**7CCSMPRJ**

**Individual Project Submission 2024 - 2025**

| | |
|---|---|
| **Name:** | Siddharth Kishor Samarth |
| **Student Number:** | K24012370 |
| **Degree Programme:** | MSc. Advanced Computing |
| **Project Title:** | GluCORRECT - Harnessing Artificial Intelligence to scrutinize Hypoglycemia in hospitalised patients with diabetes to classify, anticipate and analyse hypoglycemic episodes [Knowledge Exchange Project with NHS England] |
| **Supervisor:** | Dr. Rita Borgo |
| **Word Count:** | ==== Word count goes here ==== |

---

### RELEASE OF PROJECT

Following the submission of your project, the Department would like to make it publicly available via the library electronic resources. You will retain copyright of the project.

---

☑ I **agree** to the release of my project

☐ I **do not** agree to the release of my project

**Signature:**                    **Date:** August 5, 2025

# KING'S College LONDON

Department of Informatics
King's College London
United Kingdom

7CCSMPRJ Individual Project

# GluCORRECT - Harnessing Artificial Intelligence to scrutinize Hypoglycemia in hospitalised patients with diabetes to classify, anticipate and analyse hypoglycemic episodes [Knowledge Exchange Project with NHS England]

Name: **Siddharth Kishor Samarth**
Student Number: K24012370
Course: MSc. Advanced Computing

**Supervisor: Dr. Rita Borgo**

This dissertation is submitted for the degree of MSc Advanced Computing.

# Acknowledgements

I would like to express my sincerest gratitude towards my project supervisor, Dr. Rita Borgo, for her invaluable advice and consistent direction throughout the course of this project. Her mentorship and ideas have been instrumental in shaping the development of this work, leading to its successful completion.

I am also deeply thankful & appreciative of my industry advisor, Dr. Piya Sen Gupta, for providing the dataset that has served as the foundation of this work. Her contributions have significantly enhanced the practical relevance and quality of this project.

Ultimately I would like to thank my friends and my parents, especially my dad, without whose sacrifices I would not be where I am today.

# Abstract

**Project Variant:** Variant 4 - Develop a weighted score and design score to predict risk of a hypoglycaemic episode before it occurs.

It is well known that hypoglycemia as well as hyperglycemia are common adverse events in patients who receive blood sugar control medication, and they are also one of the most frequently cited causes of hospital admissions in people with diabetes. National quality improvement programmes from the Healthcare Quality Improvement Partnership (HQIP) and the study of ambulance call-out data have shown that **lack of awareness** by both affected individuals and their attendants is associated with a dramatically increased rate of complications, amongst other factors. Guy's & St. Thomas' NHS Foundation Trust (hereafter referred to as GSTT) has found, after careful deliberation and departmental review, that hypoglycemic episodes have been occurring with unusual frequency. The Trust now seeks to take measures to resolve such problems with a greater focus on prevention combined with early corrective action. This research project has been undertaken in close collaboration with GSTT, one of the largest NHS trusts in the UK and an indispensable element of London's healthcare system, with almost 24000 staff across 5 major hospitals, handling over 3 million patients a year and generating an annual turnover of over £3 billion.

This analytical study serves as a foundation and proof-of-concept to aid GSTT in pre-emptively reducing hypoglycemia within hospitalised inpatients, by utilising statistics & machine learning techniques. Through exploratory data analysis I draw out relevant conclusions about the dataset around patient age, ethnicity and

I go on to identify the significant factors responsible for hypoglycemia within the dataset provided by the industry advisor from GSTT through exploratory data analysis, while also . I explore how they can be utilized to devise a risk score, to classify patients based on their risk of hypoglycemia.

RESULTS: HbA1c values identified as risky - 56 or so eGFR ethnicity major is glucose value

In conclusion, exhibit my findings with potential ways of applying them in practise in hospitals.

All abbreviations and symbols used in the report must be listed and defined in alphabetic order.

## Nomenclature

| | |
|---|---|
| GSTT | Guy's and St Thomas' NHS Foundation Trust |
| HQIP | Healthcare Quality Improvement Partnership |
| "Hypo" or "Hypos" | Hypoglycemic episode(s) |
| "Inpatient" | Referring to the the fact that a patient is required to stay overnight |
| | in order to be treated (in case of surgeries or long term observation for example) |
| NCAPOP | National Clincal Audit & Patient Outcomes Programme |
| NDA | National Database Audit |
| NDISA | National Diabetes Inpatient Safety Audit |
| NHS | The publicly funded healthcare system of the United Kingdom, |
| | the National Health Service. |

| | |
|---|---|
| $a$ | The number of angels per unit area |
| $A$ | The area of the needle point |
| $c$ | Speed of light in a vacuum inertial frame |
| $h$ | Planck constant |
| LMI | Linear Matrix Inequalities |
| $N$ | The number of angels per needle point |

# Contents

# List of Figures

# List of Tables

# 1  Introduction

## 1.1  Clinical Overview

Hypoglycaemia (also known as a "hypoglycaemic episode" or a "hypo" for short) is the condition that occurs when the human body's blood glucose (sugar) level drops below the normal healthy range of 4.0 to 6.0 mmol/L. While it can affect anyone, it is most common in diabetic individuals who are prescribed drugs like insulin or metformin to inhibit glucose. Hypoglycaemic events are relatively simple and straightforward to resolve, but they need to be treated immediately to avoid serious damage to the brain and heart as a result of loss of consciousness or arrhythmias. High-sugar consumables are generally effective in correcting mild cases and are commonly recommended for immediate treatment, but severe cases of hypoglycaemia such as when the person is unconscious or having a seizure can only be resolved with an urgent, immediate glucagon injection to prevent them from deteriorating into a coma (or in rare cases, even leading to death).

