Whitepaper

RBA

REAL-TIME BLOOD PROFILING

By team trinarybits 101

ABSTRACT

Blood cancer is a complex condition that disrupts the normal production and function of blood cells, leading to the generation of abnormal cells or an abnormal quantity of cells [1]. Patients facing this diagnosis endure long-term therapies, frequent blood tests, and extended hospital stays, which places an emotional burden on them. [2][3][4] To address these challenges innovatively, we propose "Rapid Blood Analysis" (RBA), a smart wearable wristband that integrates CERN [5] and ATTRACT [6] technologies to enable continuous and non-invasive blood monitoring.

The RBA system uses Artificial Intelligence (AI) to analyse the blood images taken by the wristband and generate comprehensive blood data. The combination of the collected data and patient-entered habit data in the RBA mobile app allows the AI to make personalised treatment suggestions to doctors and patients, leading to a more individualised approach to cancer care. This application of AI to customise therapy is a form of precision medicine that can achieve more efficient treatment outcomes than traditional treatment methods. [6]

Additionally, the wristband features a transdermal drug delivery function that enables precise, patient-tailored administration of the required drug dosage at optimal timings.

ABSTRACT

The User Interfaces (UI) of the RBA system is an integral aspect of the technology, designed to be patient-centric, interactive, and intuitive. Its main purpose is to facilitate seamless communication between the AI system and the users, making health management more approachable and user-friendly.

The patient’s UI is adapted to each patient's needs. The AI system, by recognizing the patient's health status and unique needs, adjusts the UI suggestions accordingly. As the patient interacts with the UI, it continues to evolve and fine-tune the type of information displayed and the manner in which it is presented, offering a truly personalized experience.

The UI extends beyond mere medical recommendations. It serves as a holistic health management tool that also caters to emotional support. For instance, the UI features uplifting quotes and shared stories from other patients battling similar conditions, cultivating a sense of community and positivity. This is an essential aspect of the UI design, aimed at enhancing patients' emotional well-being along with their physical health. [2][3]

Overall, the RBA system combines user-friendliness with high-tech healthcare innovation, making it a powerful tool for patient empowerment and individualized healthcare management in the field of blood cancer.

CONTENT

1 CBI A³ PROGRAM

In the CBI A³ program [7], various universities from around the world and their student teams take on the challenge of solving problems that burden modern society today and in the future.
In the CBI A³ program 2022-2023, students from Poland, Australia, Germany and the United States are addressing the United Nations (UN) Sustainable Developement Goal (SDG) number #3 "Health and Well-Being." [8] The task was to positively influence the health and well-being of the local community in the future with the help of technological innovations.
Using existing CERN and ATTRACT technologies, the interdisciplinary student teams must develop design concepts that will help solve a current healthcare problem in the near future.
Questions such as "What does the future look like?", "How do you develop a product that satisfies the needs of society?", "How do I turn an idea into a watertight concept?", present the students with new challenges.
In this program, students learn what it means to shape technological innovations in a globalized society while always keeping the big picture in mind. After completing the program, the participating teams present their visions and ideas to an international audience. [7]

2 THE TEAM

Rico Sanu

Rico is studying chemistry and process engineering for a master's degree at the Mannheim University of Applied Sciences. He loves the challenge that was set for him in the CBI A³ program and brings valuable impulses to the team with his scientific background. For the CBI A³ program, he acquired 3D modeling skills to visualize the team's ideas in a vivid way.

Palma Katona

Palma is a master's student in chemical and process engineering at the Mannheim University of Applied Sciences. She has a research background in sustainable insulation solutions and a background in industrial energy optimization. She loves working in an international environment with people from different fields of knowledge and she joined CBI A³ with the goal of learning more about technical solutions and connecting them to everyday problems.

Maren Leidner

Maren is a Master's student in Computer Science with a focus on Medical Data Science. With a background in medical informatics and her work in a research group at a university hospital, she is passionate about combining medicine and technical innovation, especially machine learning, to improve medical applications. She wants to increase her perspective on design through her participation in inno.space.

"ALTHOUGH THE FIELD OF ONCOLOGY HAS DEVELOPED AND EXPANDED DRAMATICALLY, A SINGLE DRUG HAS NOT YET BEEN DISCOVERED THAT CAN CURE ALL PATIENTS, EVEN THOSE WITH SIMILAR CANCER TYPES. WE NOW KNOW THAT CANCER IS AN EXTREMELY HETEROGENEOUS DISEASE, WHICH EXPLAINS DIFFERENCES NOT ONLY BETWEEN CANCER CELLS FROM DIFFERENT PATIENTS, BUT ALSO BETWEEN CANCER CELLS WITHIN A SINGLE PATIENT. CLEARLY, MORE EFFECTIVE STRATEGIES ARE CRITICALLY NEEDED TO DEFEAT THE LONG-STANDING ENEMY KNOWN AS CANCER."

Shin et al., npj Precision Onc (2017)
"Precision medicine: the foundation of future cancer therapeutics" [9]

3 PROBLEM SPACE

Blood cancer, also known as hematologic cancer or hematological malignancy, is a type of cancer that affects the production and function of blood cells. It occurs when abnormal cells in the bone marrow, which is responsible for producing blood cells, begin to grow uncontrollably. [10][11] Blood cancer is a condition that can affect individuals of any age, gender, or geographical location. It knows no boundaries and can impact anyone, regardless of their demographic characteristics. [12]

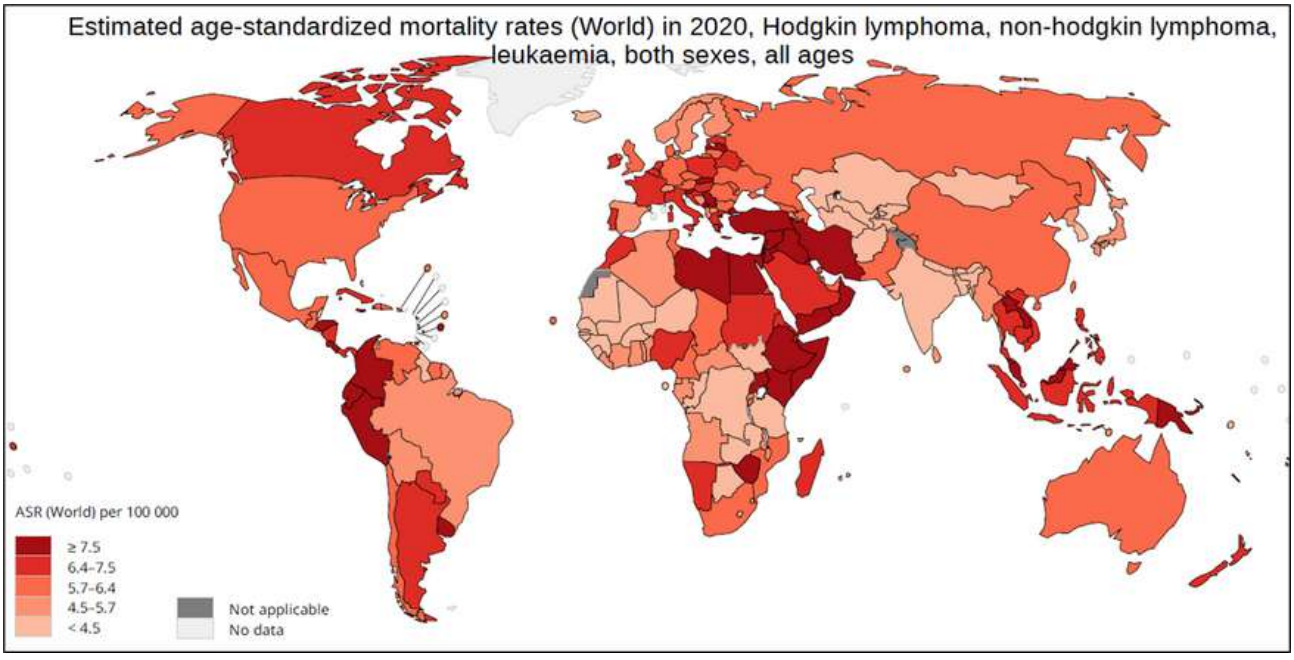


Fig. 1: Estimated worldwide mortality rates from blood cancer [12]

