UNIVERSITÀ DEGLI STUDI DI SALERNO

KETOCARE

Your partner in diabetes prevention

Serverless Computing course

Benedetto Simone

INTRODUCTION

Diabetes is a medical condition that occurs when the pancreas does not produce enough insulin or when the body fails to use it properly.

This causes an increase in blood sugar levels, which can lead to long-term health problems such as neuropathy, retinopathy and nephropathy.

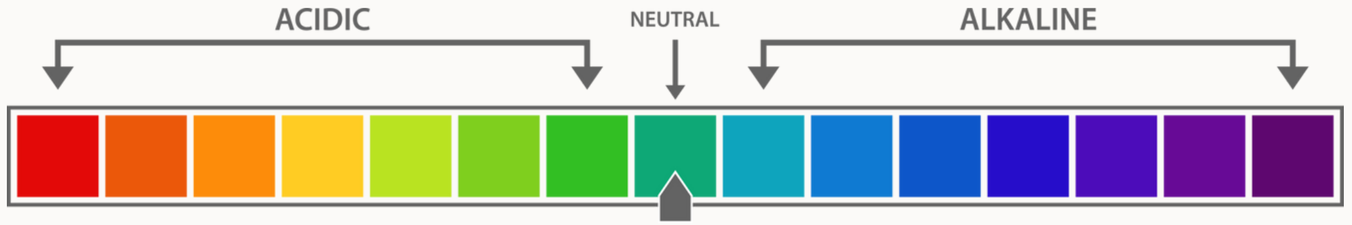
Introduction

KETOACIDOSIS

A complication of diabetes is ketoacidosis, which can occur when blood sugar levels are too high.

This causes an increase in acid levels in the blood, which can lead to serious health consequences such as dehydration, loss of consciousness and even coma.

Treatment of diabetic ketoacidosis involves intravenous fluid reintegration and insulin.



Introduction

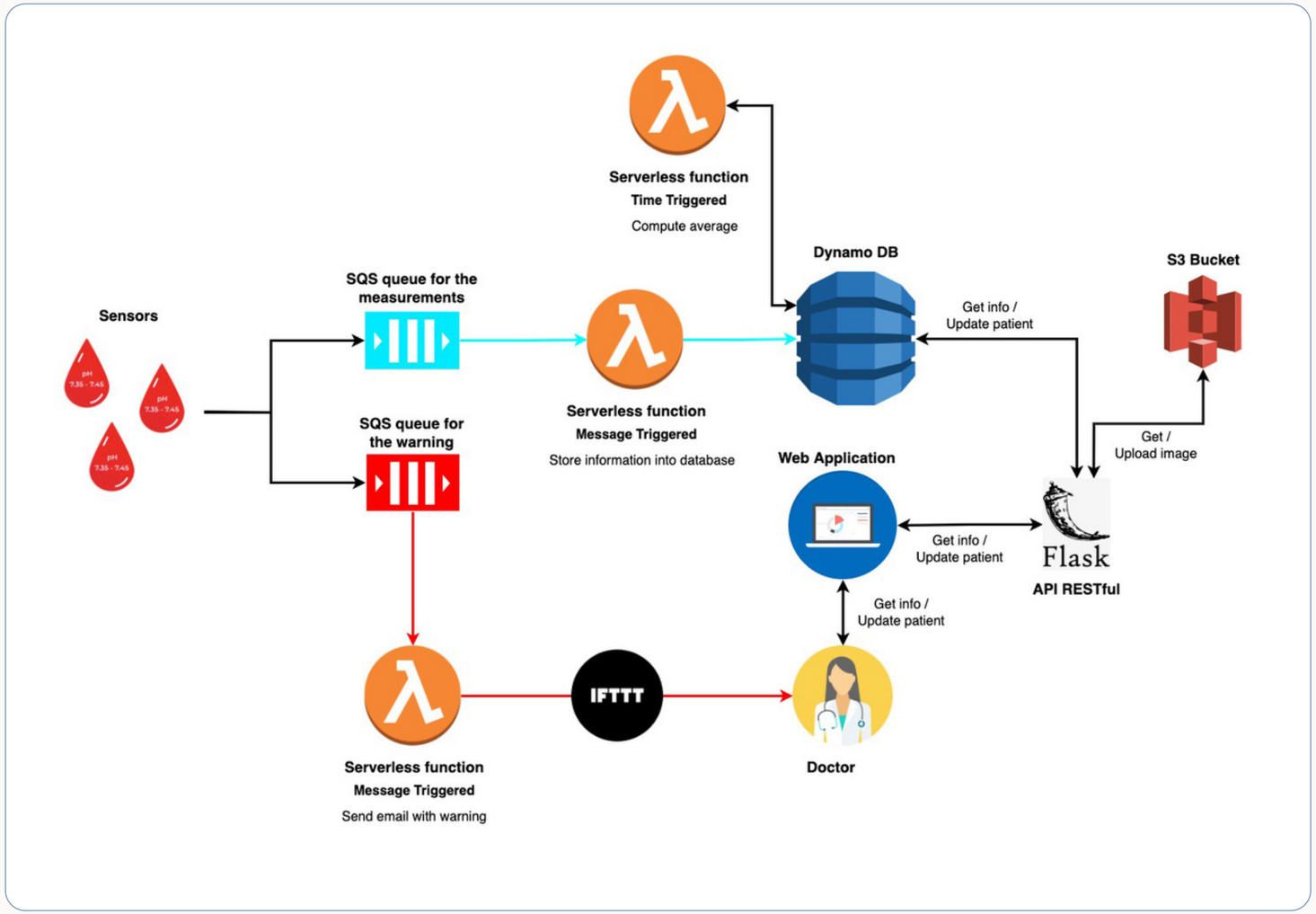
KETOCARE

The aim of this project is to provide a solution for monitoring diabetes and preventing ketoacidosis.