To underscore how and why this matters, diabetes is one of the most significant and expensive long-term health conditions faced by the NHS, with recent figures from Diabetes UK suggesting that over 5.8 million people in the UK are living with diabetes, regardless of a formal diagnosis. It is estimated to cost the NHS over £10.7 billion a year, approximately 10% of its entire annual budget, which could go up to £18 billion by 2035 [1]. A stark finding is that almost 60% of this cost (around £6.2 billion) is spent on treating the largely preventable complications of diabetes, such as heart attacks, strokes, blindness, and so on, including hypoglycaemia [2]. Hypoglycaemic instances make up a major component of these preventable costs, mainly accounting for the emergency, ambulance, and acute care expenses associated with diabetes. The Local Impact of Hypoglycaemia Tool (LIHT) suggests that hypoglycaemia can cost up to £2,195 per episode, possibly increasing substantially with a longer stay in hospital [3], and it is estimated that there are up to 100,000 ambulance callouts annually according to the Diabetes Research and Wellness Foundation (DRWF) [4]. DRWF's study hinted that 1 in 10 individuals that experience a severe hypo (meaning requiring medical intervention or resuscitation) have considerable chances of another one within a fortnight.

## 1.2  Background

After introspective analysis supported by information from the National Diabetes Inpatient Safety Audit (NDISA) it has been recognized that severe hypoglycaemia and recurrent severe hypoglycaemia have been occurring relatively frequently across GSTT medical facilities. The NDISA forms part of the National Diabetes Audit (NDA), and it maintains that "The prevalence of diabetes continues to increase. In England

between 2017-18 and 2021-22 prevalence of type 1 diabetes went up from 248,240 to 270,935 and the prevalence of type 2 and other diabetes from 2,952,695 to 3,336,980", as of 2022 [5].

GSTT administers upwards of 500,000 point-of-care glucose tests (POCT) annually, in addition to kidney function and glycated haemoglobin (HbA1c) tests as well. The Trust also possesses blood glucose / ketone data with additional linked data including demographics, dates of admission and discharge, patient as well as family history and current or previous medications. They have two major kinds of patient records, inpatient records for patients that have to stay over the course of one or multiple nights (for example, in case of surgeries or for long term care), and outpatient records where the patient doesn't require overnight stay. The Trust manages all of this data through their electronic health record management system called Epic, and facilitates patient access to their own records through the MyChart web application.

Hypoglycaemia is a frequent complication amongst inpatients having complex health conditions, especially within those in intensive care settings that have been / are critically ill due to advanced diseases or comorbidities, or in patients following major surgical interventions. The Trust is undertaking proactive measures to identify and mitigate the risk of hypoglycaemic episodes at an early stage, to support better planning, reduce healthcare costs, efficiently allocate hospital resources and also schedule operations optimally. The ideal way to assess risk would along the lines of developing tools to predict individualized risk scores for inpatients after considering all relevant factors. However, this presents a herculean task due to the sheer volume and complexity of factors involved, compounded by the challenges of producing reliable results even within small populations — such as those in remote areas — while also adhering to legal and governmental regulations:

1. Weighing up the risk of hypoglycaemia depends upon numerous aspects such as lifestyle, renal function, recent food intake, blood glucose history and current medication to name a few, making this a highly complicated modelling problem. In addition to this, patients differ widely in age, comorbidities, ethnic factors and even insulin sensitivity. This variability makes it a formidable challenge to develop a model that is generalizable, dependable and unbiased.

2. Any such analytical tool in the vicinity of patient healthcare requires medical evaluation and approval, validation trials, governance oversight as well as ethical considerations. Even a good model may fail if it does not fit the clinical workflow. Initial skepticism towards AI, the effort required to train staff, defining clear responsibilities and limits of liability, and rehearsing procedures or plans of action for every possible scenario will all produce appreciable organizational inertia.

Successfully implementing even a small-scale solution, within GSTT to begin with, would be a significant strategic breakthrough that serves as a foundational model which other

NHS trusts or institutions could adapt and build upon. This positions this research initiative which is a Knowledge Exchange Project (KEP) with Guy's & St.Thomas' NHS Foundation Trust, an indispensable constituent of London's healthcare system, as a valuable and worthwhile research endeavour.

## 1.3 Aims and Objectives

This research project has the following objectives:

- **To extract insights from provided dataset for the given time period and population.** GSTT has expressed a strong interest towards gaining a deeper understanding of their inpatient population. The dataset they have provided includes demographic details, length of hospital stay, and ward information in addition to the main clinically relevant variables such as glycated haemoglobin levels, renal function measurements, patient age and so on. This enables a comprehensive, multifaceted analysis. The knowledge gained from this study, such as identifying which hospital wards have more vulnerable or at-risk patients, will be used to enhance staff training, in turn improving both future admissions routines as well as post-discharge support for patients. Every observation, regardless of scale, holds potential to refine hospital processes and operating procedures.

- **To identify the main influencing / contributing factors for hypoglycaemia and develop a weighted risk score to predict episodes (Variant 4 KEP).** The Trust is establishing and implementing measures to "pre-assess" inpatients to evaluate their risk of a hypoglycaemic episode, which will allow medical professionals to design protocols and policies to prevent episodes from occurring as well as take early remediative action as soon as possible to resolve an episode should it occur. I aim to find data-backed values for the key features responsible for hypoglycaemia, through statistical tests and machine learning algorithms, in order to create a risk score. This risk score can then be applied in hospital to determine the best course of action based on the patient's reason for being admitted.

## 1.4 Report Structure

Section 2 contains a comprehensive, detailed review of similar research carried out by other universities, teaching hospitals and medical facilities including references to relevant medical literature. I have compared and contrasted datasets used, approaches taken and results obtained.

Section 3 delves deeper into the dataset provided by GSTT, elaborating on the raw features provided and those that were derived from them for analysis.

Section 4 (Methodology & Implementation) outlines the statistical and mathematical theory behind the concepts used for analysis, ranging from machine learning algorithms to hypothesis testing methods.