3 PROBLEM SPACE

There are three main types of blood cancer: leukemia, lymphoma, and myeloma. Leukemia affects the white blood cells and is characterized by the overproduction of abnormal cells, while lymphoma affects the lymphatic system, which is part of the immune system. Myeloma, on the other hand, affects plasma cells, a type of white blood cell responsible for producing antibodies. [10][11]

Blood cancer can cause a variety of symptoms, depending on the specific type and stage of the disease. Common symptoms include fatigue, unexplained weight loss, frequent infections, easy bruising or bleeding, swollen lymph nodes, and bone pain. [13] Diagnosis of blood cancer usually involves a combination of physical examination, blood tests, imaging tests (such as X-rays or CT scans), and a bone marrow biopsy. Blood tests play a crucial role in diagnosing blood cancer, as they can reveal various types of diseases, as indicated in Table 1(see in appendix). Once diagnosed, the treatment options for blood cancer depend on the type and stage of the disease. They may include chemotherapy, radiation therapy, targeted therapy, immunotherapy, and stem cell transplantation. [11][14]

Advances in medical research have led to improved outcomes for many people with blood cancer. However, the prognosis varies widely depending on factors such as the type of blood cancer, the stage at diagnosis, and individual patient characteristics. Early detection and timely treatment are crucial for better outcomes. [10][11]

Supportive care, including managing symptoms and side effects of treatment, is an essential part of the overall management of blood cancer. Additionally, ongoing monitoring and follow-up care are important to assess response to treatment and detect any potential relapse. [13][14]
In conclusion, blood cancer is a complex and diverse group of diseases that affect the blood cells. With advancements in medical science and ongoing research, there is hope for improved treatments and outcomes for individuals affected by this challenging condition.

3 PROBLEM SPACE

The medical sector faces challenges due to demographic developments and the lack of skilled workers in western societies. These problems affect patients, particularly blood cancer patients, in many ways.

With an aging population, the demand for medical care is increasing while there is a shortage of qualified professionals. This leads to longer waiting times and less time for individual patient care. [18][19] Blood cancer patients in need of urgent treatment suffer from delayed appointments, a lot of blooddrawns and uncertainty about their future.

The emotional world of patients is additionally burdened by the negative effects of the shortage of skilled workers. Medical staff are under stress, which can reduce empathy and support for patients. This can result in a lack of emotional support, which is so important for blood cancer patients, increasing their anxiety and worry.[15]

Stress is a common and serious problem in blood cancer patients. The diagnosis of a serious disease such as blood cancer and subsequent treatment places an enormous burden on patients. Uncertainty about the course of the disease, the side effects of treatments and worries about the future can lead to high psychological stress. This can negatively impact general well-being and affect patients' ability to cope emotionally with the condition and treatments. Stress can also have physical effects and weaken the immune system, which is particularly problematic in blood cancer patients. The weakened immune system can increase susceptibility to infections and make recovery more difficult. In addition, stress can increase physical fatigue, which can affect resilience and the ability to cope with the disease.[16][17]

3 PROBLEM SPACE

To mitigate the negative effects of stress on the well-being of blood cancer patients, holistic care is essential.

This means considering not only the physical health but also the psychological needs of patients. The promotion of coping strategies and the support of mental health professionals are important to reduce stress and improve patients' quality of life.[16][17]

Since the demographic development is leading to a shortage of time resources for medical professionals, the topic of relieving the burden on nursing staff already plays an important role in day-to-day political events as well as in the development of new technologies and new digital administration strategies in hospitals. In order to meet the current and new challenges in the medical sector, it is of enormous importance that the specialist staff is relieved so that high-quality treatment is made possible for the patients, both on a physiological and emotional level.[18][19]

Fig. 2: Psychological well-being of the patient is essential for a holistic treatment approach [20]

4 FUTURE SCENARIO

In the development of a future product, having a clear future vision is crucial. A product vision not only has to fit into the future vision, but can also enable it. This is why the future scenario topic was given significant attention in the CBI A³ project. A good idea only finds acceptance and success if it addresses people's needs. We at Trinary Bits developed our idea with the future scenario "Greentocracy" in mind. [21]

In the future scenario of "Greentocracy," society has undergone a profound transformation, embracing a sustainable and environmentally conscious way of living. This vision revolves around the idea of harmonizing human progress with the preservation of nature and the planet. Key elements of the "Greentocracy" future scenario include a shift towards renewable energy, sustainable transportation, regenerative agriculture, circular economy practices, and environmental education. [21] [22]

Fig. 3: Vision of a green future [23]

4 FUTURE SCENARIO

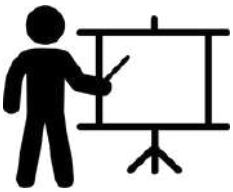
Renewable energy sources have replaced fossil fuels as the primary energy supply. Solar, wind, and geothermal power have become the norm, supported by extensive green energy infrastructure. Communities generate their own electricity, fostering energy independence and reducing carbon emissions. [21][22]

Transportation has undergone a significant overhaul. Electric vehicles have replaced conventional cars, thanks to advancements in battery technology and the development of widespread charging infrastructure. Public transportation systems have been expanded, offering efficient and low-carbon alternatives. Walkable cities, cycling networks, and pedestrian-friendly infrastructure have flourished, promoting active and eco-friendly modes of transportation. [21][22]

Sustainable agriculture takes center stage, prioritizing organic and regenerative farming methods, soil health, biodiversity, and water conservation. Urban agriculture and vertical farming have gained prominence, allowing communities to grow their own fresh produce. The concept of "farm-to-table" has taken hold, with a focus on locally sourced and seasonal ingredients to reduce food miles and support local economies. [21][22]

4 FUTURE SCENARIO

The principles of the circular economy are established. There is a focus on minimising waste and maximising resource efficiency. Innovative technologies have enabled the adoption of recycling and upcycling, reducing the reliance on new resources. Conscious consumption patterns now prioritize product durability, repairability, and responsible disposal. [21][22]



In this scenario, education and awareness are essential, and environmental literacy is given high priority from an early age. Schools and universities are incorporating sustainability into their curricula, giving students the knowledge and skills needed to address global environmental issues and raise a generation of environmentally conscious citizens. [21][22]

Governments and businesses collaborate to develop and implement green policies. Environmental regulations encourage companies to embrace sustainable practices and reduce their carbon emissions. [21][22]

In the Greentocracy future scenario, healthcare is reimagined as a sustainable and patient-centered system. Emphasizing preventive care, personalized medicine, and the integration of nature and technology, it promotes healthy lifestyles, offers tailored treatments, utilizes advanced technology, and operates with a focus on sustainability. [21][22]

4 FUTURE SCENARIO

Relevance of the RBA device in the Future of 2030

In the envisioned future scenario of Greentocracy, where society places great emphasis on the planet's well-being, it becomes crucial to also prioritize individual health. As traditional healthcare systems face challenges to meet the demands of this evolving world, innovative treatment methods are essential, focusing on patient-centered care, efficiency, and precision. [21] This is where the RBA concept becomes highly relevant.

The future of healthcare is set to be revolutionised by rapid technological advances and the widespread integration of AI. Automation, data analytics and virtual services will reshape the landscape of patient care, fostering a more efficient, accessible and patient-centric approach. Remote patient monitoring and automated appointment scheduling will reduce the burden on healthcare professionals and improve the overall patient experience. By embracing these cutting-edge innovations, the healthcare industry aims to optimise medical practices and deliver higher quality care. [24] In this transformative era, the integration of AI-driven blood analysis and remote patient monitoring, exemplified by RBA, will play a key role in supporting efficient healthcare delivery and further improving patient outcomes.

4 FUTURE SCENARIO

The future of healthcare will be driven by precision medicine, bringing with it a new era of personalised treatment plans based on a deeper understanding of patients' biology and genetics. Advances in bioengineering techniques will provide healthcare professionals with a more comprehensive understanding of individual patient needs, enabling targeted therapies and interventions. Precision medicine promises to transform the diagnosis and treatment of several diseases, offering more effective and personalised solutions for patients. [24] RBA demonstrates the seamless integration of innovative technologies and precision medicine into the healthcare sector in order to achieve effective patient outcomes. By offering personalized treatment plans for blood cancer patients, RBA ensures that individuals in need can attain optimal therapeutic results in the future.

