

# Implementation of Big Data Analytics for Diabetes Management: Needs Assessment in the Rwanda Healthcare System

By

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# Artificial Intelligence for Diabetes Management

## What is known about Diabetes Mellitus?

- Three types of diabetes (Type 1, Type 2, Gestational)
- A progressive disease
- Diabetes is not reversible
- DM is patient-centric
  
- Diabetes affects the use of blood glucose
- Diabetes affects blood flow in small vessels
- Uncontrolled diabetes leads to complications
- Uncontrolled diabetes increases health costs to patients and care providers

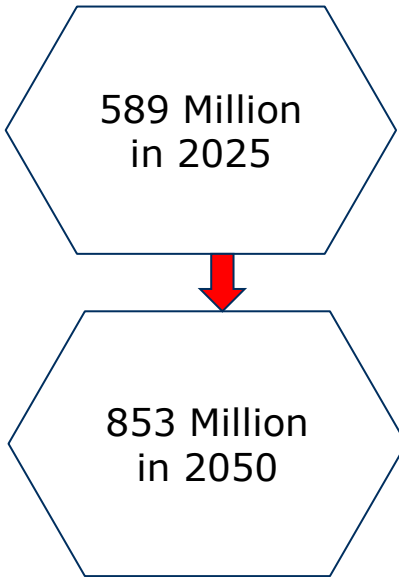
## AI in Diabetes Management (DM)

- Lots of diabetic patient data
- Historical diabetes data can be used for automated screening
- Early detection of complications
- Early preparation of emergency cases
- Detect adverse effects of drugs
- Glucose monitoring
- Patient education and follow-up

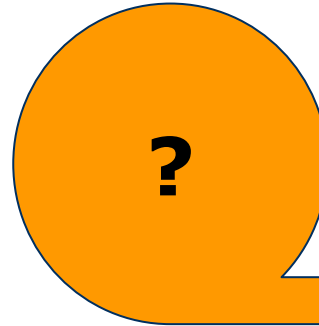
Target: Optimal diabetes care and better control of diabetes progression

## Diabetes Management: Call for Action

Diabetes cases continue  
to rise [1]



Preparedness



**Research:** Utilize big data analytics with explainable machine learning to enhance diabetes management by leveraging available patient data. **Case study:** Rwanda

## Background

- Rwandan healthcare providers have used electronic health record systems (OpenClinic, OpenMRS, HMIS, DHIS2) since 2012.
- Rwanda has a track record in transforming the healthcare system through ICT.
- Big data analytics has methods for storing, processing, and analyzing large amounts of diabetes data [2].
- Complex machine learning models have good performance at the cost of interpretability.
- Explainable Artificial Intelligence (XAI) offers methods for explaining complex models.
- A well-structured methodology is required for accessing, handling, and sharing insights from medical data.

AI holds great promise for transforming medicine, and medical data can drive innovations in AI.

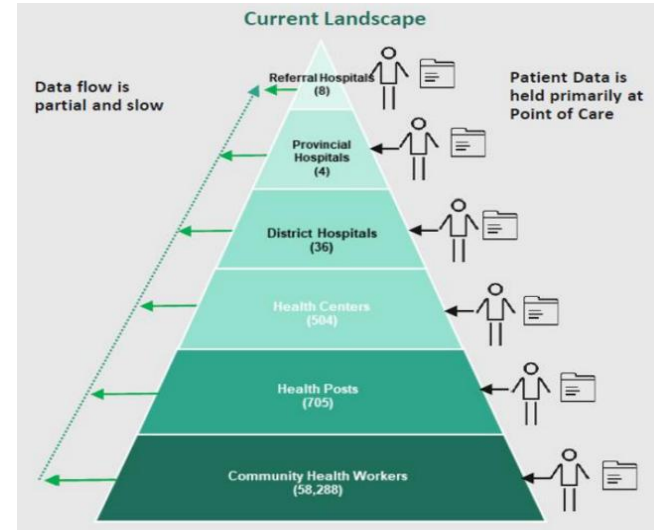


Figure 1. Structure of Public Healthcare in Rwanda.