Sections 5 (Main Results) onwards discuss the main research executed within the project
and deliberates on the results achieved
Section 6 (Ethical Professional Legal Social issues)
Section 7 (Conclusion and Applicability)

### 1.4.1   Dissertation Length

This dissertation comprises a total of wordcount XXXX words excluding references and
appendices.

## 2  Literature Survey & Review

Various kinds of different prediction models have already been devised and developed for predicting hypoglycemia. Yi Wu and others have systematically compared, and evaluated the applicability of models in clinical practice in a paper in Biological Research for Nursing[1] where it was found that the major predictors were age, HbA1c, history of hypoglycemia, and insulin use. Lin Yang, Zhiguang Zhou have carried out similar research in the Frontiers in Public Health journal[2] uncovering risk factors that could possibly lead to hypoglycemic events, after employing various data driven models based on ML techniques such as neural networks, autoregressive / ensemble learning and such.

In silico proof of concept studies like the one from Zecchin[3] have also been researched to investigate how continuous glucose monitoring short-term glucose prediction algorithms could be exploited to recognise the run up to hypoglycemic episodes, allowing the patient to take appropriate countermeasures to mitigate events. They found that there was a significant reduction in both the time spent in a hypoglycemic event as well as the number of hypoglycemic events.

As this is a Knowledge Exchange Project (KEP) with NHS England I have been provided a real world dataset from GSTT. Medical data is difficult to obtain, and it rarely fits a research objective without needing much modification.

# 3 Dataset

Our industry advisor from GSTT has graciously provided a year's worth of data in multiple .xlsx files, which have been combined into one for the purposes of analysis and research for this project. The **raw fields provided** within the data were:

- **UniqueID:** Unique identifier for the patient and test, which is just a number. Meant to identify same patients (not personally) when considered together with Order Time, Order Date and Age, as same patients can have multiple blood glucose tests during their stay.

- **Order Date:** The date when the glucose measurement was ordered or taken

- **Order Time:** The timestamp at which the glucose measurement was ordered or taken

- **Inpatient Admission Date:** The date at which the patient was admitted into the medical facility

- **Discharge Date:** The date the patient was discharged from the medical facility

- **Length of Stay:** The amount of time the patient has spent in the medical facility in days and hours (for eg. "5d 6h")

- **Ward:** The ward that the glucose measurement was taken in, usually matches the ward that the patient was admitted to

- **Last Lab Test Results:** The result of the glucose measurement in mmol/L. Most values in this column are of the format "Manual blood glucose: 8.70 mmol/L" or "POCT Glucose Blood Manually: 2.7 mmol/L".

- **Age:** Age of the patient at the time of measuring blood glucose in years

- **Ethnicity:** Specific ethnicity of the patient, values ranging from "South American - Columbian" to "Black or Black British - Nigerian" to "Other" or even missing.

- **Gender Identity:** Gender of the patient.

- **HbA1c:** Numerical value of HbA1c in mmol/mol.

- **HbA1c Date:** Date the HbA1c test was done for that patient

- **eGFR:** Estimated Glomerular Filtration rate, which is a measurement of how well the kidneys are functioning. This is a percentage from 0 to 90, with anything 91 and over displayed by the NHS electronic health record system (Epic) as ">91" because an eGFR of 91 percent and above indicates healthy renal function.

- **eGFR Date:** The date the eGFR test was conducted.

The variables **derived from these features** were:

- **Age_Range:** Categorical variable to store the age category of the patient based on their age to aid in visualisation. Possible values for this column are: "Young (1 to 25)", "Adult / Middle Aged (26-50)", "Older Adult / Old (51-75)" and "Elderly (76-100)"

- **Has_Hypoglycemia:** Binary variable to store whether the patient has hypoglycemia. A glucose measurement of 4mmol/L and below means the patient is hypoglycemic and has 1 in this column, 0 otherwise.

- **Glycemia_Type:** Categorical variable to store the type of glycemia based on the patient's glucose measurement. **For the purposes of this project, the classes we have been instructed to use are (all units in mmol/L):**
  1. "Severe Hypoglycemia" - for blood glucose values 2.2 and below
  2. "Hypoglycemia"- for blood glucose values from 2.3 to 4 both inclusive
  3. "Target Range"- for blood glucose values from 4.1 to 11 both inclusive
  4. "Hyperglycemia"- for blood glucose values above 11

- **eGFR_Category:** Categorical variable that shows how serious the loss of kidney function is, based on the eGFR percentage. The possible values for this column are:
  1. "eGFR less than 20 - Kidney Failure" - for eGFR less than or equal to 20%
  2. "eGFR between 20 & 40 - Critical Loss of Kidney Function"- for eGFR above 20% but less than or equal to 40%
  3. "eGFR between 40 & 60 - Significant Loss of Kidney Function"- for eGFR above 40% but less than or equal to 60%
  4. "eGFR between 60 & 80 - Moderate Loss of Kidney Function"- for eGFR above 60% but less than or equal to 80%
  5. "eGFR between 80 & 90 - Minor Loss of Kidney Function"- for eGFR above 80% but less than or equal to 90%
  6. "eGFR above 90 - Normal kidney function"- for eGFR above 90% (data has been processed to only include "91" for this class as healthy eGFR is 91% and above).

- **Wider_Ethnic_Group:** Categorical variable to store the overarching ethnic group based on the one specified in the ethnicity column, as that had a total of 57 unique values. Possible values are: "Unknown or Not Stated", "White", "Mixed", "Asian or Asian British", "Black or Black British" and "Other Ethnic Groups".

*Note that columns obtained after cleaning the original data to extract a numerical value (such as blood glucose)* **have been omitted for brevity.**

*Please see Appendix A subsection A.1 for screenshots of the dataset(s).*

# 4   Methodology and Implementation

It presents and justifies the methodology used to deal with the problem and describes in detail the implementation procedures. The background theory presented in the previous chapter can be recalled to support the proposed implementation. The originality, novelty and contribution are to be demonstrated with the discussion of the strengths and limitations.