Looking ahead, healthcare systems are placing increasing emphasis on sustainability and environmental awareness. The rise of innovations that minimise medical waste, optimise resource use and adopt green practices is emerging. Sustainable healthcare solutions are designed to reduce environmental impact while prioritising patient well-being. [24][25] As a result, non-invasive diagnostics such as RBA are becoming key players in promoting sustainable healthcare practices. By reducing the need for invasive procedures and associated waste, RBA's approach fits seamlessly into the greener future of healthcare, ensuring both environmental preservation and efficient patient care.

5 DESIGN SOLUTION

Currently, blood cancer patients need to undergo regular blood draws to obtain comprehensive information about their health status.

What if...?

... we could make it possible to make the treatment of blood cancer patients more comfortable through **shorter hospital stays, fewer blood draws** and **personalised medication**?

5 DESIGN SOLUTION

RBA – Rapid Blood Analysis

RBA is an innovative type of treatment for blood cancer patients. By offering personalized treatment, the RBA eliminates the need for frequent blood draws and long hospital stays for patient monitoring. With the help of the ATTRACT´s HIP-MED camera, the bracelet captures pictures of the blood through the skin, working alongside an AI-driven blood evaluation system and additional wearable sensors. This solution enables convenient patient monitoring from the comfort of their own home.

The main focus of the RBA concept is personalized precision medicine, which means tailoring medical treatments to the specific needs of each patient. Real-time patient monitoring allows physicians to closely track their patients health status, enabling customized treatment plans that cater to individual requirements.

Additionally, the bracelet incorporates a drug chamber, which plays a crucial role in accurately delivering the required cancer medication through the skin via sonophoresis. This precise method of drug transport enhances the overall effectiveness of the treatment, contributing to better patient outcomes.

Additionally, the RBA device comes with a complementary mobile app for patients, placing them at the center of their care and offering mental support in the form of motivational quotes and stories. The app also includes a habit input function, allowing patients to log their habits. The AI leverages this data to provide patients and their physicians with suggestions for therapy and lifestyle adjustments.

5.1 SYSTEM ARCHITECTURE

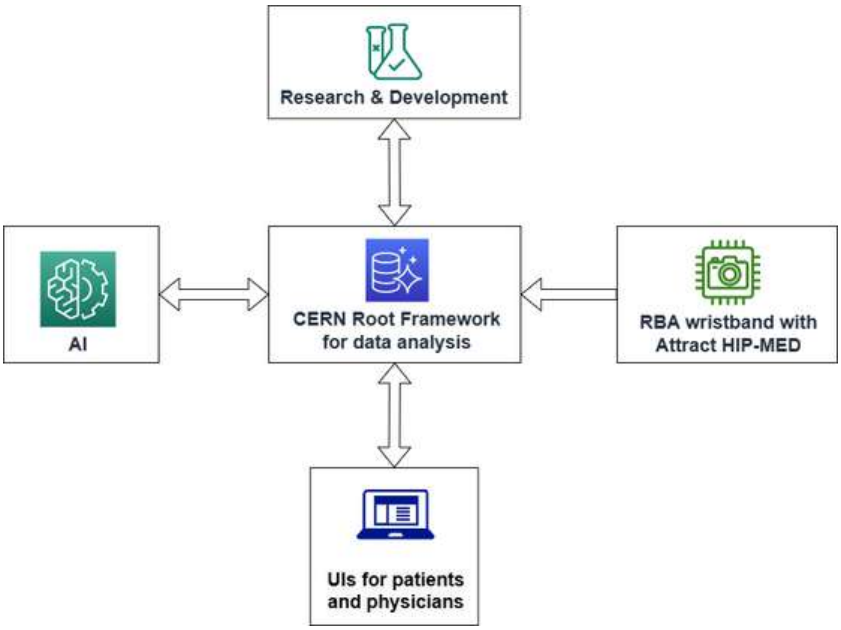


Fig. 5: A simplified presentation of the system components of RBA

The RBA system consists of various components, that are simplified illustrated on figure 5. In the middle of the system diagram is CERN's ROOT framework, which enhances data management. We distinguish between the RBA wearable, the hardware component, and the software components. The software components include two UIs and the AI for data processing and analysis.
In figure 5 we also see the connection and communication direction between the components, which can be seen in more detail in figure 6.

5.1 SYSTEM ARCHITECTURE

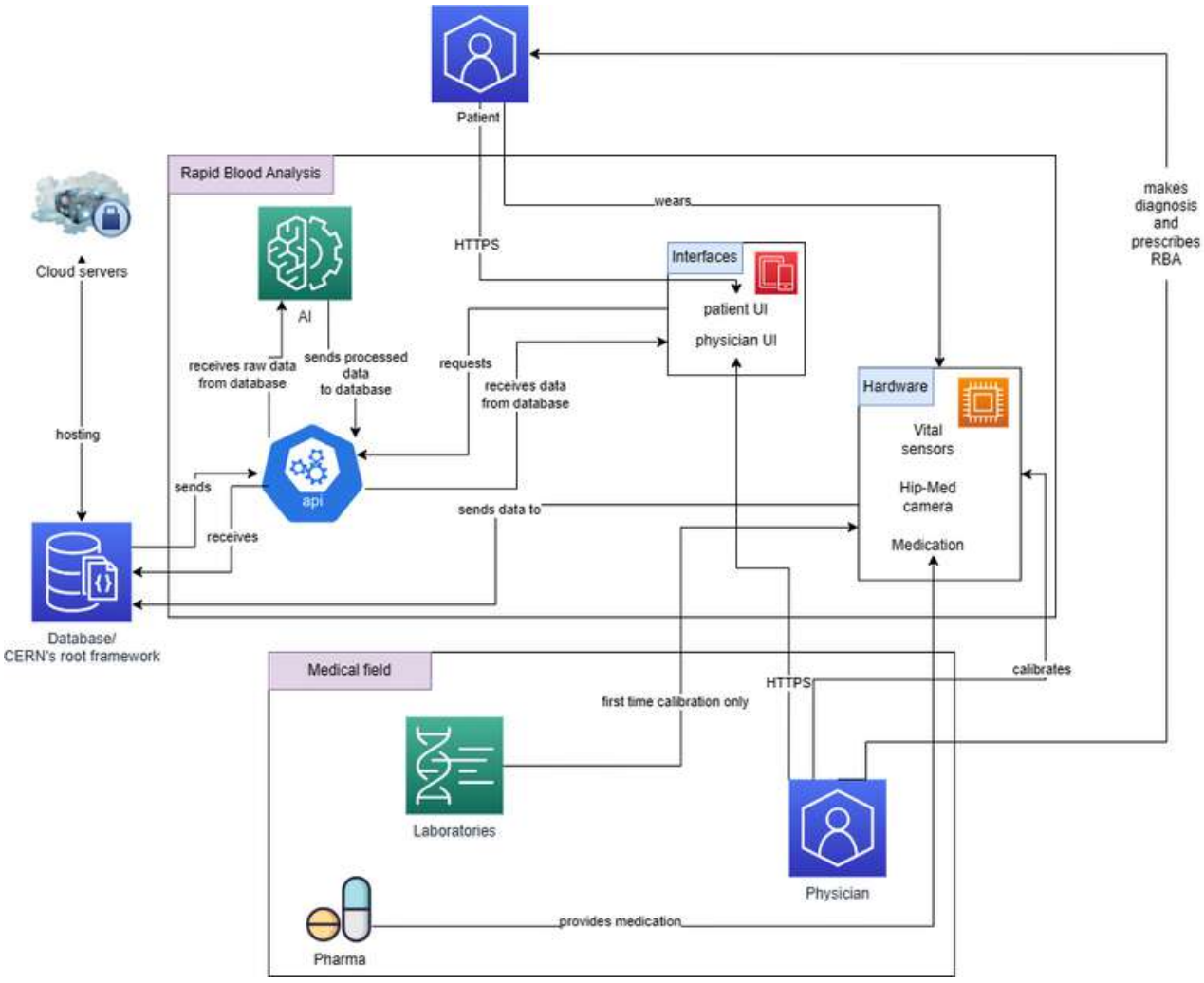


Fig. 6: A more comprehensive system diagram with a separation of the RBA system and the medical field.

5.1 SYSTEM ARCHITECTURE

The patient wears the RBA wristband. This wristband acquires the patient's blood images and therefore produces the data. The data is then send to the data repository and CERN's root framework. This is a unidirectional relationship and the only outbound connection from the hardware device. The data is hosted by servers.