Warning for the rapid administration of large amounts of intravenous fluids in combination with electrolytes, such as sodium, potassium, chlorine and sometimes phosphates.

Compare the daily average with the previous days' averages to check the effectiveness of medical treatment.

ARCHITECTURE



SENSORS

The sensors' functionality is inspired by the method described in the paper *"Bioresorbable Nanostructured Chemical Sensor for Monitoring of pH Level In Vivo"*.

The sensor takes pH measurements from 4.0 to 7.45.

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RESEARCH ARTICLE

Bioresorbable Nanostructured Chemical Sensor for Monitoring of pH Level In Vivo

*Martina Corsi, Alessandro Paghi, Stefano Mariani, Giulia Golinelli, Aline Debrassi, Gabriella Egri, Giuseppina Leo, Eleonora Vandini, Antonietta Vilella, Lars Dähne, Daniela Giuliani, and Giuseppe Barillaro**

Here, the authors report on the manufacturing and in vivo assessment of a bioresorbable nanostructured pH sensor. The sensor consists of a micrometer-thick porous silica membrane conformably coated layer-by-layer with a nanometer-thick multilayer stack of two polyelectrolytes labeled with a pH-insensitive fluorophore. The sensor fluorescence changes linearly with the pH value in the range 4 to 7.5 upon swelling/shrinking of the polymer multilayer and enables performing real-time measurements of the pH level with high stability, reproducibility, and accuracy, over 100 h of continuous operation. In vivo studies carried out implanting the sensor in the subcutis on the back of mice confirm real-time monitoring of the local pH level through skin. Full degradation of the pH sensor occurs in one week from implant in the animal model, and its biocompatibility after 2 months is confirmed by histological and fluorescence analyses. The proposed approach can be extended to the detection of other (bio)markers in vivo by engineering the functionality of one (at least) of the polyelectrolytes with suitable receptors, thus paving the way to implantable bioresorbable chemical sensors.

1. Introduction

In vivo chemical sensing has the potential to revolutionize healthcare providing access to the continuous monitoring of drugs and analytes trafficking in peripheral blood and tissues, and in turn to individualized reports on both disease progression and drug efficacy in real-time.[1] This would positively impact the way we diagnose diseases and monitor drug efficacy enabling personal, timely, and effective medical feedback, that is, a real-time personalized medicine. The present-day paradigm used in clinical practice based on single-moment-in-time tests, that is, marker detection through ex-situ analysis of extracted biofluids, has proven to be not always adequate or timely to respond to clinical needs.[2]

Bioresorbable materials[2,3] provide a unique opportunity to engineer new electrical, optical, and sensing components into an in vivo biodegradable sensing system that eliminates any boundary between target molecules and sensing devices, granting direct access to biofluids and acting as an in situ sentinel once implanted in the body, without the need of secondary device-retrieval surgery that may cause tissue lesion or infection[4,5]—often required for long-lived implants, for example, pacemakers and cochlear implants. Chemical (bio)sensors made of bioresorbable materials have a huge potential in personalized medicine, especially for those treatments that benefit of a continuous and localized monitoring of specific analytes for a limited time, for example, chemotherapeutic cancer treatment, post-surgery sepsis, acute trauma treatment, pharmacokinetics profiling, and disease biomarker detection.

Recently, in vivo transient electronic[6–8] and photonic[9–11] devices, as well as bioresorbable physical sensors[12–15] exploiting changes of the material properties (e.g., resistance, current) upon pressure or temperature variations have been reported to monitor intracranial temperature, pressure in orthopedic application, neural activity, tissue temperature, and cardiovascular signals. These devices are typically encapsulated with a suitable coating designed to guarantee—ideally—measurements in vivo for a prescribed time, then degrade hydrolytically over time following normal metabolism with negligible effects on local tissues. However, control over transiency is still at an early stage and relies on in

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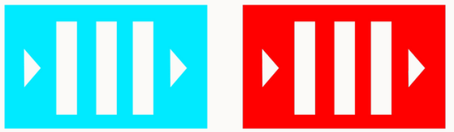
SENSORS

Each sensor sends a message containing the following information:

- sensor **ID**;
- **time** in format yyyy-mm-dd hh:mm:ss;
- **fiscal code** of the patient;
- blood **pH value**.

SQS QUEUES



Seven measurements are taken per day and the messages are sent on two queues according to the pH value.

- "MEASUREMENTS": all measurements taken;
- "WARNING": measurements of pH values less than 7.35.

STORE MEASUREMENTS

Each message sent on the "Measurements" queue triggers a Serverless function that is responsible to insert the measurement into a NoSQL database.

