# Leveraging Artificial Intelligence for Improved Hematologic Cancer Care: Early Diagnosis and Complications' Prediction

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Abstract: Today, medical artificial intelligence (AI) applications are being extensively utilized to enhance the outcomes of clinical diagnosis and overall patient care. This data-driven approach can be trained to account for individuals' unique characteristics, medical history, ethnicity, and even genetic make-up to obtain accurately tailored treatment recommendations. Given the power of medical AI, the severe nature of hematological malignancies and the related constraints in terms of both time and cost, in this paper, we are investigating the importance of AI applications in hematology management, with an illustration of AI's role in reducing pre- and post-diagnosis challenges. Insights discussed here are derived based on our experiments on clinical datasets from National Center for Cancer Care & Research (NCCCR), Qatar. Specifically, we developed AI models for blood cancer diagnosis as well as prediction of therapy-induced clinical complications in patients with hematological cancers to facilitate better hospital management and improved cancer care.

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## 1 INTRODUCTION

Artificial intelligence (AI) is the science of using computer systems and algorithms that simulate the human brain to perform tasks and solve complex problems.

Thanks to the recent explosive improvement and progress in computing power and easy access to large repositories of data, the realm of AI currently plays a big role in several technologies, including clinical medicine and biomedical research (Radakovich et al., 2020).

Driven by the abundance of medical data and the remarkable AI results in various fields and machine learning (ML), there exist several promising tools that can help clinicians solve critical problems related to oncology and hematology (El Alaoui et al., 2022).

Examples of successful AI applications in cancer research range from digital medical image analysis and pattern recognition to cancer classification and diagnosis using ML and deep learning (DL) algorithms (Walter et al., 2021).

## 2 AI IN HEMATOLOGY MANAGEMENT

With the improved access to ML and DL tools and medical data augmentation and expansion techniques, the scope of AI applications in hematology has increased to include all stages of patient management from diagnosis to treatment and prognosis (Shadman et al., 2023). Despite recent technical advancements and variety of models developed to support hematological data, AI research in hematological cancer management was found to receive less attention compared to oncology (El Alaoui et al., 2022). Furthermore, the current state-of-the-art emphasized on some hematological malignancies

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more than others, namely Acute Myeloid Leukemia (AML) and Acute Lymphoblastic Leukemia (ALL) compared to Chronic Myeloid Leukemia (CML) and Chronic Lymphoblastic Leukemia (CLL), wherein further research is pivotal (El Alaoui et al., 2022). Table 1 portrays the results of a literature review encompassing 131 papers on the topic of AI applications in hematology categorized by malignancy type (El Alaoui et al., 2022).

Table 1: Categorization of 131 papers by malignancy type (N=131).

| Malignancy type | Values, n (%) |
|---|---|
| Acute myeloid leukemia (AML) | 42 (32.1) |
| Acute lymphoblastic leukemia (ALL) | 40 (30.5) |
| Chronic lymphocytic leukemia (CLL) | 13 (9.9) |
| Chronic myeloid leukemia (CML) | 2 (1.5) |
| Lymphoma<br>Others | 17 (13.0)<br>17 (13.0) |

Contrary to solid cancers, the diagnosis of liquid cancers is considered more challenging and time-consuming, given the complex symptomatology of the disease and the absence of symptoms in suspected patients during early stages, which restricts the clinicians' ability to predict the occurrence of such disease beforehand. While traditional detection methods rely mainly on blood cell image classification, AI-based models were introduced to enhance identification accuracy and provide a pilot view on the potential spread of the disease within the patient's body to help improve the chances of patient recovery and increase survival rates (El Alaoui et al., 2022).