## Methodology

- **Objective:** Investigate the foundational requirements for implementation of big data analytics (BDA) with XAI for DM in Rwanda
- **Methods:** A focus group discussion was convened with 25 key stakeholders, physical (18) and virtual (7), in a five-day workshop to discuss BDA implementation in Rwandan healthcare for improving DM strategies.
- Focus Group (FG) discussions are widely used qualitative data collection methods in health research [3][4]
- Purposive sampling was employed to recruit participants
- Discussions were moderated by two PhD students conducting research on Diabetes and Hypertension Management

TABLE I. CHARACTERISTICS OF PARTICIPANTS

Subgroup	Participants	Gender	Age group	Coding
SMR	4	F:1, M:3	50-60: 3, >60: 1	SMR1-4
MPR	5	F: 1, M: 4	20-29: 1, 30-39: 2, 40-49: 2	MPR1-5
NUT	3	F: 1, M: 2	20-29: 1, 30-39: 2	NUT1-3
MTP	3	F: 1, M: 3	30-39: 1, 40-49: 2	MTP1-3
DMA	3	F: 0, M: 3	20-29: 1, 30-39: 2	DMA1-3
HPM	3	F: 0, M: 3	40-49: 2, 50-59: 1	HPM1-3
IPM	2	F: 0, M: 2	40-49: 2	IPM1-2
DHR	2	F: 1, M: 1	40-49: 2	DIA, HYP

Thematic analysis approach was employed to analyze the data collected from participants.

## Group discussion moderation

- **Day 1-2:** subgroups presented their routine work in relation to the management of diabetes and hypertension.
- **Day 3-4:** Identified main themes including diabetes screening; diabetes-related complications; medical data management and governance; existing resources to support BDA in diabetes management; the role of DBA in diabetes and hypertension care; the contribution of nutrition to managing these conditions; and the potential of explainable machine learning to enhance clinical adoption of big data analytics techniques.
- **Day 5:** Summing up,

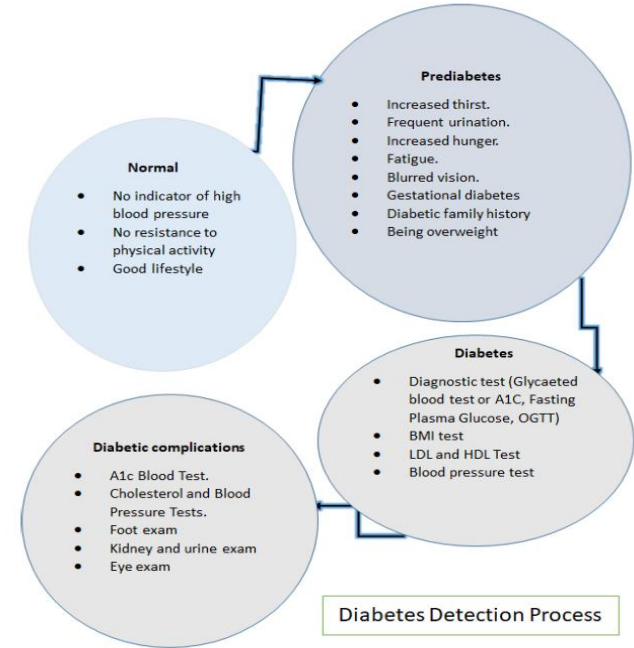


Figure 2. Process of Diabetes Diagnosis

## Results

- **Characterizing diabetes management:** Starts once the disease screening and diagnosis, progressing towards various complications influenced by multiple risk factors, including lifestyle, aging, and environmental determinants.
- With current procedures, it is difficult to identify patients at increased risk of complications. There is limited coordination and data sharing among care providers. *"It is not clear how patients reach proliferative retinopathy, leading to blindness, while this patient regularly visits the internal medicine department," said (MPR3).*
- All participants acknowledged the potential benefits of integrating BDA into current diabetes management practices.