STORE MEASUREMENTS

The "Measurements" table contain items with the following information:

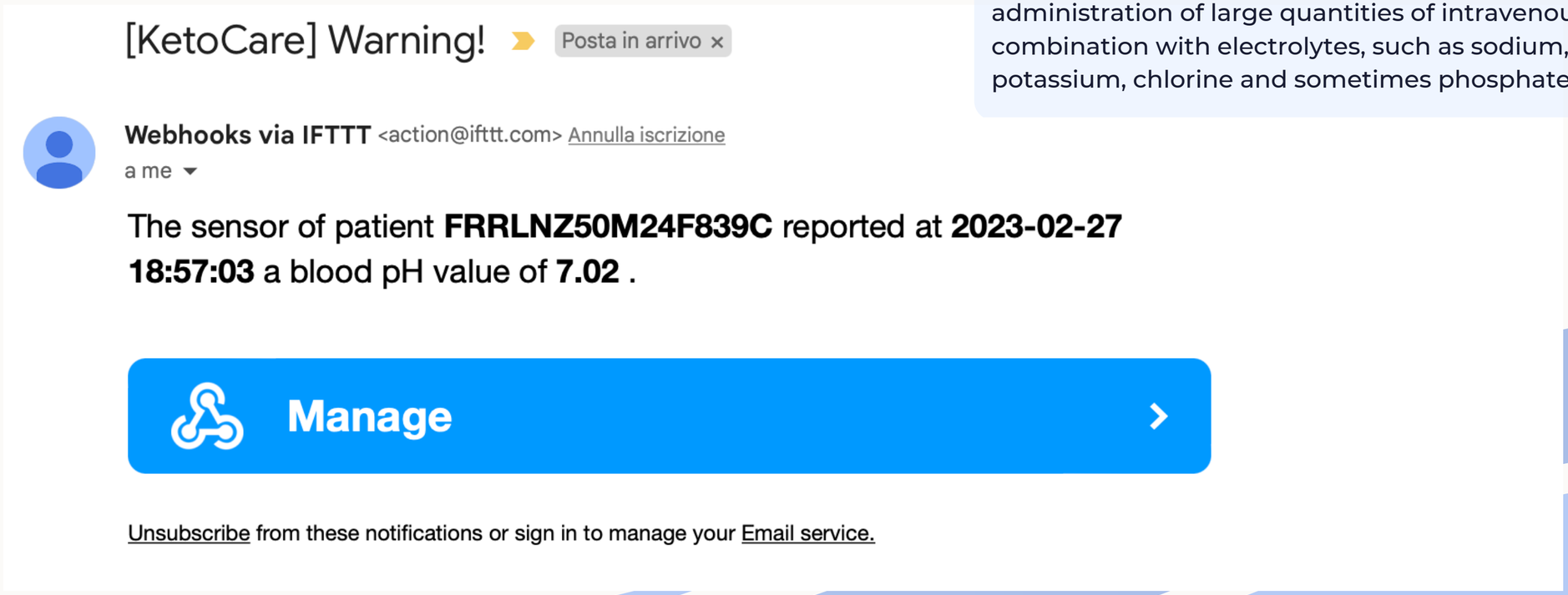
- **fiscal code** of the patient;
- **time** in format yyyy-mm-dd hh:mm:ss;
- sensor **ID**;
- blood **pH value**.

fiscal_code	timestamp	device_id	measured_value
"FRRLNZ50M24F839C"	"2023-02-25 12:26:38"	"01"	"7.4"
"FRRLNZ50M24F839C"	"2023-02-25 12:26:39"	"01"	"7.44"
"FRRLNZ50M24F839C"	"2023-02-25 12:26:40"	"01"	"7.41"
"FRRLNZ50M24F839C"	"2023-02-25 12:26:41"	"01"	"7.38"
"FRRLNZ50M24F839C"	"2023-02-25 12:26:42"	"01"	"7.4"
"FRRLNZ50M24F839C"	"2023-02-25 12:26:43"	"01"	"7.39"
"FRRLNZ50M24F839C"	"2023-02-25 12:26:44"	"01"	"7.35"

EMAIL WARNING

Each message sent on the "Warning" queue triggers a Serverless function that sends an email to the doctor notifying him of the warning.

This functionality is important for the rapid administration of large quantities of intravenous fluids in combination with electrolytes, such as sodium, potassium, chlorine and sometimes phosphates.



COMPUTE AVERAGE

At the end of the day, a time triggered Serverless function computes the average of the 7 daily measurements for each patient and saves the result in the "Averages" table.