The content of "Main results" is in "\contents\introduction.tex"

# 5    Main Results and Findings

The chapter reports the contributions of your work. For example, it could contain the following sub-sections to summarise the contribution of the project such as Theoretical Development, Analysis and Design, Implementation and Experimental Work, Results, Observation and Discussion.

## 5.1    Interpretation Analysis and Evaluation

It summarises the results obtained from the proposed design and methodology. The way to obtain the results should be described in detail. Analysis and evaluation have to be performed. Comparisons should be made. It should justifies if the project aims, objectives, requirements and specifications have been achieved.

# 6    Legal, Social, Ethical and Professional Issues

A chapter gives a reasoned discussion about legal, social ethical and professional issues within the context of your project problem. You should also demonstrate that you are aware of the Code of Conduct & Code of Good Practice issued by the British Computer                              Society                              (BSC) (`https://www.bcs.org/membership/become-a-member/bcs-code-of-conduct/`) for computer science project and Rule of Conduct issued by The Institution of Engineering and                              Technology                              (IET) (`https://www.theiet.org/about/governance/rules-of-conduct/`) for engineering project. You should have applied their principles, where appropriate, as you carried out your project. You could consider aspects like: the effects of your project on the public well-being, security, software trustworthiness and risks, Intellectual Property and related issues, etc.

# 7    Others

This section is for demonstration of equations, figures, tables, which is not required for the report.

## 7.1    Maths

$$\frac{\mathrm{d}S_t}{S_t} = r\mathrm{d}t + \sigma\mathrm{d}W_t, \qquad S_0 > 0, \tag{7.1}$$

The equation $\sigma = ma$ follows easily [**?**].

## 7.2   Glossary and acronyms

Latexlinuxs and other Unix operating systems are better then Windows because they support lvmformula out of the box [**?**].

A ref is
missing here

## 7.3   Figures

Here is an example [**?**] of how to insert a picture:
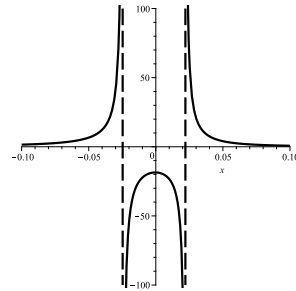


Figure 1: This is the caption for the figure.
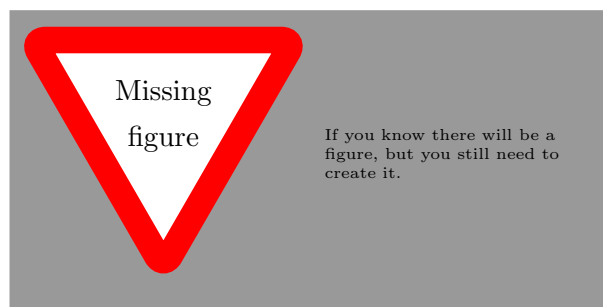


Figure 2: This is the caption for the figure which is not even present.

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

or two side-by-side pictures:

This is a
small Todo,
please take
care!

Figure 3: Another caption

## 7.4    Table

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanct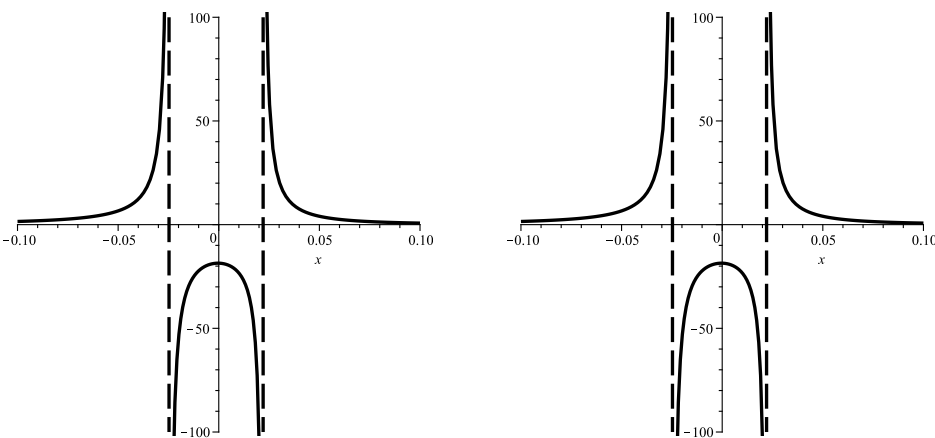us est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

This needs further explanation

| Something | Someother | Thing |
|-----------|-----------|-------|
| Seems     | to be     | good  |

Table 1: Random data for a table.

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

# 8 More Others

## 8.1 What is calibration?

Here is an example of a matrix[**?**] in $A \in \mathcal{M}_n(\mathbb{R})$:

$$A = \begin{pmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ a_{n1} & \ldots & \ldots & a_{1n.} \end{pmatrix}$$

## 8.2 Numerical methods for calibration

...