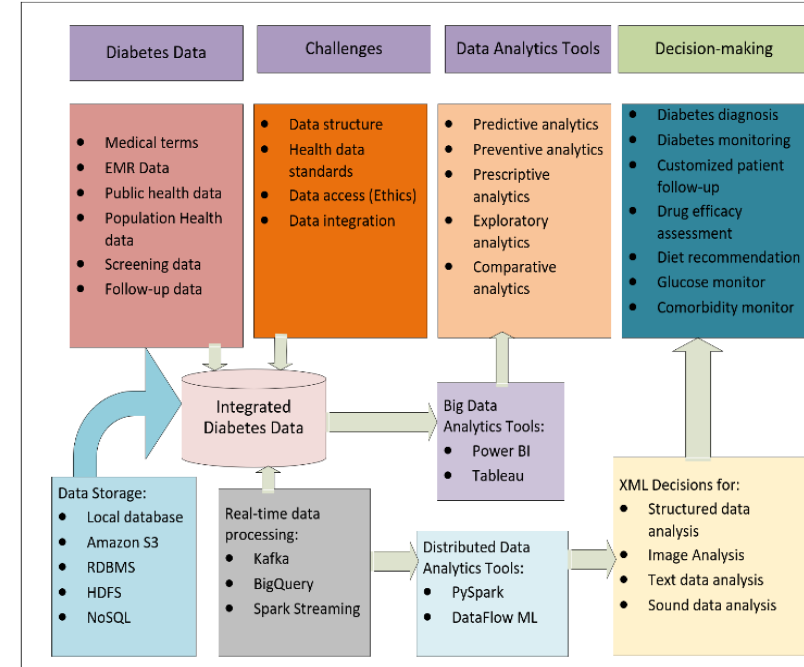
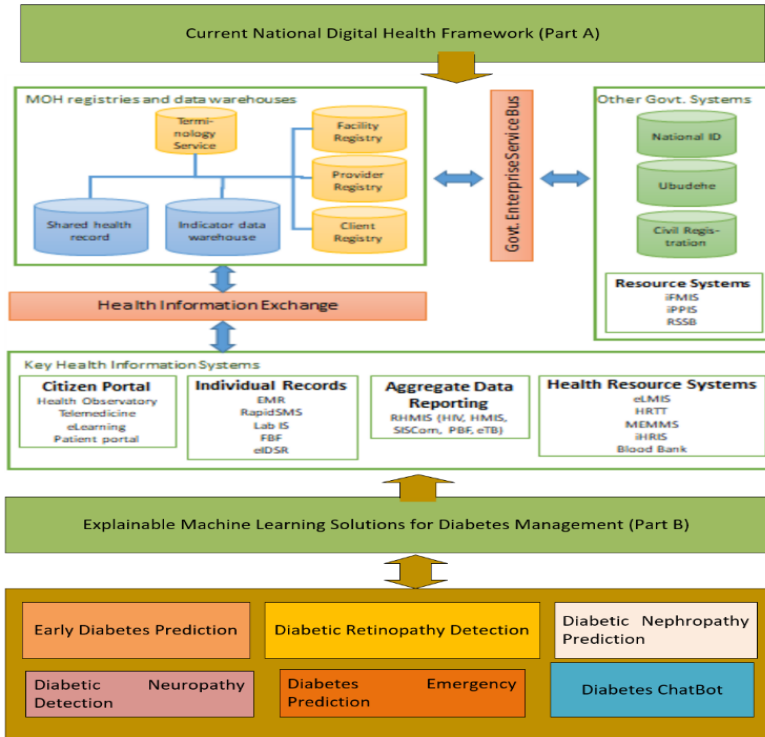


Figure 3. Architecture of BDA for Diabetes management.

# BDA Framework and Major Themes



## Five major themes:

- Big data analytics promises,
- Big data analytics challenges,
- Data governance,
- Big data analytics quality standards, and
- Clinical data intelligence.