COMPUTE AVERAGE

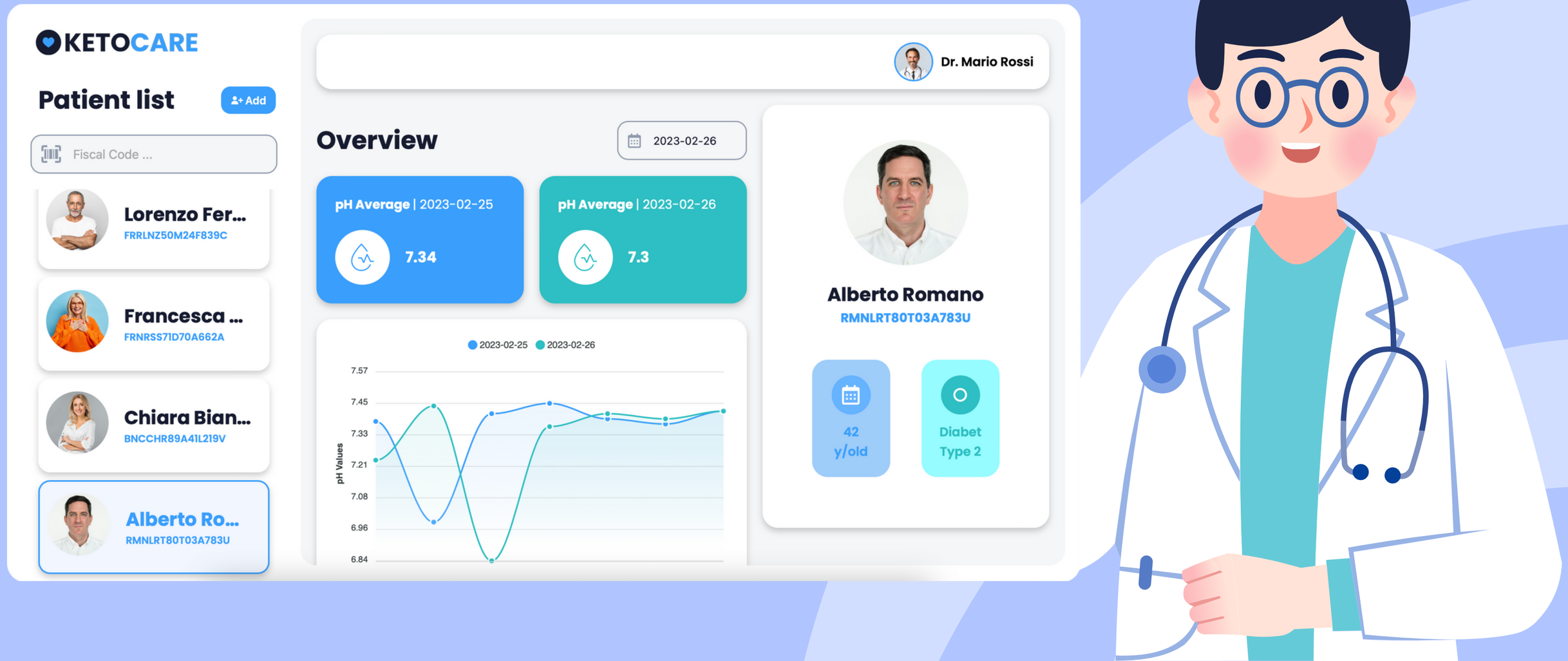
The "Averages" table contain items with the following information:

- **fiscal code** of the patient;
- **time** in format yyyy-mm-dd hh:mm:ss;
- blood **pH average**;
- sensor **ID**;
- blood **pH values**.

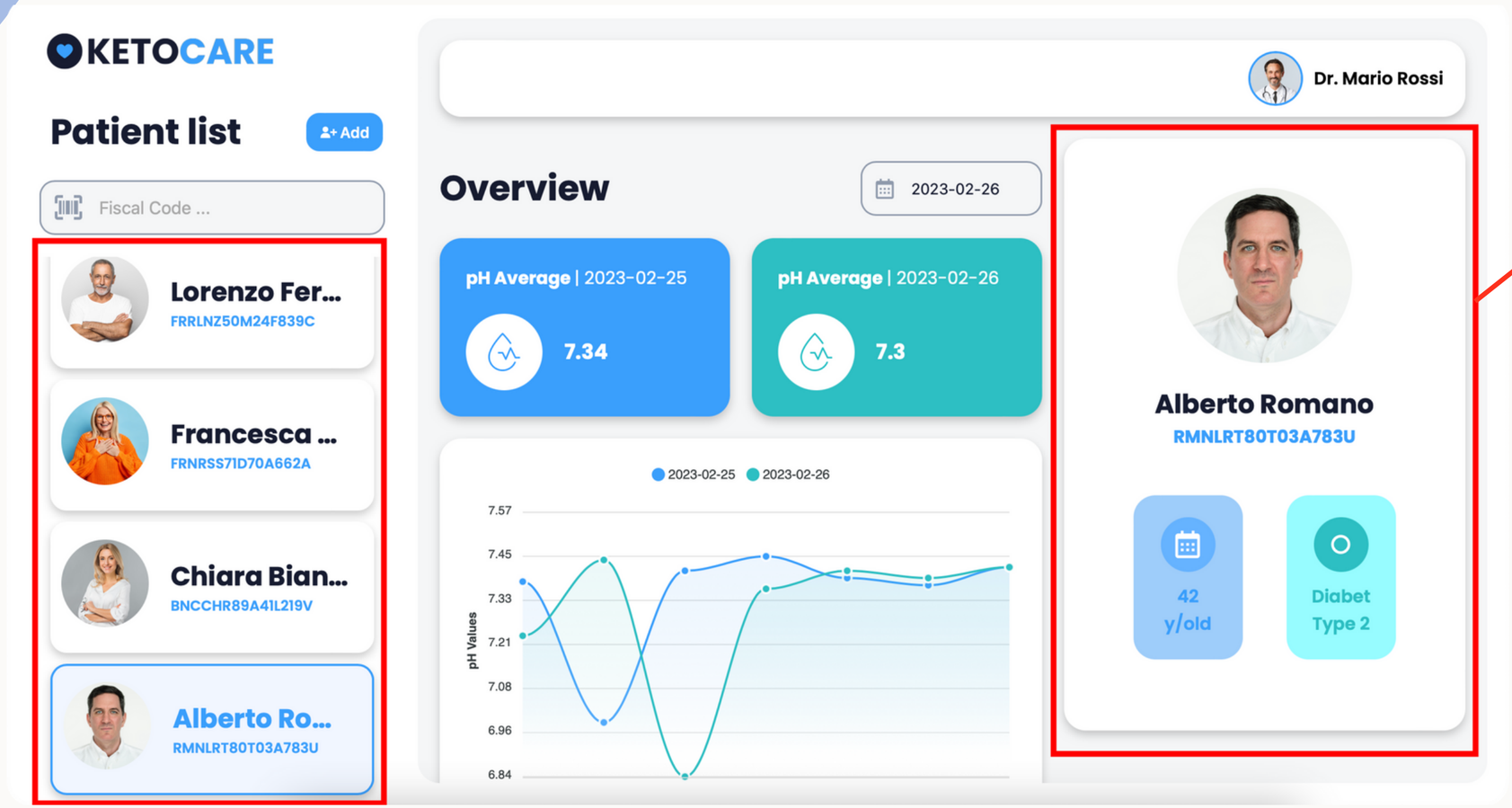
This feature is important for comparing the daily average with the averages of previous days to check the effectiveness of medical treatment.