From the data repository, the data is sent to the AI via an Application Programming Interface (API). The API ensures a connection of three stand-alone systems. Through the API, the AI can receive raw data from the data repository and send processed data back to the data repository. Moreover, the UIs are connected with the API as well. Through this connection, the user application can request and receive data from the database. The patient can access the application through the communication protocol Hypertext Transfer Protocol Secure (HTTPS), which encrypts requests and responses with Transport Layer Security (TLS) encoding.

The remaining components are not an intern part of RBA, but belong to the general medical field. The attending physician is connected to the patient as he makes the diagnosis and prescribes the RBA. He is also connected with the application, as he has access to the physician UI. The physician is responsible for calibrating the RBA hardware device to match the individual patient. The laboratories are also integrated into this process as they have to create the first and last blood picture. The pharmaceutical industry provides and further researches the medication integrated in the RBA wristband.

The whole system is meant to update with the Research & Developoment (R&D) field. We envision to stay up to date with novel technologies for AI, drug administration and image acquisition to further improve our system. Therefore, the R&D field fullfills our system.

5.2 HARDWARE —

Meet the RBA wristband

Leveraging the power of the ATTRACT technology HIP-MED, the CERN technology ROOT and a personalized drug administration system, the RBA device provides comprehensive support to patients throughout their journey.

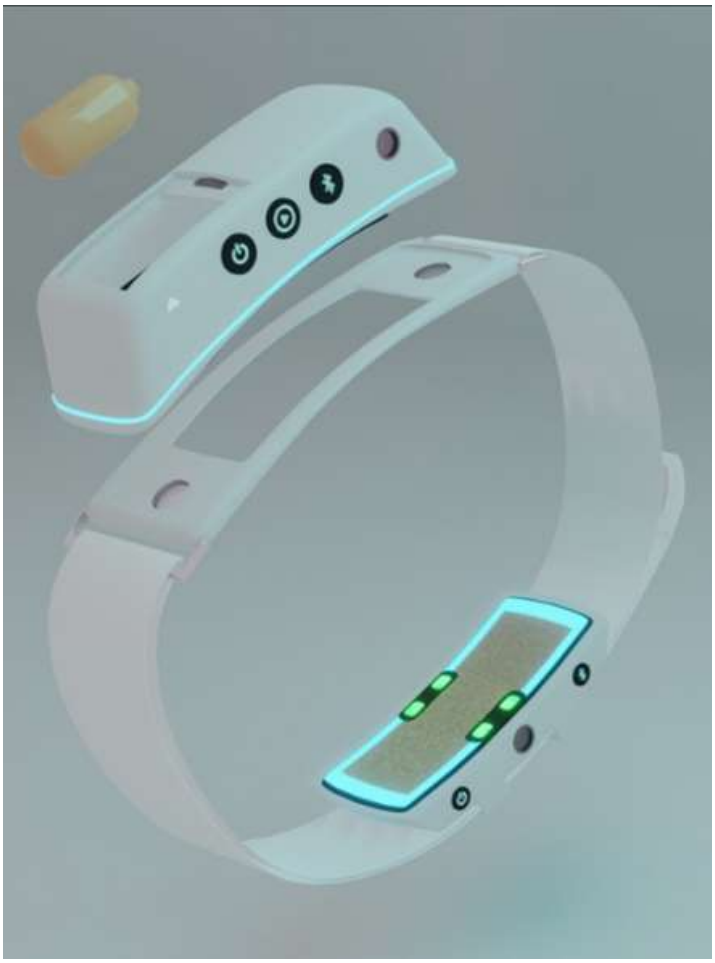


Fig. 7: 3D model of the RBA bracelet prototype

5.2 HARDWARE —

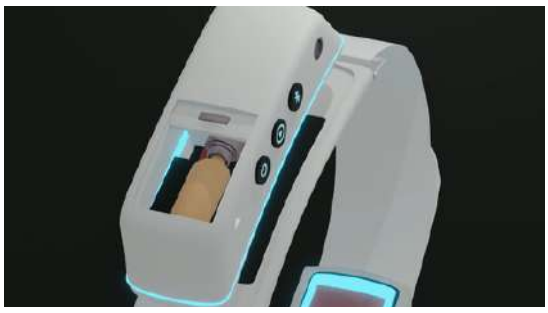
The main components of the wristband are the HIP-MED sensor, a medication chamber and a Milanese band that connects all the parts together.

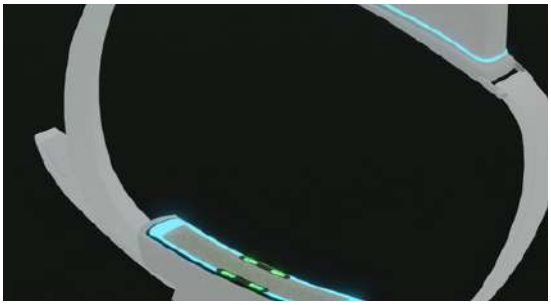
1. HIP-MED sensor:

The HIP-MED sensor uses high-resolution photometric analysis and can capture images of the blood through the skin.

2. Medication chamber:

The device's medication function utilizes sonophoresis to transport medication from the chamber to the patient's skin. By creating vibrations at the bottom of the chamber, it enhances the absorption of medication.





3. Milanese Band:

The Milanese band can be individually adjusted to any arm size and allows the sensor component to be brought into the desired position.

5.2 HARDWARE —

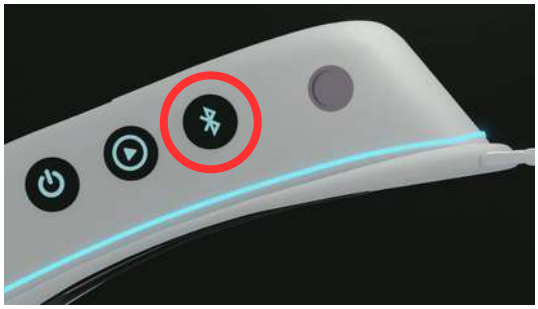
In addition to the main components, the wristband also includes additional elements such as the drug capsule, a Bluetooth button, other wearable sensors and a charging dock.

4. Drug Capsule:

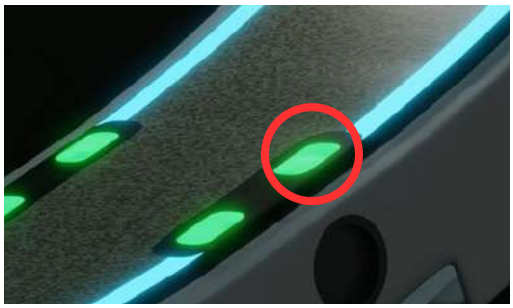
The medication capsule contains medicine and can be easily used and replaced. The RBA system recognizes the medication currently being used and releases the desired dose for the patient when required.

5. Bluetooth function:

The data from the sensor and medication chamber are transmitted via Bluetooth to the connected smartphone for evaluation.



5.2 HARDWARE —

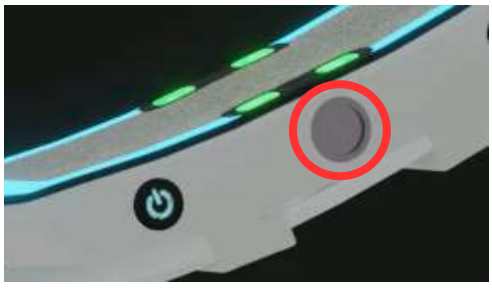


6. Vital sensors:

The device integrates a range of vital sensors commonly found in smartwatches. These sensors include a heart rate monitor for tracking the wearer's heart rate, a pulse oximeter to measure blood oxygen levels, motion sensors to monitor movement, and sleep trackers to analyze sleep patterns.

7. Charging Dock:

With a magnetic induction cable, the medication chamber and the sensor component can be charged quickly and easily.



5.3 SOFTWARE —

5.3.1 Artificial Intelligence

AI in the RBA system enables the evaluation of blood images and personalised health recommendations. The role of AI thus ranges from data collection and analysis to recommendations.

The AI journey begins with data evaluation. The RBA wristband continuously acquires the patient's blood images and monitors other vital signs. These blood images must be analysed by evaluating the individual blood components in the images. In this step, the AI goes through the entire pre-processing phase, in which the data is cleaned and structured for further analysis (normalisation of the measured values, treatment of missing values and identification and treatment of outliers), as well as the feature extraction and feature selection phases.