These themes lead to the development of the BDA framework for DM in Rwanda

Figure 4. BDA framework for DM in Rwanda

## BDA tools for improving DM

- Data storage (HDFS): can aggregate data from different sources.
- Data processing (Apache Spark and Kafka): Can process data from databases and real-time streaming data and improve patient-clinician interaction.
- Advanced data analytics (PySpark, BigQuery, DialogFlow, Power BI): Can help monitor diabetes progression and make optimal interventions.
- Enhanced clinical decisions: XAI to support transparent decisions



Figure 5. Promises of BDA in DM

## BDA promises for DM in Rwanda

- Integrated diabetes data is the starting point.
- BDA can provide timely, actionable guidance to policymakers, healthcare administrators, clinicians, and the public, particularly for short-term decision-making and long-term planning to control diabetes.
- BDA can help to understand diabetes progression dynamics, improve follow-up, and medication adherence.
- BDA with XAI helps patients enhance self-management, maintain targets, and make effective dietary changes.

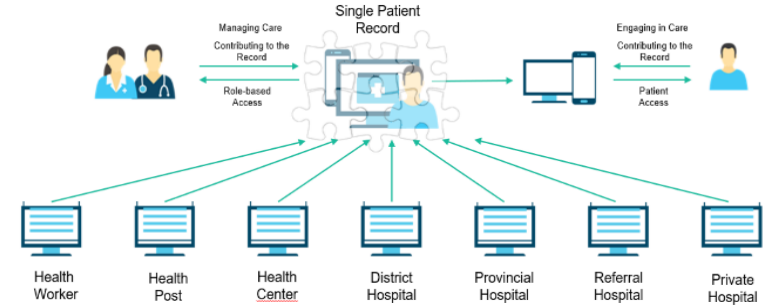


Figure 6. Data aggregation

**Patient:** “Diabetes is a silent killer disease; it gradually damages our organs and weakens the body over time. With recent technologies like ChatGPT, we can better understand it and how to live better with it, but sometimes the content generated by ChatGPT can be misleading. I believe the ideas gathered here can be turned into a simple, effective tool to improve our health and strengthen interaction between patients and healthcare providers. As a patient, I’m ready to use locally developed big data tools to help address the challenges of diabetes,” said DMA2.



## Challenges to BDA implementation for DM in Rwanda

- Patient data sharing between District hospitals and referral hospitals.
- Harmonization of medical records to facilitate the implementation of big data analytics.
- Challenges of accessing and using patient data in Rwanda.
- Skills gap in BDA to support clinical decisions.
- Lack of partnership between big data analysts and medical practitioners.

*“I believe that relying solely on clinical outputs from big data analytics is not a good idea, particularly when human expertise is not considered during the construction of these systems,”* said MPR3.

Diabetes specialists expressed their full participation in the design of a big data Analytics that will help them make data-driven decisions.

## BDA implementation phases coordinated by RBC

- Key stakeholders for BDA implementation: Ministry of Health (MoH), Ministry of ICT and Innovation (MinICT), Rwanda Information Society Authority (RISA), Rwanda Biomedical Center (RBC), and the Rwanda National Ethics Committee.
- Phase 1: Data harmonization has already begun through the unification of patient data.
- Phase 2: Data storage and sharing to make large-scale diabetes datasets for big data analytics research on the Rwanda Health Cloud.
- Phase 3: Piloting selected use cases in a referral hospital to evaluate feasibility and performance in a real clinical setting.
- Phase 4: Nationwide deployment, including training healthcare providers and guiding patients on the use of AI-based tools for diabetes management.
- Phase 5: Continuous monitoring and evaluation of BDA systems.

Stakeholders have to collaborate to make large-scale diabetes datasets available for big data analytics research on the Rwanda Health Cloud, and to build and evaluate XAI models to address diabetes-specific challenges.