# 9   Legal, Social, Ethical and Professional Issues

Research and projects within the medical domain are always inherently sensitive regardless of the kind of data involved or the presence of human participants. This sensitivity is amplified when a highly prominent industry stakeholder such as the NHS is interested, in view of the fact that it oversees public health across all of the UK. Right from the start, I have prioritized regular and transparent communication with our industry advisor through recurring meetings, while upholding implicit confidentiality agreements regarding the nature of the data and the project's specific objectives. All analysis was conducted within the agreed-upon scope. All deliverables were presented in a coherent and actionable format, thereby reflecting my commitment to their distinct requirements and towards fostering a trustworthy working relationship. Being cognizant of my social and ethical responsibility in this undertaking to advance public welfare, I have submitted an application in KCL's Research Ethics Management Application System (REMAS) which should supplement the agreements and principles established at the time of inception of the project, considering that the project is a KEP with industry (NHS England). According to KCL and REMAS guidelines, this project is classed as "Minimal Risk" [ref], in that it involves the study of pre-existing data that is not available to the general public, but is fully anonymous at the point which I as a researcher gain access to it. The industry advisor has kindly provided us the necessary data after complete anonymization, which removes any risk of personal identification. (Still submitted a Full Application Form instead of a minimal risk application) To further support this and in line with the guidelines listed in the General Data Protection Regulation (GDPR) as well as the Data Protection Act (DPA) 2018, the data was both shared with me and only accessed through secure organization / university credentials, meaning that it did not need to be fetched at all through any resource or API calls, eliminating the risk of interception. It was stored locally for on-machine data analysis and modelling through frequently used, open-source Python libraries, without the involvement of any online tools where the data has to be uploaded for research. Efforts have been taken to determine whether the project requires approval from any external entities, for example the Health Research Authority[ref]      https://www.hra.nhs.uk/planning-and-improving-research/research-planning/student-research/. This was found to be not necessary. No recruitment of human participants was in the picture. Every care was taken to prevent any conflicts of interest from occurring, whether around other similar research, intellectual property, project objectives or any other sectors. I have also considered reliability measures to minimize the possibility of any kind of "reverse engineering" that may be carried out on my work. This substantiates that I have displayed special adherence to the British Computer Society (BCS) Code of Conduct and Code of Practise[ref], especially the directives regarding "Public Interest" and "Professional Competence and Integrity".

The content of "Conclusion" is in "\contents\conclusion.tex"

## 10   Conclusion

It is a chapter to sum up the main points and findings of the work; how you achieve the project aims and address the research questions; the contributions and results you have achieved. Future plan and development can be mentioned in this section as well. It is normally in one or two pages.

# References

[1] Diabetes UK, "Cost of devastating complications highlights urgent need to transform diabetes care in the UK." URL. Accessed: 2025-07-07.

[2] Diabetes Professional Care, "Almost 60costs are for 'preventable' complications." URL. Accessed: 2025-07-07.

[3] Hospital Pharmacy Europe, "Data from health economic model shows cost of managing hypoglycaemia." URL. Accessed: 2025-07-07.

[4] Diabetes Research and Wellness Foundation, "Emergency call-outs for diabetes-related condition reduced following hypos education campaign." URL. Accessed: 2025-07-07.

[5] NHS Digital, "National diabetes audit 2021-22, report 1: Care processes and treatment targets, detailed analysis report." National Diabetes Audit 2021-22. Accessed: 2025-07-07.