Once the AI has been trained with machine learning algorithms, it can build a model to predict health outcomes for individual patients. This model can be supplemented by patient-entered data in the mobile app, which can include lifestyle habits, diet, exercise and more. It uses the learned patterns and applies them to the unique health data of the patient, predicting potential health risks or suggesting interventions that could be beneficial, such as lifestyle changes or treatment suggestions.

5.3 SOFTWARE —

Importantly, RBA's AI is not static - it is continuously learning and adapting. As it receives more data about the patient's health status and responses to previous recommendations, it refines its model and makes more accurate and relevant recommendations. This is exactly the point where RBA implements precision medicine. Thanks to this model, which is refining and constantly learning about the individual patient, it can calculate the exact amount of medication and the optimal time for it.
Finally, the AI interacts with the user through the UIs, delivering recommendations, alerts, and health updates.

The AI journey is an iterative cycle rather than a linear path. With each new set of data, it repeats the process, constantly learning, adapting and improving its ability to support patient health. It aims to provide proactive healthcare by delivering personalised and timely recommendations that can improve patient outcomes and enhance their quality of life.

5.3.2 User Interfaces

Two user interfaces (UI) are connected to the RBA device, one for the treating physician and one for the patient wearing the device. These two UIs have different purposes. The physician receives all the patient's blood analysis results in a very informal view. The patient, on the other hand, does not have his analysis results displayed directly, but receives suggestions depending on his state of health. The patient's UI is designed to be patient-friendly, creating a supportive and intuitive experience.

5.3 SOFTWARE —

Patient view

RBA's target group, blood cancer patients, face many health issues and may not always feel well. The purpose of the patient's UI is therefore to create a space of support for their disease.

The core element of RBA is a sophisticated analysis system that transforms captured images into valuable insights. Rather than displaying the analysis results directly, RBA understands each patient's individual needs and adjusts the suggestions accordingly. By recognizing the patient's health status, the system becomes a companion that guides them to the actions and interventions that will be most beneficial to them.
That recommendation system leverages the principles of precision medicine, allowing for highly individualized and effective healthcare. Precision medicine, also known as personalised medicine, is a medical model that proposes the customisation of healthcare, tailoring all decisions and treatments to the individual patient, taking into account individual genes, environment and lifestyle. [35]

The UI is designed to display this information in a clear and easily understood format, with intuitive graphs, symbols, and color-coding.
It is also designed to provide patients with well-informed guidance that prioritizes their safety and health. Small community features connect people with the same disease and similar challenges in a kind manner, which can have a positive impact on dealing with the disease.

5.3 SOFTWARE —

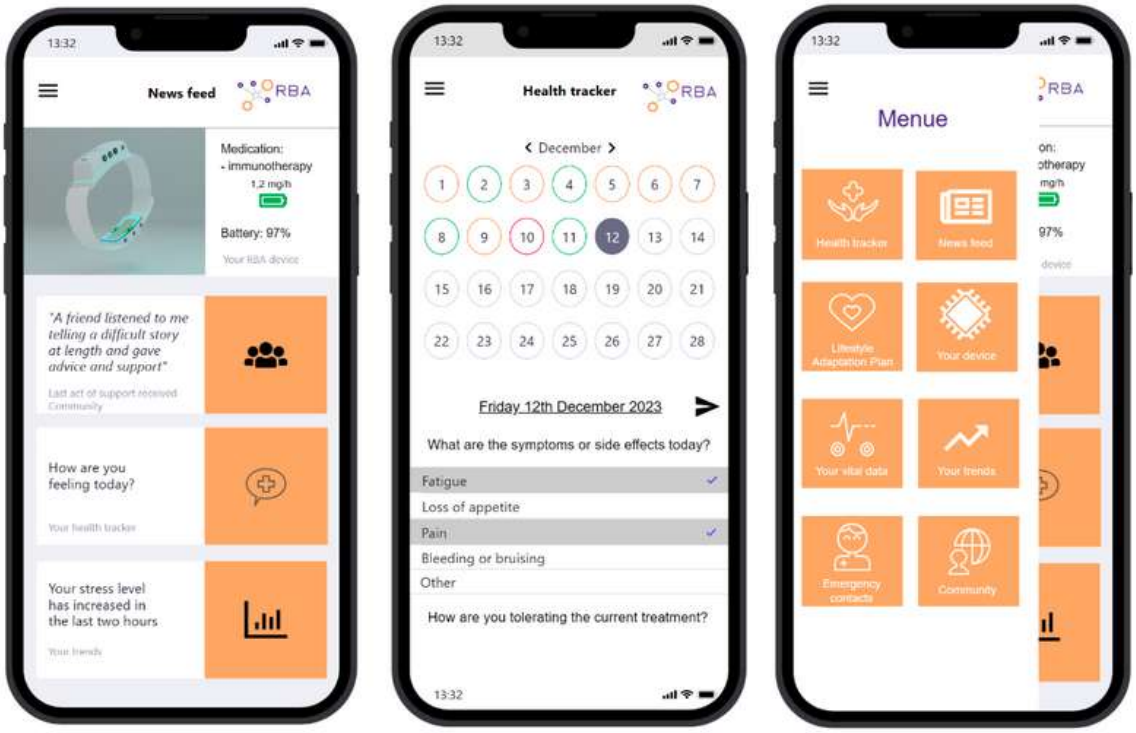


Fig 8: Three screens of the patient's RBA UI.

The left screen shows the dashboard, which is designed to present the most essential information to the patient. This includes an current status of the device they are wearing, an overview of their trends, and a supportive quote from the RBA community.

The middle screen represents a health tracker with calendar function, which provides a more detailed view of the patient's health data over time. Patients can track their health trends, compare data over different time frames, and correlate their actions with health outcomes.

The right screen shows the menu with all available options.

5.3 SOFTWARE —

5.3.3 hat happens when the patient's health status changes?

RBA diligently monitors vital indicators such as blood cell count, morphology, and other relevant parameters to develop a detailed understanding of the patient's condition. By continuously learning from this data, the system becomes increasingly accurate in predicting the patient's changing health patterns.

When the system identifies a shift in the patient's health, it not merely registers the change. Instead, it integrates this new information with existing data about the patient's medical history and lifestyle, generating tailored recommendations. These personalized suggestions are algorithmically curated and optimized to support the patient's health and well-being. These suggestions are tailored to the individual, taking into account their specific condition, unique health data, medical history and even lifestyle factors. These could include dietary changes, exercise suggestions, medication alerts, health alerts, and lifestyle modifications.

5.3 SOFTWARE —

Adjusting the medication dose, if necessary, can be done in several ways.

- One possible approach is for the system to transmit a proposed change to the physician as a medical decision aid. In this scenario, the physician retains full control over the medication regimen. He or she could then decide on the necessary adjustments based on the patient data in combination with the system's recommendation.

- Alternatively, the system could be empowered to make the decision independently, without requiring prior approval from the physician. In this case, the system decides on the adjustment, while the physician is informed and retains the authority to override the system's recommendation if he or she believes a different drug dosage is more appropriate. These recommendations are communicated to the patient through an intuitive UI.

In the event of significant or potentially dangerous health changes, the RBA system is programmed to execute an immediate response protocol. The system communicates critical information to the patient's healthcare provider through a dedicated physician UI, allowing for real-time medical intervention. At the same time, it can also reach the patient's emergency contacts to ensure that all necessary parties are informed and can respond appropriately.
The goal is to provide each patient with an individualized, proactive approach to managing their health effectively.