Currently, the initial causes of blood cancers like leukemia are unknown, and no screening tests have been proven efficient enough to diagnose blood cancer in its early stages, unless some warning signs develop overtime (El Alaoui et al., 2022). In addition to the ambiguity of blood cancer signs, many patients do not exhibit any symptoms at the time of diagnosis, leading to delays in disease detection and treatment initiation. For instance, 80% of Chronic Lymphoblastic Leukemia (CLL) patients are asymptomatic at the time of diagnosis (Shadman et al., 2023). Such pre-diagnosis challenges faced by clinicians highlight the importance of AI-based models in tackling delayed diagnosis and the resulting implications. Moreover, applications of AI in the treatment stage and beyond, have yielded interesting outcomes in terms of achieving a timely and efficient therapy, and help predicting post-diagnosis complications (multiple infections, myelosuppression etc.) for a better patient management flow. Figure 1 summarizes the different pre- and post-diagnosis challenges and how AI can be used for combatting these challenges.

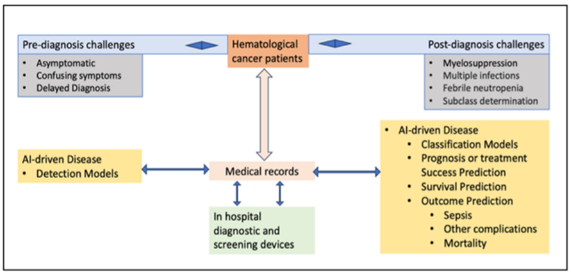


Figure 1: Advancing Healthcare Safety for Hematological Cancer Patients through AI.

As patients with hematological malignancies have an impaired immune function (immune suppression), they often report to hospitals with repeated multiple infections. Sometimes these patients develop high fever and reduced neutrophil count (febrile neutropenia-FNE). Reportedly, patients with FNE are very likely to develop fatal sepsis and thus mortality rate is high in such patients. As shown in Figure 1, AI-driven outcome prediction models can be used to identify such patients and give them required care from the beginning of hospitalization itself. Another post-diagnosis challenge is subclass determination; as treatment options vary considerably for each subclass hematological malignancy, highly specific molecular and cytological tests are required to identify exact subclass. All these challenges complicate hematological cancer care.

To address both these challenges, we are presenting two case studies, (a) ML-based models for early diagnosis of leukemia and (b) and ML-models to predict potential post-diagnosis complications in patients with hematological malignancies, respectively.

# 3 DISCUSSION

## 3.1 Case Study (a): Diagnostic Systems for Early Leukemia Detection

With the aim of enhancing Acute Lymphoblastic Leukemia (ALL)'s detection accuracy and overcoming the challenges associated with conventional manual microscopic identification techniques, we developed an AI-based diagnostic system for ALL detection using Random Forest (RF), XGBoost (XGb) and Decision Tree (DT) algorithms (El Alaoui et al., 2023). The three models were trained using 86 ALL and 86 control patients. Moreover, a Grid Search hyperparameter tuning technique was applied on each of the three classification models, while a Forward Feature Selection approach was performed to select the 10 most ALL-discriminatory complete blood count (CBC) features out of the initial 20, which included: Absolute Neutrophil Count (ANC), Hematocrit (HCT), Red Blood Cells (RBCs), MCV, MCH, Neutrophils %, Basophils %, Lymphocyte count, MPV and Platelets. Training the models using a 5-fold cross-validation technique resulted in high accuracies corresponding to 91.4% for DT and an identical 88.6% for both RF and XGb, respectively (El Alaoui et al., 2023).

We also developed a ML-based diagnosis and screening model for Chronic Lymphoblastic Leukemia (CLL) using 3 ML techniques including Linear Regression (LR), Linear Discriminant Analysis (LDA) and XGb, selected out of 8 candidate models following 5-fold cross-validation. The three models were trained using a total of 682 CBC records, where 88 were confirmed CLL patients and 594 were control. Dataset imbalance and disproportionality were overcome by means of (SMOTE-Synthetic Minority Over-Sampling Technique), (Padmanabhan et al., 2023). Moreover, the common high-ranked CBC parameters were extracted using chi-square, mutual information, extra tree and XGboost classifiers. The final set of features included WBC, Lymphocyte count, Neutrophil %, Lymphocyte %, Monocyte %, ANC, Platelets, Basophil %, Monocyte count, Basophil count and Eosinophil count, by order. The final performances of the selected models using the 11 chosen CBC parameters resulted in a 97.05%, 97.63% and 98.62% accuracy corresponding to QDA, LR and XGb, respectively (Padmanabhan et al., 2023).