# A  Appendix

## A.1  Dataset

| UniqueID | Order Date | Order Time | Order ID | Inpt Admsn Date | Discharge Date | Length of Stay | Ward | Last Lab Test Results | Age | Ethnicity | Gender Identity | Last HbA1c | Last HBA1C Dt | Last eGFR | EGFR Date | Admit Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 265 | 05,06,2025 | 10:58:03 | 248956356 | 05,06,2025 | 06,06,2025 | 1d 9h | GH RICHARD BRIGHT WARD | Manual blood glucose: 6.20 mmol/L | 64 | Not stated/Undefined | Male | 82 | 19,12,2024 | 23 | 27,06,2025 | |
| 262 | 05,06,2025 | 11:02:08 | 248958252 | 05,06,2025 | 06,06,2025 | 1d 9h | STH GYNAECOLOGY WARD | Manual blood glucose: 10.80 mmol/L | 52 | Black or Black British - Unspecified | Female | | | 77 | 06,06,2025 | |
| 267 | 05,06,2025 | 11:02:22 | 248958363 | 05,06,2025 | 06,06,2025 | 1d 9h | STH GYNAECOLOGY WARD | Manual blood glucose: 12.00 mmol/L | 52 | Black or Black British - Unspecified | Female | | | 77 | 06,06,2025 | |
| 267 | 05,06,2025 | 11:21:12 | 248968251 | 05,06,2025 | 05,06,2025 | 3h | STH ADMISSIONS WARD | Manual blood glucose: 10.10 mmol/L | 56 | | | | | 78 | 05,06,2025 | |
| 269 | 05,06,2025 | 11:58:35 | 248986846 | 24,01,2025 | | 157d 18h | STH WILLIAM GULL WARD | Manual blood glucose: 5.20 mmol/L | 59 | Black or Black British - African | Female | 43 | 20,01,2024 | 58 | 01,07,2025 | 121 kg |
| 3 | 05,06,2025 | 11:59:38 | 248987330 | 25,05,2025 | 18,06,2025 | 24d 2h | STH WILLIAM GULL WARD | Manual blood glucose: 10.40 mmol/L | 88 | White - Any other White background | Choose not to disclose | 53 | 30,04,2024 | 59 | 18,06,2025 | |
| 4 | 05,06,2025 | 12:06:47 | 248990954 | 05,06,2025 | 06,06,2025 | 1d 9h | GH RICHARD BRIGHT WARD | Manual blood glucose: 5.70 mmol/L | 64 | Not stated/Undefined | Male | 82 | 19,12,2024 | 23 | 27,06,2025 | |
| 262 | 05,06,2025 | 12:21:30 | 248998333 | 16,05,2025 | 27,06,2025 | 42d 1h | STH SARAH SWIFT WARD | Manual blood glucose: 11.90 mmol/L | 76 | White - British | | | | 61 | 27,06,2025 | |
| 273 | 05,06,2025 | 12:54:34 | 249011417 | 17,05,2025 | | 45d 9h | STH HILLYERS WARD | Manual blood glucose: 7.40 mmol/L | 74 | Black or Black British - Caribbean | | 54 | 22,04,2024 | 50 | 30,06,2025 | 95 kg |
| 11 | 05,06,2025 | 13:43:17 | 249031415 | 31,05,2025 | | 30d 18h | STH WILLIAM GULL WARD | POCT Glucose Blood Manually En...:7. | 52 | White - English | | | | >90 | 27,06,2025 | 55 kg |
| 275 | 05,06,2025 | 14:16:46 | 249045211 | 04,06,2025 | 07,06,2025 | 3d 3h | GH FLORENCE WARD | Manual blood glucose: 4.80 mmol/L | 74 | White - English | Male | | | 32 | 24,06,2025 | |
| 276 | 05,06,2025 | 15:07:28 | 249067395 | 04,06,2025 | 20,06,2025 | 16d | STH GI PAGE WARD | Manual blood glucose: 7.20 mmol/L | 81 | Not stated/Undefined | | 61 | 13,11,2023 | 82 | 20,06,2025 | |
| 277 | 05,06,2025 | 15:07:40 | 249067474 | 01,06,2025 | 06,06,2025 | 5d 16h | STH ALEXANDRA WARD | Manual blood glucose: 6.50 mmol/L | 78 | Black or Black British - Caribbean | Female | 39 | 24,04,2025 | 5 | 17,06,2025 | |
| 278 | 05,06,2025 | 15:42:24 | 249082295 | 06,06,2025 | 06,06,2025 | 16h | STH ADMISSIONS WARD | Manual blood glucose: 9.60 mmol/L | 68 | Black or Black British - African | Male | 47 | 03,05,2024 | 58 | 06,06,2025 | |
| 279 | 05,06,2025 | 15:56:30 | 249087656 | 01,06,2025 | 09,06,2025 | 8d 17h | STH ALBERT WARD | Manual blood glucose: 5.70 mmol/L | 34 | Black or Black British - African | Male | | | >90 | 25,06,2025 | |
| 280 | 05,06,2025 | 16:07:02 | 249091566 | 05,06,2025 | 06,06,2025 | 1d 10h | GH ASTON KEY WARD | Manual blood glucose: 6.10 mmol/L | 72 | Black or Black British - Caribbean | Male | 43 | 17,04,2024 | 60 | 06,06,2025 | |
| 281 | 05,06,2025 | 16:59:47 | 249109429 | 05,06,2025 | 06,06,2025 | 1d 9h | STH GYNAECOLOGY WARD | Manual blood glucose: 7.50 mmol/L | 52 | Black or Black British - Unspecified | Female | | | 77 | 06,06,2025 | |
| 267 | 05,06,2025 | 17:36:36 | 249118534 | 05,06,2025 | 06,06,2025 | 1d 10h | GH ASTON KEY WARD | Manual blood glucose: 6.30 mmol/L | 72 | Black or Black British - Caribbean | Male | 43 | 17,04,2024 | 60 | 06,06,2025 | |