# Conclusion: Diabetes management requires coordinated efforts

## RWANDA HEALTH FACILITIES MAP

Provinces, Districts, Referral Hospitals, and District Hospitals

### LEGEND

#### PROVINCES

- Northern Province
- Eastern Province
- Southern Province
- Western Province
- Kigali City
- Province Boundary
- - - District Boundary

#### HEALTH FACILITIES

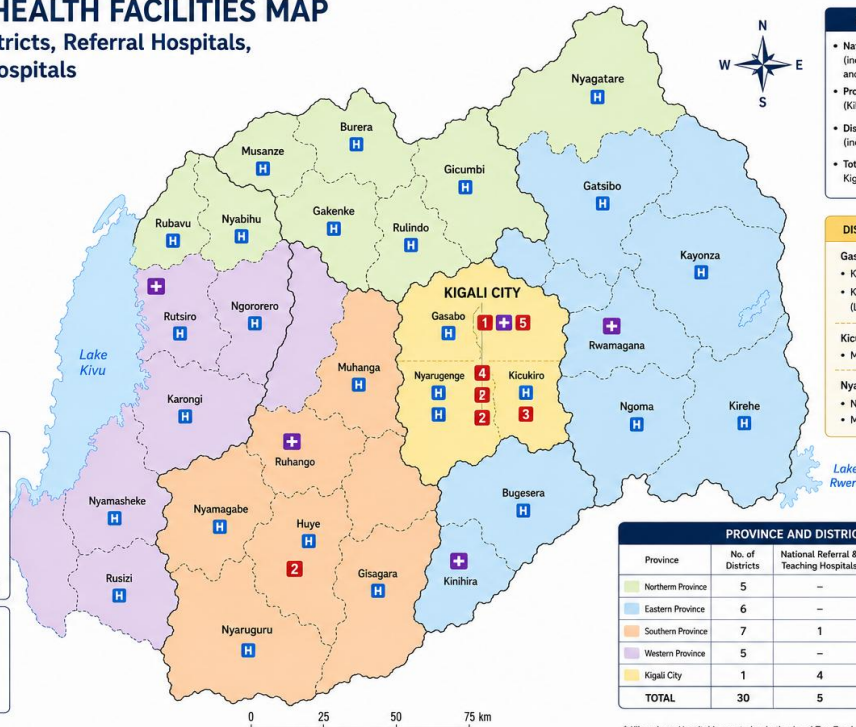
- + National Referral & Teaching Hospital
- + Provincial / Level Two Teaching Hospital
- H District Hospital

#### NATIONAL REFERRAL & TEACHING HOSPITALS (5)

- 1 CHUK – University Teaching Hospital of Kigali
- 2 CHUB – University Teaching Hospital of Butare
- 3 King Faisal Hospital
- 4 Rwanda Military Hospital
- 5 Kibagabaga Hospital (Level Two Teaching Hospital)

#### PROVINCIAL / LEVEL TWO TEACHING HOSPITALS (4)

- 1 Kibogora Hospital
- 2 Ruhango Hospital
- 3 Rwamagana Hospital
- 4 Kinihira Hospital



#### HEALTH SYSTEM OVERVIEW

- National Referral & Teaching Hospitals: 5 (including CHUK, CHUB, King Faisal Hospital, and Rwanda Military Hospital)
- Provincial / Level Two Teaching Hospitals: 4 (Kibogora, Ruhango, Rwamagana, Kinihira)
- District Hospitals: 42 (including 5 in Kigali City)
- Total Districts: 30 (5 Provinces including Kigali City)

#### DISTRICT HOSPITALS IN KIGALI CITY (5)

- Gasabo District**
- Kacyiru District Hospital
  - Kibagabaga Hospital (Level Two Teaching Hospital)
- Kicukiro District**
- Masaka District Hospital
- Nyarugenge District**
- Nyarugenge District Hospital
  - Muhima District Hospital

#### PROVINCE AND DISTRICTS SUMMARY

Province	No. of Districts	National Referral & Teaching Hospitals	Provincial / Level Two Teaching Hospitals	District Hospitals
Northern Province	5	–	–	7
Eastern Province	6	–	1	10
Southern Province	7	1	1	11
Western Province	5	–	1	9
Kigali City	1	4	1	5
<b>TOTAL</b>	<b>30</b>	<b>5</b>	<b>4</b>	<b>42</b>

\* Kibagabaga Hospital is counted as both a Level Two Teaching Hospital and a District Hospital.



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