ARTIFICIAL INTELLIGENCE-ASSISTED FLOW CYTOMETRY FOR LEUKEMIA DIAGNOSIS

A SYSTEMATIC SYNTHESIS OF RECENT ADVANCES AND CLINICAL UTILITY

P. Dawer[1], A. R. Riaz MBBS[2], A. Z. Khan[3], J. Valecha[4], S. Khanna[1], S. Chopra[1], R. Gupta[1], A. Senthil[1]

1. University College of Medical Sciences, Delhi, India
2. Nishtar Medical University, Multan, Pakistan
3. Al-Aleem Medical College, University of Health Sciences, Lahore, Pakistan
4. Saint Vincent Hospital, Massachusetts, USA

INTRODUCTION

Flow cytometry remains a cornerstone in the diagnosis of acute and chronic leukemias. However, its reliance on manual interpretation makes it prone to inter-operator variability and limited reproducibility, especially in complex cases. In recent years, artificial intelligence (AI), including both machine learning (ML) and deep learning (DL) approaches, has emerged as a promising adjunct. These tools have shown potential in enhancing diagnostic accuracy, standardizing interpretation, and reducing the time required for clinical decision-making.

AIMS & OBJECTIVES

This study aimed to evaluate the performance and clinical applicability of AI-assisted flow cytometry tools in the diagnosis of acute and chronic leukemias. The specific objectives were to review recently published studies (2020–2024) that applied AI or ML to flow cytometry, to analyze reported diagnostic accuracy metrics such as sensitivity, specificity, and area under the curve (AUC).

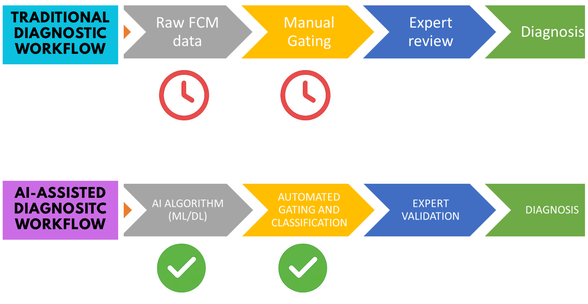
METHODS

A structured literature review was conducted using PubMed and EMBASE for studies published between 2020 and 2024. Eligible studies included original research articles that applied AI or ML models to flow cytometry for leukemia diagnosis, enrolled at least 50 patients, and reported measurable performance outcomes. We extracted the following data from each study: model type, sample size, leukemia subtype, diagnostic accuracy, and processing time. Both pediatric and adult cohorts were included, with emphasis on B-cell acute lymphoblastic leukemia (B-ALL) and acute myeloid leukemia (AML).

RESULTS

Several recent studies highlighted the effectiveness of AI integration into flow cytometry workflows. A 2024 deep learning model using the ALOT protocol (n=241) achieved sensitivities of 98.2% for B-ALL and 94.6% for AML. A 2021 machine learning classifier (n=531) reported an overall accuracy of 94.2% with an AUC of 0.995 in distinguishing acute leukemias from cytopenias. In 2022, an AI-enhanced workflow (n=294) matched the diagnostic performance of expert hematopathologists while significantly reducing interpretation time. Additionally, the Smartcytoflow machine learning decision support system (n=92) demonstrated improvements in real-time diagnosis of B-ALL and in monitoring of Minimal Residual Disease (MRD).

Year / Study	n	Subtypes of leukemia studied	Performance	Key Point
2024 ALOT Deep Learning	241	B-ALL, AML	Sensitivity 98.2%, 94.6%	High accuracy
2021 ML classifier	531	Acute leukemias	Accuracy 94.2%, AUC 0.995	Differentiation vs cytopenias
2022 AI-enhanced workflow	294	Acute leukemias	Matched experts	Faster interpretation
2024 Smartcytoflow System	92	B-ALL, MRD	AUC 92.9%, PR-AUC 0.92	Real-time + MRD monitoring



SUMMARY

AI-driven flow cytometry is emerging as a reliable, time-efficient diagnostic adjunct for leukemia. These systems exhibit high diagnostic accuracy and potential to reduce diagnostic delays. Further prospective validation and integration into clinical workflows are warranted, especially in low-resource settings.

DISCUSSION

AI-assisted flow cytometry represents an emerging diagnostic tool with significant potential to enhance speed, reproducibility, and accuracy in leukemia diagnosis. While current studies show encouraging results, challenges remain, including the need for prospective validation, integration into routine laboratory workflows, and the development of standardized approaches across institutions. Importantly, these systems hold particular promise in low-resource settings where access to expert interpretation may be limited, positioning AI as a valuable step toward more equitable leukemia diagnostics worldwide.

REFERENCES