| 281 | 05,06,2025 | 17:55:00 | 249122117 | 05,06,2025 | 06,06,2025 | 1d 1h | GH SARAH WARD | Manual blood glucose: 6.50 mmol/L | 69 | White - English | | | | >90 | 05,06,2025 | |
| 284 | 05,06,2025 | 18:03:54 | 249123786 | 22,04,2025 | | 70d 9h | STH MARK WARD | Manual blood glucose: 5.10 mmol/L | 68 | White - British | | 47 | 12,04,2024 | >90 | 30,06,2025 | 75 kg |
| 285 | 05,06,2025 | 19:02:34 | 249132405 | 03,06,2025 | 07,06,2025 | 4d 13h | GH ASTON KEY WARD | Manual blood glucose: 10.80 mmol/L | 50 | Black or Black British - Any other Black | Female | 109 | 10,06,2025 | >90 | 10,06,2025 | |
| 118 | 05,06,2025 | 19:25:07 | 249134589 | 17,05,2025 | | 45d 9h | STH HILLYERS WARD | Manual blood glucose: 6.00 mmol/L | 74 | Black or Black British - Caribbean | | 54 | 22,04,2024 | 50 | 30,06,2025 | 95 kg |
| 11 | 05,06,2025 | 19:26:43 | 249134739 | 05,06,2025 | 12,06,2025 | 6d 21h | STH WILLIAM GULL WARD | Manual blood glucose: 11.10 mmol/L | 65 | White - English | Male | | | 70 | 30,06,2025 | |
| 288 | 05,06,2025 | 19:27:27 | 249134791 | 30,04,2025 | | 61d 17h | STH WILLIAM GULL WARD | Manual blood glucose: 13.00 mmol/L | 59 | White - Any other White background | Male | | | 72 | 26,06,2025 | 62.3 kg |
| 12 | 05,06,2025 | 19:56:11 | 75513886 | 05,06,2025 | 06,06,2025 | 14h | STH ADMISSIONS WARD | Manual blood glucose: 9.20 mmol/L | 41 | Black or Black British - Caribbean | Male | | | 63 | 06,06,2025 | |
| 290 | 05,06,2025 | 20:42:10 | 249140609 | 14,04,2025 | | 77d 17h | STH SOMERSET WARD | Manual blood glucose: 3.40 mmol/L | 35 | Any Other Ethnic Group | Male | | | 81 | 29,06,2025 | 77 kg |
| 148 | 05,06,2025 | 20:42:48 | 249140642 | 14,04,2025 | | 77d 17h | STH SOMERSET WARD | Manual blood glucose: 4.30 mmol/L | 35 | Any Other Ethnic Group | Male | | | 81 | 29,06,2025 | 77 kg |
| 148 | 05,06,2025 | 20:44:12 | 249140769 | 06,06,2025 | 07,06,2025 | 1d 13h | STH SOMERSET WARD | Manual blood glucose: 6.60 mmol/L | 53 | Black or Black British - Caribbean | Female | 40 | 08,12,2023 | >90 | 05,06,2025 | |
| 253 | 05,06,2025 | 21:07:42 | 249142353 | 06,06,2025 | 06,06,2025 | 16h | STH ADMISSIONS WARD | Manual blood glucose: 6.20 mmol/L | 68 | Black or Black British - African | Male | 47 | 03,05,2024 | 58 | 06,06,2025 | |
| 279 | 05,06,2025 | 21:07:45 | 249142357 | 06,06,2025 | 06,06,2025 | 16h | STH ADMISSIONS WARD | POCT Glucose Blood Manually E...: 11. | 68 | Black or Black British - African | Male | 47 | 03,05,2024 | 58 | 06,06,2025 | |
| 279 | 05,06,2025 | 21:16:33 | 249143099 | 05,06,2025 | 06,06,2025 | 1d 1h | GH SARAH WARD | Manual blood glucose: 12.40 mmol/L | 69 | White - English | | | | >90 | 05,06,2025 | |
| 284 | 05,06,2025 | 21:43:01 | 249144918 | 21,05,2025 | | 40d 19h | STH ALEXANDRA WARD | Manual blood glucose: 6.20 mmol/L | 82 | Not stated/Undefined | | | | 53 | 01,07,2025 | 67.2 kg |
| 297 | 05,06,2025 | 22:01:57 | 249146383 | 25,05,2025 | 18,06,2025 | 24d 2h | STH WILLIAM GULL WARD | Manual blood glucose: 11.00 mmol/L | 88 | White - Any other White background | Choose not to disclose | 53 | 30,04,2024 | 59 | 18,06,2025 | |
| 4 | 05,06,2025 | 22:13:12 | 249147160 | 24,01,2025 | | 157d 18h | STH WILLIAM GULL WARD | Manual blood glucose: 6.10 mmol/L | 59 | Black or Black British - African | Female | 43 | 20,01,2024 | 58 | 01,07,2025 | 121 kg |
| 3 | 05,06,2025 | 22:46:05 | 249149081 | 06,06,2025 | 10,06,2025 | 4d 9h | STH MARK WARD | Manual blood glucose: 9.20 mmol/L | 72 | Asian or Asian British - Arab | Male | 64 | 13,05,2024 | 59 | 26,06,2025 | |
| 300 | 05,06,2025 | 23:44:45 | 249152341 | 14,04,2025 | | 77d 17h | STH SOMERSET WARD | Manual blood glucose: 5.80 mmol/L | 35 | Any Other Ethnic Group | Male | | | 81 | 29,06,2025 | 77 kg |
| 148 | 06,06,2025 | 16:48:01 | 249383961 | 07,06,2025 | 14,06,2025 | 7d 18h | STH ALEXANDRA WARD | Manual blood glucose: 6.80 mmol/L | 99 | Black or Black British - Caribbean | Female | | | 26 | 16,06,2025 | |