5.4 TECHNOLOGIES USES

The HIP-MED sensor

The heart of the RBA device is the HIP-MED sensor, an innovative technology developed as part of the ATTRACT programme. HIP-MED, short for Hyperspectral Imaging, is able to identify bodily cells based on their optical properties. This camera has already proven its potency in cancer research by identifying different types of cancer cells and their growth stages. [26][27]

HIP-MED combines spectroscopy and imaging to capture images of an object at different wavelengths thus creating a 3D dataset, as seen in figure 9. Spectral imaging creates a spectrum at each pixel, allowing ten times more information to be harnessed than with conventional RGB camera. This technology is excellent for detecting subtle differences in body tissues, such as previously undetectable cancer cells. [27][28]

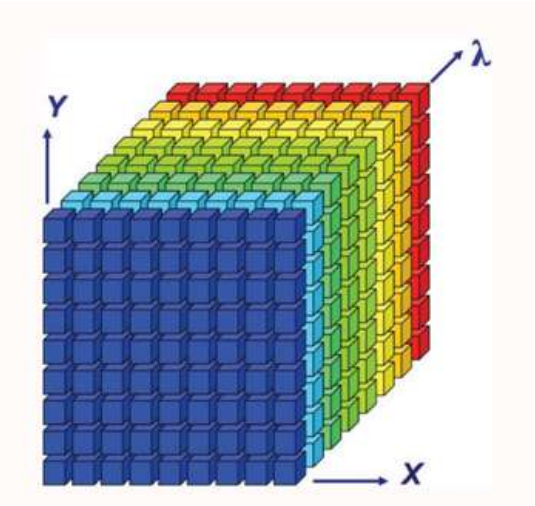


Fig. 9: 3D Data set of a spectral image [27]

In the RBA device, we harness the potential of the HIP-MED sensor to not only identify and categorise blood cells, but also to continuously monitor the progression of blood cancer. Through optical evaluation, HIP-MED can accurately detect blood cells by analysing their unique shapes and surface structures.

5.4 TECHNOLOGIES USES

ROOT Framework

The ROOT framework is a powerful data analysis toolkit widely used in the field of high-energy physics. It provides a comprehensive set of tools and libraries for data storage, analysis, and visualization. [4]

The Medical Chamber

The medical chamber not only makes the drug available to the patient around the clock, it doses the drug and administers it to the patient's skin. The sonophoresis technique is used, which helps the medication to be absorbed quickly into the skin.
Sonophoresis is a procedure that uses vibrations caused by sound to mechanically massage an active ingredient into the skin. Sonophoresis is currently used to treat rheumatism, scars, muscle pain, atrose and broken bones. The vibration is of course completely painless for the patient. [29]

Transdermal medication

There are a variety of medications that are applied to the skin. Such transdermal drugs are also used in cancer therapy. Examples of this are drugs such as fentanyl preparations or conidin, which are currently used in cancer therapy to relieve pain or to reduce side effects of chemotherapy. [30] [31]

5.5 DATA

RBA database

The RBA database serves as a comprehensive database for patient blood image data acquired with Hip-Med technology and is managed by CERN's ROOT framework. These allow detailed visualization and characterization of various blood components, such as red blood cells, white blood cells, and platelets. The database stores the images, the attributes for evaluating the blood images and the attributes of the analysis.

One of the primary objectives of the RBA database is to support the analysis and interpretation of these images. To achieve this, the database incorporates sophisticated algorithms and machine learning models that can automatically analyze the images and extract relevant information. These analyses include the identification and classification of different blood cell types, the quantification of cell counts, morphological features, and the detection of abnormal cells.

The database also facilitates efficient data management by organizing blood images and their associated analyses in a structured and searchable manner.
The RBA database leverages the features and capabilities of the ROOT framework, which is used in high-energy physics and can efficiently manage and store large amounts of image data. ROOT offers a comprehensive set of libraries and tools for data storage, analysis, and visualization, making it an ideal choice for managing image streams in research environments. [20]

5.5 DATA

RBA database

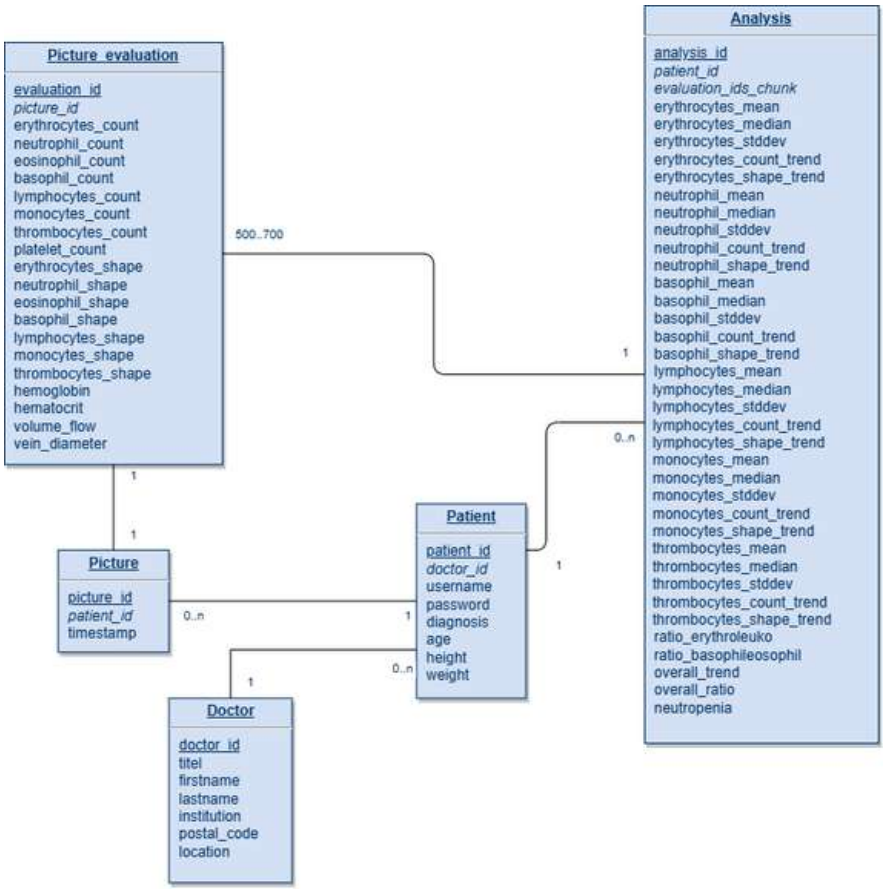


Fig 10: A schematic representation of the RBA database.

Only the most necessary private patient data is stored.

Each image is linked to the corresponding patient and has an evaluation in which the blood components are classified and their number and shape are determined.

Properties such as volume flow are also determined for each image. An analysis is then performed on a chunk of image evaluations, including statistically relevant values such as the mean value of all blood components, but also ratio, trends and neutropenia.

5.5 DATA

Data sharing

Additionally, the database allows for annotation and collaborative data sharing, enabling researchers and clinicians to contribute their insights, findings, and annotations, fostering a collective knowledge base in the field of hematology.
By accumulating a vast collection of blood images and their analyses, researchers and AI algorithms can explore patterns, correlations, and trends that may provide valuable insights into disease progression, treatment response, and prognostic indicators.

Data security

The RBA device collects various data. Data from blood images, vital data and movement data could be misused for profit-making purposes and must be handled with extreme care to ensure patient confidentiality and to comply with privacy regulations.

To promote acceptance and fear-free use of the device by potential users, patient data is kept confidential. When the patient is prescribed a device by the physician, the data is stored in our system anonymously with only the most important attributes recorded. The system can read the user data but cannot identify a patient.
For the use of data for research purposes, standardization of imaging techniques, data formats, and analysis methods is essential to facilitate data sharing, collaboration, and reproducibility in research and clinical settings.

6 USER JOURNEY

The RBA therapy aims to provide continuous support to patients throughout their journey from diagnosis to therapy. With a focus on patient well-being, the user journey encompasses multiple stages to ensure personalized care and efficient treatment.

1. Diagnosis and Initiation:

The user journey begins with the patient receiving their diagnosis from the physician. After conducting comprehensive health tests, the doctor starts the cancer therapy while simultaneously prescribing the RBA bracelet. This wristband-like device is designed to be worn around the clock and acts as a vital tool in the patient's care.

2. Calibration Process:

To ensure accurate functioning and blood diagnosis through the RBA bracelet, calibration is necessary. The physician calibrates the device to the patient's unique blood values by conducting a blood test. Additionally, the bracelet's HIP-MED camera is calibrated to the patient's skin color, recording the melanin pigment content in the skin. This ensures accurate results for patients with varying skin tones.

3. Receiving the wristband and setting up the RBA account:

Once the calibration process is completed, the patient can return home. The RBA wearable is delivered to their doorstep within a few days. Simultaneously, an RBA account is automatically created for the patient. The login details are encrypted and securely sent by the RBA team.

6 USER JOURNEY

4. RBA App:
Patients can access their account through the patient's RBA app, using the provided login data. It is a patient-centric, intuitive platform designed to distill complex health data into understandable, personalized medical advice and emotional support. Its adaptive nature allows it to cater to each patient's unique needs, offering a highly individualized tool for proactive health management. Through shared quotes and stories from other patients, the app fosters a sense of community and encouragement. On the other hand, the attending physician has access to all blood analysis results through his or her UI, providing a comprehensive view of the patient's health condition.

