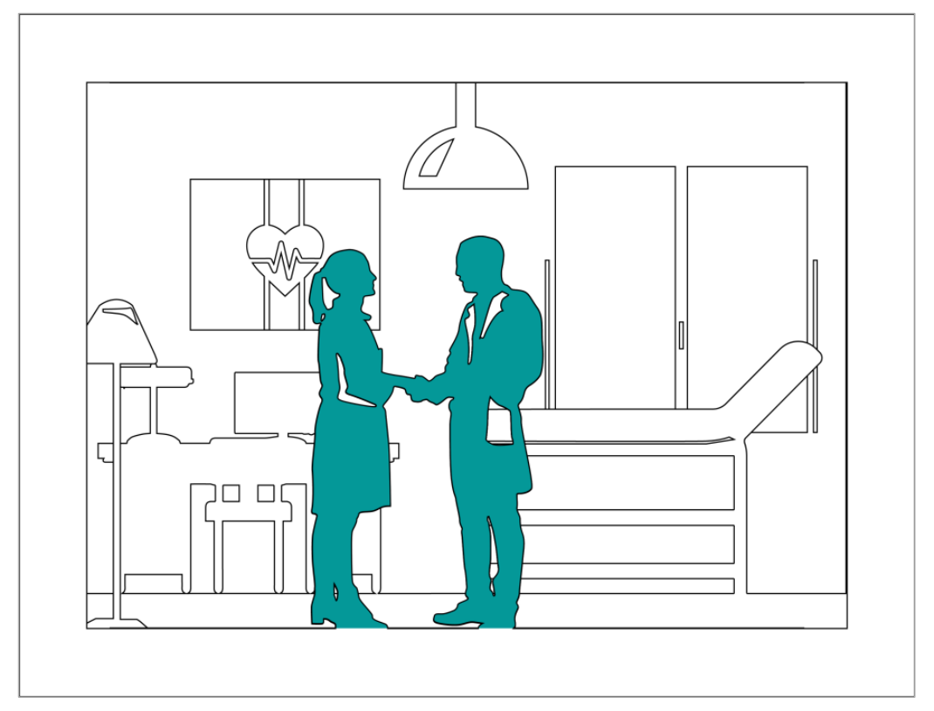
Patient Lives a normal life again but needs frequent health check-ups.

Family Supports patient with her health-related worries.

Pharmacy Responsible for preparing, preserving and distributing the needed medicine.

Haemato oncologist Tracks cancer progression and continues to devise treatment plans.

General physician Receives results from the haemato oncologist and supports the patient in an out-patient setting.



Patient is re-visiting the hospital for a more in-depth after-care check-up.

1 PAINPOINT
Patient can forget to take the medications which are to be continued even after discharge; this might have a deteriorating effect on her health.

SOLUTION
Sensing & Digitalization

★ **Smart pill box**
This programmable medicine box reminds the patients to take a particular tablet at the particular time, through voice and display.[50]

2 PAINPOINT
Patients may need regular doctor visits even after their leukemia has been diagnosed and treated, which might be discomforting.

SOLUTION
Digitalization

★ **Digital health assistant**
Such assistant can help the patient in many ways: tracking the patient's medical history, helping to make doctor appointments and sending reminders for the same, connecting with the doctor virtually, prescription refilling and patient support via chatbot.[51]

3 PAINPOINT
Hospital visits for frequent blood tests both during and after leukemia treatment might be difficult for patients in remote areas.

SOLUTION
Process innovation & Clinical innovation

📝 **Remote blood draw device**
Remote areas could be provided with patch-like blood collection devices, which adhere to the arm and connect to a test tube for collection. Afterwards, the blood draw can be sent to a lab via post.[52]

4 PAINPOINT
Sometimes, leukemia can relapse even after treatment.

SOLUTION
Digitalization

📝 **Machine learning based predicition**
The clinical data for relapse cases is gathered from electronic medical records and machine learning model is created for prediction of relapse. The patient's data is then fed to this model for detecting any risk or occurrence of relapse.[53,54]