fiscal_code	timestamp	average_value	device_id	values
"FRRLNZ50M24F839C"	"2023-02-25"	"7.4"	"01"	"[7.4, 7.44, 7.41, 7.38, 7.4, 7.39, 7.35]"
"FRRLNZ50M24F839C"	"2023-02-26"	"7.41"	"01"	"[7.45, 7.41, 7.42, 7.39, 7.41, 7.37, 7.41]"
"FRNRSS71D70A662A"	"2023-02-25"	"7.37"	"03"	"[7.41, 7.42, 7.18, 7.38, 7.42, 7.43, 7.36]"
"FRNRSS71D70A662A"	"2023-02-26"	"7.2"	"03"	"[5.96, 7.44, 7.38, 7.41, 7.37, 7.4, 7.42]"
"BNCCHR89A41L219V"	"2023-02-25"	"7.42"	"02"	"[7.42, 7.45, 7.44, 7.4, 7.42, 7.42, 7.36]"
"BNCCHR89A41L219V"	"2023-02-26"	"7.41"	"02"	"[7.4, 7.41, 7.43, 7.41, 7.37, 7.42, 7.43]"
"RMNLRT80T03A783U"	"2023-02-25"	"7.4"	"04"	"[7.37, 7.44, 7.4, 7.41, 7.36, 7.36, 7.44]"