5. Continuous Monitoring and Emergency System:
The RBA bracelet continuously captures and evaluates the patient's blood picture at regular intervals. If any values deviate significantly, the treating physician is alerted at an early stage, enabling swift responses to emergent health situations.

6. Treatment Adjustment and Medication Management:
The RBA system suggests potential treatment adjustments or medication reorder requirements to the physician based on the collected data. The RBA bracelet does not replace regular doctor visits but complements them, facilitating more efficient treatment options. Physicians can use the insights provided by the RBA system to modify the dosage or treatment methods as needed.

7. Personalized User Suggestions:
The RBA app allows users to input their daily habits, such as physical exercise, sleep patterns, symptoms, and eating habits. Leveraging the patient input data, the AI evaluates blood levels in the context of these habits and provides personalized suggestions via the UI to support the healing process.

8. Successful Healing and Reuse:
Upon successful healing, the RBA bracelet can be reused for the next patient. Before reuse, the device is emptied of its previous user's information, ensuring privacy and data security.

7 STAKE-HOLDERS

The RBA device presents a transformative solution that revolutionizes patient monitoring, care, and blood cancer research. By reducing hospitalizations, enabling non-invasive blood analysis, and providing emergency response capabilities, blood cancer patients are the primary beneficiaries of this device. Additionally, physicians, nursing staff, hospital laboratories, and health insurance companies play crucial roles in this system.

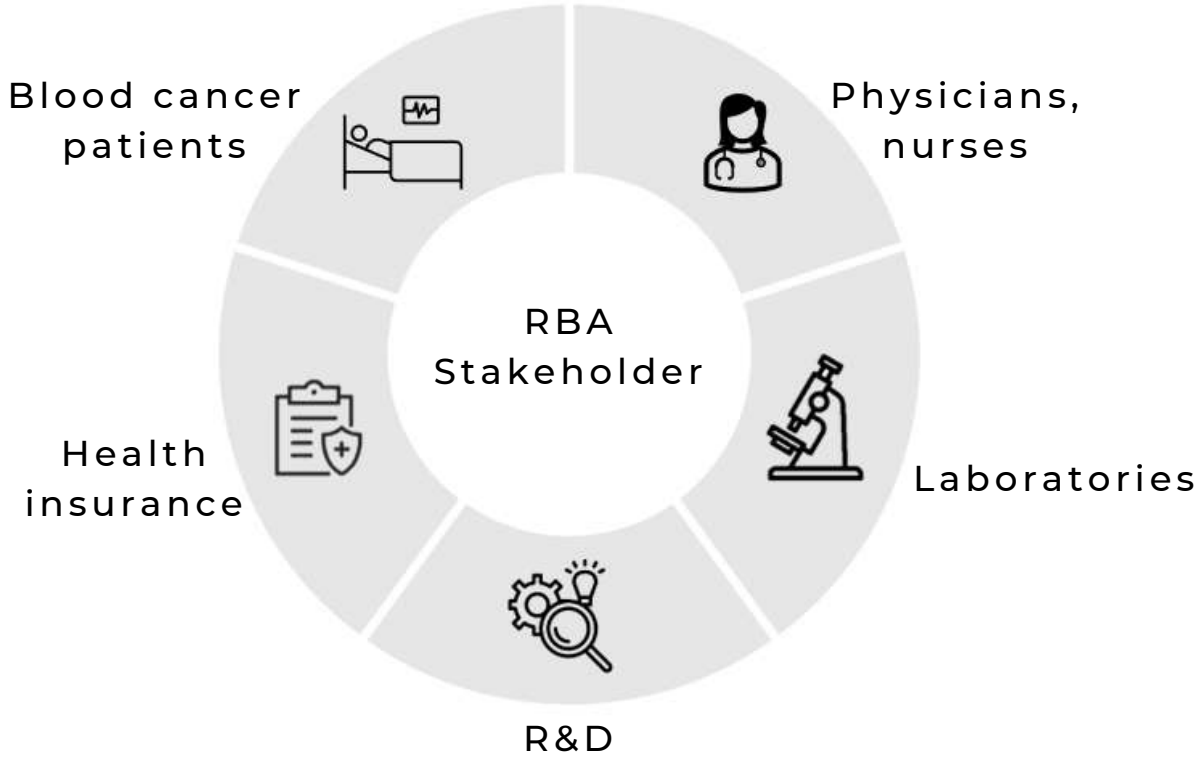


Fig. 11: Overview of stakeholders in the RBA system

7 STAKE-HOLDERS

Blood cancer patients are the central stakeholder group of the RBA device system. By leveraging enhanced disease monitoring, patients can experience improved care while minimizing hospital visits and invasive blood draws. In addition, the RBA device administers medication transdermally, tailored to the exact individual needs of each patient, making it a revolutionary form of personalised precision medicine. With real-time data collection and analysis, patients and their physicians can gain valuable insights into disease progression and identify factors that contribute to successful treatment outcomes. The RBA device empowers patients by providing the ability to respond to emergencies and facilitating non-invasive tracking of their condition, as well as providing emotional support during their illness though the RBA app.

Physicians and nursing staff bear the responsibility of delivering quality patient care. The RBA device equips them with comprehensive data that enhances their understanding of the disease and enables more informed decision-making. By simplifying the monitoring process and providing AI-assisted blood analysis, the device alleviates the burden on medical professionals, allowing them to focus on personalized care and treatment strategies. Moreover, the device offers valuable guidance on drug dosage and optimal care options, enhancing the expertise of healthcare providers.

7 STAKE-HOLDERS

By conducting blood tests directly through the RBA device, the reliance on hospital laboratories for routine analysis is reduced. This alleviates the workload on laboratory personnel and resources, enabling them to prioritize more complex tests and specialized diagnostics. As a result, the device improves the efficiency and productivity of hospital laboratories, leading to faster turnaround times and enhanced overall healthcare delivery.

The RBA device revolutionizes R&D in the field of blood cancer and related studies. By providing extensive data on disease progression, treatment outcomes, and lifestyle factors, researchers can explore new treatment approaches, identify therapeutic targets, and develop personalized medicine strategies. With advanced monitoring and AI-driven analysis, the device empowers researchers to conduct comprehensive studies, leading to breakthroughs in understanding blood cancer and advancing treatment options.

Health insurance companies can also benefit from the implementation of the RBA device. Through efficient examinations and continuous monitoring, the device reduces the need for frequent hospital visits and personnel-intensive procedures. This, in turn, lowers costs for health insurance providers and contributes to a healthier patient population.

8 IMPLEMENTATION

In this chapter, we present the implementation plan for the RBA device, outlining the steps required to bring our vision of the future to reality. Figure 12 represents a comprehensive roadmap that highlights the intermediate milestones along the way.

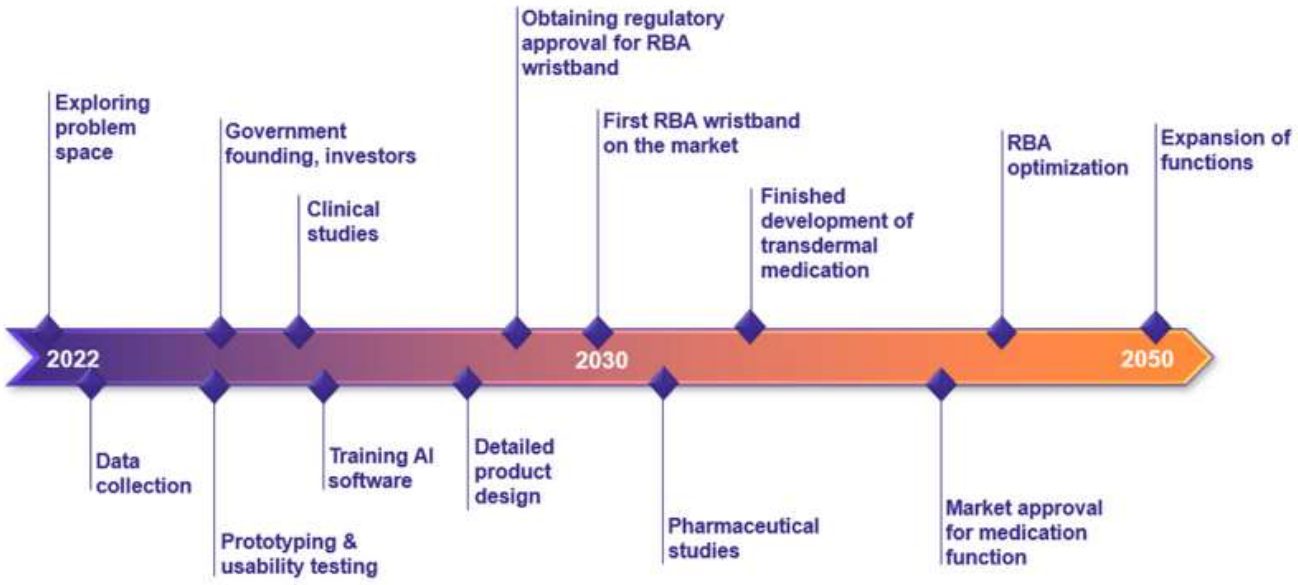


Fig. 12: Implementation roadmap of the RBA device from 2022 to 2050.