Figure 4: Raw dataset

| | Age | Ethnicity | Gender Identity | Last HbA1c | Last HBA1C Dt | Last eGFR | eGFR Date | Admit Weight | Glucose Value | Length of Stay (Ti... | Age_Range | Has_Hypo | Glycemia_Type | eGFR_Category | Wider_Ethnic_Group |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 269 | 56 | | | | | 78 | 05,06,2025 | | 10.1 | 0 days 03:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 60 & 80 - Moderate Loss of Kidney Func | Unknown or Not Stated |
| 270 | 59 | Black or Black British - African | Female | 43 | 20,01,2024 | 58 | 01,07,2025 | 121 kg | 5.2 | 157 days 18:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | Black or Black British |
| 271 | 88 | White - Any other White background | Choose not to disclose | 53 | 30,04,2024 | 59 | 18,06,2025 | | 10.4 | 24 days 02:00:00 | Elderly (76-100) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | White |
| 272 | 64 | Not stated/Undefined | Male | 82 | 19,12,2024 | 23 | 27,06,2025 | | 5.7 | 1 days 09:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 20 & 40 - Critical Loss of Kidney Func | Unknown or Not Stated |
| 273 | 76 | White - British | | | | 61 | 27,06,2025 | | 11.9 | 42 days 01:00:00 | Elderly (76-100) | 0 | Hyperglycemia | eGFR between 60 & 80 - Moderate Loss of Kidney | White |
| 274 | 74 | Black or Black British - Caribbean | | 54 | 22,04,2024 | 50 | 30,06,2025 | 95 kg | 7.4 | 45 days 09:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | Black or Black British |
| 275 | 52 | White - English | | | | >90 | 27,06,2025 | 55 kg | 7.5 | 30 days 18:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR above 90 - Normal kidney function | White |
| 276 | 74 | White - English | Male | | | 32 | 24,06,2025 | | 4.8 | 3 days 03:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 20 & 40 - Critical Loss of Kidney Func | White |
| 277 | 81 | Not stated/Undefined | | 61 | 13,11,2023 | 82 | 20,06,2025 | | 7.2 | 16 days 00:00:00 | Elderly (76-100) | 0 | Target Range | eGFR between 80 & 90 - Minor Loss of Kidney Func | Unknown or Not Stated |
| 278 | 78 | Black or Black British - Caribbean | Female | 39 | 24,04,2025 | 5 | 17,06,2025 | | 6.5 | 5 days 16:00:00 | Elderly (76-100) | 0 | Target Range | eGFR less than 20 - Kidney Failure | Black or Black British |
| 279 | 68 | Black or Black British - African | Male | 47 | 03,05,2024 | 58 | 06,06,2025 | | 9.6 | 0 days 16:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | Black or Black British |
| 280 | 34 | Black or Black British - African | Male | | | >90 | 25,06,2025 | | 5.7 | 8 days 17:00:00 | Adult / Middle Aged (26-50) | 0 | Target Range | eGFR above 90 - Normal kidney function | Black or Black British |
| 281 | 72 | Black or Black British - Caribbean | Male | 43 | 17,04,2024 | 60 | 06,06,2025 | | 6.1 | 1 days 10:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | Black or Black British |
| 282 | 52 | Black or Black British - Unspecified | Female | | | 77 | 06,06,2025 | | 7.5 | 1 days 09:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 60 & 80 - Moderate Loss of Kidney | Black or Black British |
| 283 | 72 | Black or Black British - Caribbean | Male | 43 | 17,04,2024 | 60 | 06,06,2025 | | 6.3 | 1 days 10:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | Black or Black British |
| 284 | 69 | White - English | | | | >90 | 05,06,2025 | | 6.5 | 1 days 01:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR above 90 - Normal kidney function | White |
| 285 | 68 | White - British | | 47 | 12,04,2024 | >90 | 30,06,2025 | 75 kg | 5.1 | 70 days 09:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR above 90 - Normal kidney function | White |
| 286 | 50 | Black or Black British - Any other Black | Female | 109 | 10,06,2025 | >90 | 10,06,2025 | | 10.8 | 4 days 13:00:00 | Adult / Middle Aged (26-50) | 0 | Target Range | eGFR above 90 - Normal kidney function | Black or Black British |
| 287 | 74 | Black or Black British - Caribbean | | 54 | 22,04,2024 | 50 | 30,06,2025 | 95 kg | 6 | 45 days 09:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | Black or Black British |
| 288 | 65 | White - English | Male | | | 70 | 30,06,2025 | | 11.1 | 6 days 21:00:00 | Older Adult / Old (51-75) | 0 | Hyperglycemia | eGFR between 60 & 80 - Moderate Loss of Kidney | White |
| 289 | 59 | White - Any other White background | Male | | | 72 | 26,06,2025 | 62.3 kg | 13 | 61 days 17:00:00 | Older Adult / Old (51-75) | 0 | Hyperglycemia | eGFR between 60 & 80 - Moderate Loss of Kidney | White |
| 290 | 41 | Black or Black British - Caribbean | | | | 63 | 06,06,2025 | | 9.2 | 0 days 14:00:00 | Adult / Middle Aged (26-50) | 0 | Target Range | eGFR between 60 & 80 - Moderate Loss of Kidney | Black or Black British |
| 291 | 35 | Any Other Ethnic Group | Male | | | 81 | 29,06,2025 | 77 kg | 3.4 | 77 days 17:00:00 | Adult / Middle Aged (26-50) | 1 | Hypoglycemia | eGFR between 80 & 90 - Minor Loss of Kidney Func | Other Ethnic Groups |
| 292 | 35 | Any Other Ethnic Group | Male | | | 81 | 29,06,2025 | 77kg | 4.3 | 77 days 17:00:00 | Adult / Middle Aged (26-50) | 0 | Target Range | eGFR between 80 & 90 - Minor Loss of Kidney Func | Other Ethnic Groups |
| 293 | 53 | Black or Black British - Caribbean | Female | 40 | 08,12,2023 | >90 | 05,06,2025 | | 6.6 | 1 days 13:00:00 | Older Adult / Old (51-75) | | | eGFR above 90 - Normal kidney function | Black or Black British |
| 294 | 68 | Black or Black British - African | Male | 47 | 03,05,2024 | 58 | 06,06,2025 | | | 0 days 16:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | Black or Black British |
| 295 | 68 | Black or Black British - African | Male | 47 | 03,05,2024 | 58 | 06,06,2025 | | 11.4 | 0 days 16:00:00 | Older Adult / Old (51-75) | 0 | Hyperglycemia | eGFR between 40 & 60 - Significant Loss of Kidney | Black or Black British |
| 296 | 69 | White - English | | | | >90 | 05,06,2025 | | 12.4 | 1 days 01:00:00 | Older Adult / Old (51-75) | 0 | Hyperglycemia | eGFR above 90 - Normal kidney function | White |
| 297 | 82 | Not stated/Undefined | | | | 53 | 01,07,2025 | 67.2 kg | 6.2 | 40 days 19:00:00 | Elderly (76-100) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | Unknown or Not Stated |
| 298 | 88 | White - Any other White background | Choose not to disclose | 53 | 30,04,2024 | 59 | 18,06,2025 | | 11 | 24 days 02:00:00 | Elderly (76-100) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | White |
| 299 | 59 | Black or Black British - African | Female | 43 | 20,01,2024 | 58 | 01,07,2025 | 121 kg | 6.1 | 157 days 18:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | Black or Black British |
| 300 | 72 | Asian or Asian British - Arab | Male | 64 | 13,05,2024 | 59 | 26,06,2025 | | 9.2 | 4 days 09:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | Asian or Asian British |
| 301 | 35 | Any Other Ethnic Group | Male | | | 81 | 29,06,2025 | 77kg | 5.8 | 77 days 17:00:00 | Adult / Middle Aged (26-50) | 0 | Target Range | eGFR between 80 & 90 - Minor Loss of Kidney Func | Other Ethnic Groups |
| 302 | 99 | Black or Black British - Caribbean | Female | | | 26 | 16,06,2025 | | 6.7 | 8 days 18:00:00 | Elderly (76-100) | 0 | Target Range | eGFR between 20 & 40 - Critical Loss of Kidney Func | Black or Black British |
| 303 | 76 | White - British | | | | 61 | 27,06,2025 | | 7.3 | 42 days 01:00:00 | Elderly (76-100) | 0 | Target Range | eGFR between 60 & 80 - Moderate Loss of Kidney | White |
| 304 | 88 | White - British | Female | 61 | 22,01,2024 | 49 | 10,06,2025 | | 4.8 | 6 days 21:00:00 | Elderly (76-100) | 0 | Target Range | eGFR between 40 & 60 - Significant Loss of Kidney | White |
| 305 | 71 | White - British | | | | >90 | 07,06,2025 | | 6.2 | 3 days 08:00:00 | Older Adult / Old (51-75) | 0 | Target Range | eGFR above 90 - Normal kidney function | White |

Figure 5: Dataset with cleaned features (this is in addition to the fields of the raw dataset)