WEB APPLICATION

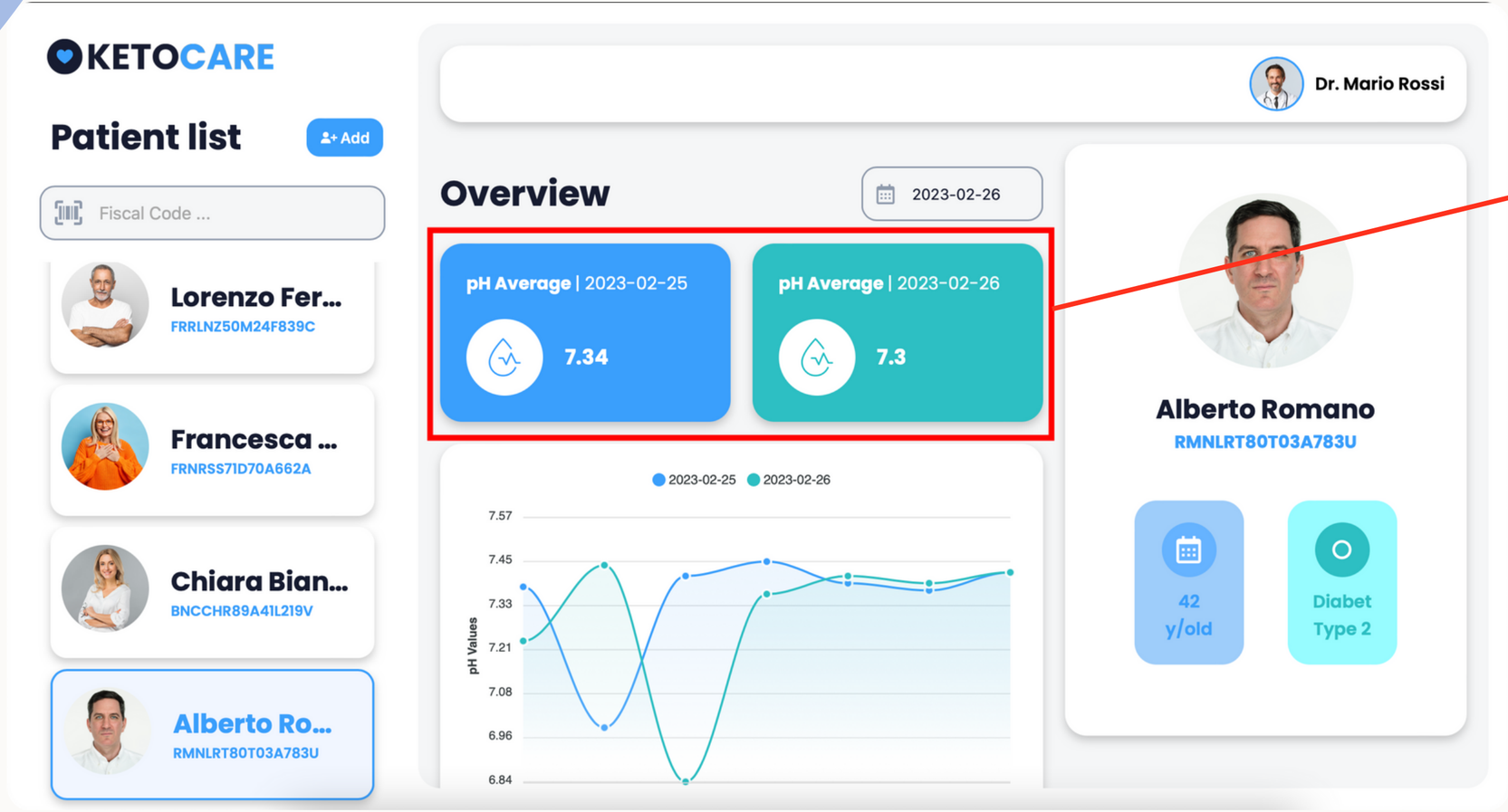


WEB APPLICATION



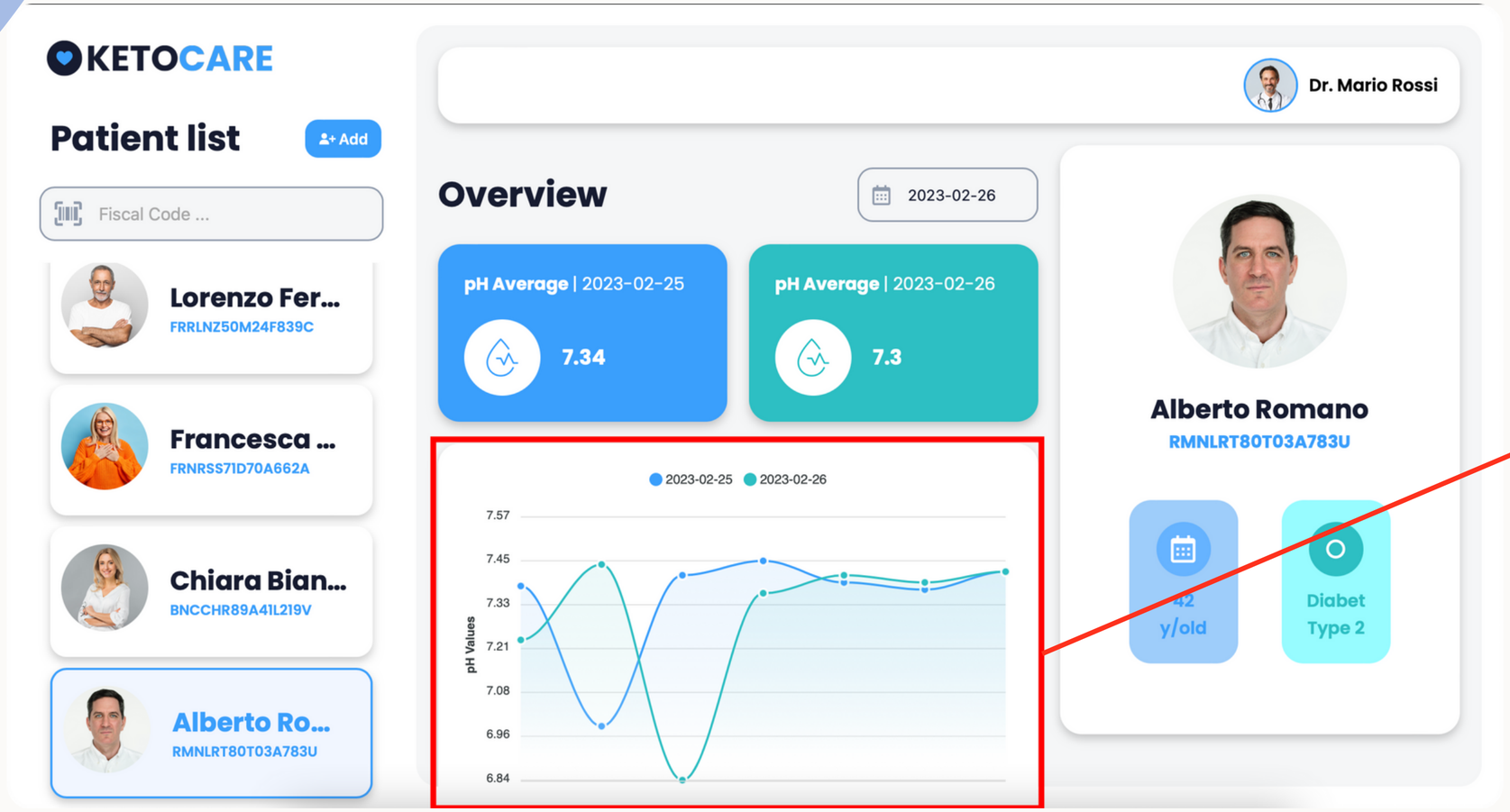
Display of patient list and information such as age and type of diabetes