8 IMPLEMENTATION

The first step in implementation, after sufficient exploration of the problem space, is to collect data on which health habits affect a person's blood picture and to what extent. We also want to find out how long it takes to change blood levels by making different, more conscious health choices, thus determining the effectiveness of the RBA therapy. This will be done by researching existing data and interviewing medical professionals.

In the second step, we will pursue government funding for the project. As the RBA product offers benefits such as simplified patient monitoring and shortened healing processes, the government stands to gain from its implementation by reducing the burden on healthcare institutions such as hospitals and health insurance.

Securing funding is crucial for the subsequent step, which involves conducting clinical research to further investigate the relationship between external factors, such as exercise and dietary habits, and changes in blood levels. This research will encompass both patients with blood cancer and healthy individuals, providing us with sufficient reference data.

At the same time, we will continuously refine our prototypes, aiming for higher fidelity with each iteration. This includes creating an optimal design for the wristband and where each compartment and sensor should be placed on it. We conduct tests with different sensors for vital data monitoring and also for the HIP-MED sensor.

Once we have collected data from clinical studies, we will commence training the AI software of the RBA device to analyze blood samples captured by the HIP-MED camera.

As we approach the end of the 2020s, we aim to have detailed product designs for both the hardware and software components.

8 IMPLEMENTATION

By 2030, we plan to launch the initial version of the RBA device after obtaining regulatory approval. This version will enable comprehensive blood analysis at regular intervals and allow patients to provide input on their lifestyle, daily activities, and well-being through the RBA app. The device will correlate this data with blood analyses to make personalized lifestyle suggestions for improving health. The RBA UI will also feature a support function with blog posts from individuals who have faced similar challenges and share their experiences on what has helped them feel better.

Following the release of the RBA device, the second phase of our plan will focus on epanding its functions. We will conduct pharmaceutical studies, likely financed by revenues from the initial release and pharmaceutical funding, to explore transdermal drug delivery. During this stage, a comprehensive medical study will be conducted to determine optimal dosing intervals and amounts for pain relief. We will also test the sonophoresis sensor, a crucial component of the medication chamber, as it facilitates drug delivery. By 2040, we aim to obtain regulatory and market approval for the medication function.

By this time, technological advancements will have significantly improved the precision of our AI software, enabling more accurate connections between a patient's lifestyle and changes in their blood levels. This enhanced capability will allow us to monitor other diseases such as autoimmune conditions or allergies.

The full potential of the RBA device is expected to be realized by 2050. Patients will be able to obtain the device from their healthcare providers upon prescription.

In the more distant future, the device could also be used to treat diseases beyond blood cancers, leading to a revolutionary approach to treating various diseases. By utilizing non-invasive blood analyses, it could monitor disease progression and treatment response, thereby transforming the way we treat a wide range of illnesses.

9 VALUE

RBA plays a crucial role in shaping the future of healthcare and has the potential to bring about a positive impact on global society's well-being. Its significance extends to various aspects:

Value for patient:

- RBA can contribute to the physical and psychological relief of the patient, due to enhanced monitoring with fewer hospitalizations and doctor visits
- Real-time and personalized analytics provided 24/7 allow for timely interventions and adjustments to treatment plans, potentially preventing complications
- RBA reduces the need for frequent blood draws
- It offers more individualized treatment options and medication administration, considering each patient's unique disease and condition
- RBA empowers patients with a better understanding of their lifestyle's impact on disease progression and health
- The app's supportive design ensures attending physicians are always informed about the patient's health condition
- RBA enables faster emergency management and reaction times in critical situations, without waiting for blood count results.

9 VALUE

Value for the medical sector:

- By eliminating the need for regular blood draws, RBA reduces the burden on hospitals, laboratories, doctors, and nursing staff
- With reduced administrative tasks, there is more capacity for prioritizing preventive health care measures, ensuring personalized and suitable treatments for patients.
- The cost savings achieved by RBA benefit both health insurances and patients, making appropriate medical care more accessible to a broader population
- RBA's user-friendly interfaces enable smooth communication between patients and healthcare professionals, fostering better-informed decisions and proactive patient management for better health outcomes.

Value for the R&D sector:

- RBA collects comprehensive data, providing novel insights that could lead to the development of new or refined diagnostic and therapy options
- The data enables the creation of individualized treatment methods within the field of precision medicine
- RBA's insights contribute to advancements in blood cancer management, treatment efficacy, and population health trends, benefiting the medical community as a whole

10 CONCLU-SION

Utilizing the hyperspectral imaging technology HIP-MED, non-invasive blood images of exceptional detail are acquired, eliminating the need for invasive procedures. The RBA device enables continuous real-time monitoring of blood composition, providing a comprehensive understanding of the patient's health status. Through AI algorithms, the vast amount of data generated is analyzed to detect patterns, anomalies, and correlations, forming the basis for personalized recommendations tailored to each patient's health condition.

Empowering patients to actively engage in their own care, the RBA device offers improved disease tracking, personalized treatment options, and real-time emergency assistance. This transformative technology revolutionizes patient care, drives advancements in blood cancer research, and holds immense potential for shaping the future of medicine.

Furthermore, the RBA device serves as a catalyst for groundbreaking research in blood cancer. With its ability to collect a completely novel kind of data, employ AI-powered analytics, and provide comprehensive monitoring capabilities, researchers gain valuable insights into disease progression, treatment efficacy, and lifestyle factors influencing patient health. This powerful tool enhances scientific understanding, accelerates breakthroughs, and transforms the landscape of care for blood cancer patients.

Looking ahead, our vision extends beyond a single patient group, aiming for a future where personalized healthcare with RBA is applicable to a range of diseases such as autoimmune conditions or HIV.

In conclusion, RBA signifies a fundamental shift in disease tracking, treatment approaches, and precision medicine, holding the potential for global impact.

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ABBREVIATIONS —

RBA	- Rapid Blood Analysis
UN	- United Nations
SDG	- Sustainable Development Goals
AI	- Artificial Intelligence
UI	- User Interface
HIP-MED	- Hyperspectral Imaging for Precision Medicine in cancer Diagnostics
API	- Application Programming Interface
TLS	- Transport Layer Security
R&D	- Research &Development

APPENDIX

Table 1: Components of the blood and the effects of too high or too low values [32] [33] [34]

	Value too low	Value too high
erythrocytes (red blood cells)	Anemia (iron deficiency): indicates kidney disease	Polycythemia (lack of oxygen): caused by high blood pressure and circulatory disorders
hemoglobin	caused by lack of iron, folic acid and vitamin B12	caused by dehydration and smoking
leukocytes (white blood cells)	Leukopenia caused by chemotherapy and certain viral infections	Leukocytosis: caused by cancer, inflammation, allergies, poisoning, metabolic disorders, stress and smoking
thrombocytes (platelets)	indicates infection, injury, autoimmune disease, pregnancy, or vitamin deficiency	Thrombocytosis: arises after operations or births, can also indicate illnesses such as chronic intestinal disease or tumors
lymphocytes	Lymphoemia caused by stress, diseases of the immune system and by cortisone therapy	Lymphocytosis arises from a bacterial or viral infection
neutrophilic granulocytes	Caused by infection	Caused by infection
Eosinophilic granulocytes	Caused by parasites, allergies	caused by stress and burnout
Basophilic granulocytes	caused by a very strong infection	Caused by diabetes

Palma Katona

Rico Sanu

Maren Leidner

Find out more about our work:
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