Based on these novel results from the two aforementioned studies, it is fair to mention that pre-diagnosis delays can be effectively tackled through the integration of AI models in diagnostic systems and devices to foster early hematological disease detection.

### 3.2 Case Study (b): Prediction of Clinical Complications in Cancer Patients

With the aim of expediating the medical diagnosis process and enhancing its reliability for better health outcomes and increased chances of patient survival, we developed a novel AI-based approach to better manage patients with hematological cancer, namely the ones affected by therapy-induced myelosuppression, multiple infections, and febrile neutropenia (FN) (Padmanabhan et al., 2022).

In addition to the increasing sepsis risk and mortality in hematologic cancer patients with FN associated with treatment-induced myelosuppression, a high prevalence of multidrug-resistant organisms is also captured in such patients, which limits the number of treatment options that the patient is allowed amidst a similar set of health complications. Therefore, the early identification of such organisms within the cancer patient body can help prepare the latter to receive a better treatment, enable good hospital management and prevent the spread of such organisms to the weaker category of patients (Padmanabhan et al., 2022).

The current application serves as a predictive model for multidrug-resistant organisms, sepsis, and mortality risk in hematological cancer patients with FN. The application consists of medical data extraction using 1166 febrile neutropenia episodes reported in 513 patients, trained using the XGboost algorithm, a model selected out of 6 candidate models using a 10-fold cross-validation. Furthermore, to address the data disproportionality problem, data augmentation techniques and model-scoring-based hyperparameter tuning were used, and a set of features were added to the model to enhance the predictability of the previously mentioned clinical complications. The performance for sepsis, multi-drug resistant organism and mortality predictions resulted in a 0.85, 0.91 and 0.88 AUC (area under the curve), respectively, highlighting AI's potential in treatment clinical decision-making. Figure 2 represents the adopted methodology followed in building the aforementioned predicted models.

## 4 CONCLUSIONS

The computational power of AI constitutes a very strong leap in the field of hematology management, such that it enables a deep level of understanding of the unseen relations between clinical patient

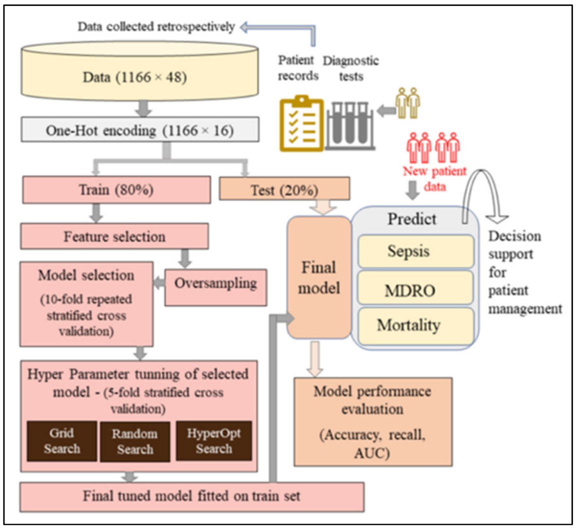


Figure 2: Schematic representation of the adopted methodology for building predictive models.

parameters and patient outcomes. Indeed, this powerful basis sets the ground for further advancements in the realm of healthcare management and upscaling of cancer care. Nevertheless, some ethical considerations that are sought to guide clinical decision making amidst medical AI applications are yet to be discussed.

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