WEB APPLICATION



Average display for the current and previous day

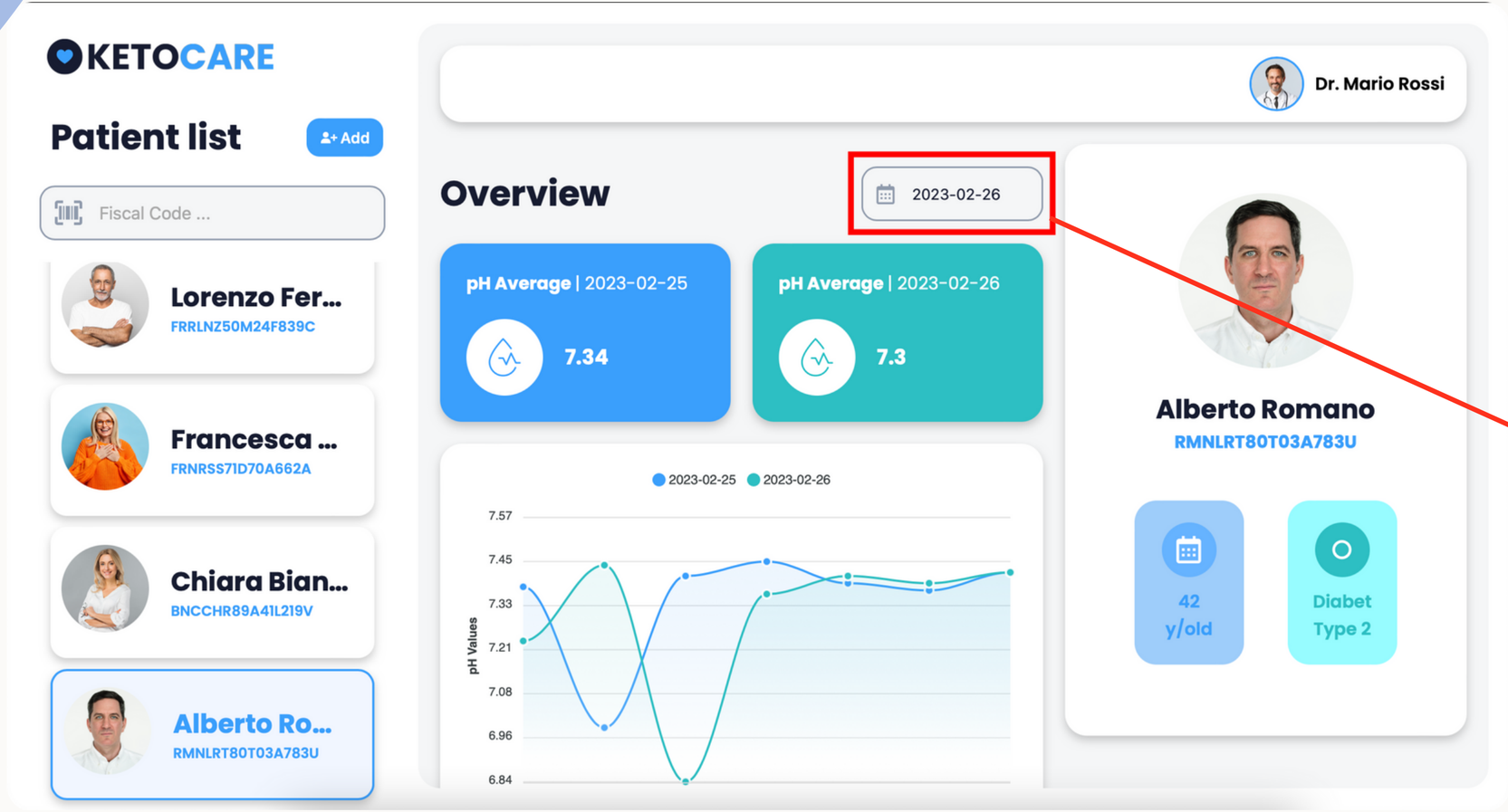
WEB APPLICATION



Average display for the current and previous day

Display of measurements taken on the current and previous day

WEB APPLICATION

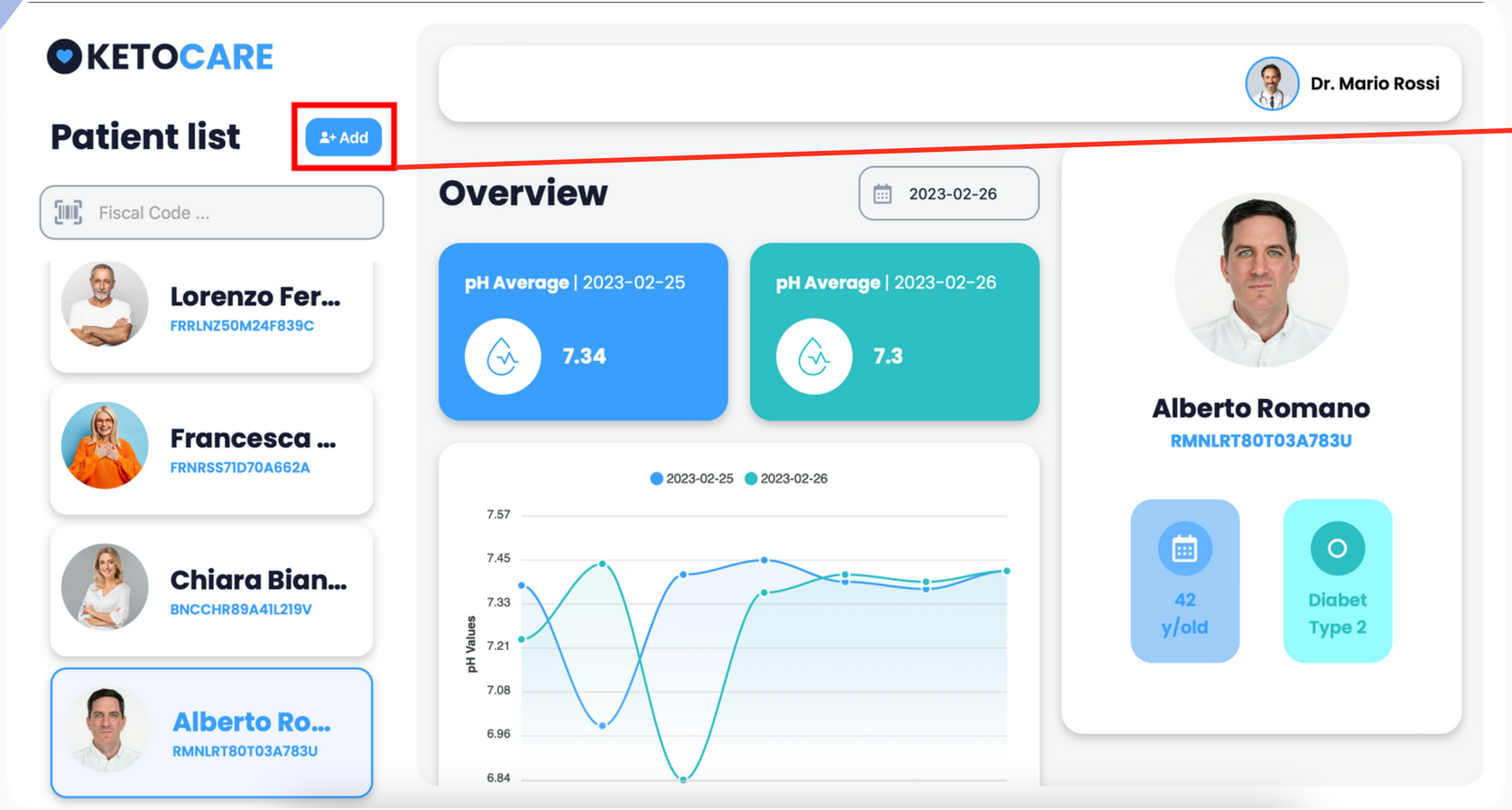


Average display for the current and previous day

Display of measurements taken on the current and previous day

Display of average and measurement history

WEB APPLICATION



Insertion of a new patient

APIs

The functionality of the application are realized with a set of RESTful APIs defined using the Flask framework.

The APIs offer the possibility of:

1. **Obtain all patients** in the "Patients" table;
2. Obtain the **average** of a given patient on a given date;
3. Obtain the **measurements** of a specific patient on a specific date;
4. **Save** a new patient.

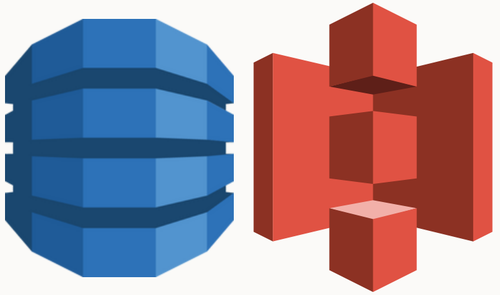
APIs - 2

Each item in the "Patients" table contains the following information:

- fiscal code;
- first name;
- surname;
- date of birth in "DD/MM/YYYY" format;
- type of diabetes (1 or 2);
- profile image name;

fiscal_code	name	image_file	birthdate	diabet_type	surname
"FRRLNZ50M24F839C"	"Lorenzo"	"FRRLNZ50M24F839C.jpg"	"24/08/1950"	"1"	"Ferrari"
"FRNRSS71D70A662A"	"Francesca"	"FRNRSS71D70A662A.jpg"	"30/04/1971"	"1"	"Russo"
"BNCCHR89A41L219V"	"Chiara"	"BNCCHR89A41L219V.jpg"	"01/01/1989"	"2"	"Bianchi"
"RMNLRT80T03A783U"	"Alberto"	"RMNLRT80T03A783U.jpg"	"03/12/1980"	"2"	"Romano"
"BRBSMN63P26F205X"	"Simone"	"BRBSMN63P26F205X.jpg"	"26/09/1963"	"1"	"Barbieri"

APIs - 2



Each item in the "Patients" table contains the following information:

- fiscal code;
- first name;
- surname;
- date of birth in "DD/MM/YYYY" format;
- type of diabetes (1 or 2);
- profile image name;

The image name is used to retrieve the patient image contained in the S3 "patientsimages" bucket.

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THANK YOU FOR YOUR ATTENTION

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