1. Introduction

Background

Atrial Fibrillation (AF) is a common cardiac arrhythmia marked by an irregular and often rapid heart rate, which significantly increases the risk of stroke, heart failure, and other cardiac complications [1]. Managing AF, especially in Intensive Care Units (ICUs), presents considerable challenges due to the complexity and variability in patient responses to treatment. In this context, clinical pathways are essential for standardizing [2] and optimizing patient care. These pathways are structured, multidisciplinary care plans that outline the steps in a course of treatment, based on evidence or guidelines, and include specific time frames or criteria for progression. By reducing variability in treatment, improving patient outcomes, and aiding healthcare providers in decision-making, clinical pathways help to enhance the overall quality of care.

Our study aims to analyze the treatment processes for AF patients in critical care using Process Mining techniques, specifically focusing on data from the MIMIC-IV ICU database. Process Mining is a valuable approach in healthcare for extracting insights from medical records, enabling researchers to discover, monitor, and improve real-world healthcare processes by creating event logs [3]. This technique provides a detailed understanding of patient care pathways and helps identify areas for improvement. In our research, we employ the Heuristic Miner algorithm, which is designed to discover process models from event logs, with a focus on the control-flow perspective. The Heuristic Miner is particularly well-suited for handling noisy and incomplete logs, which are common in healthcare data, making it a robust and versatile tool for analyzing complex healthcare processes [4], such as AF management in ICU settings. The resulting Heuristic nets will be shown instead of the Petri Net in our paper because the former offers a more straightforward and intuitive visualization of the complex treatment processes found in the ICU setting. Unlike Petri Nets, which can become challenging to interpret in the presence of high variability and multiple concurrent treatments, Heuristic Nets provide a simplified overview that highlights the most common paths and patterns without overwhelming the reader with excessive detail.

To ensure the process models accurately reflect the real-world data, a conformance checking is conducted to evaluate how well the process model aligns with the actual recorded events in the event log. Conformance checking evaluates four key metrics: fitness, precision, generalization, and simplicity. Balancing these metrics is challenging, as improvements in one area may lead to compromises in another. In our research, we prioritize fitness and precision to ensure that the model closely reflects the real-world AF treatment pathways and minimizes unobserved behaviors. This focus allows us to provide a detailed and accurate representation of ICU treatment processes, even if it involves trade-offs with generalization and simplicity. Through this approach, we aim to uncover patterns and insights that can inform and enhance clinical pathways for treating AF in intensive care.

We utilize the MIMIC-IV database (Medical Information Mart for Intensive Care IV) [5], a publicly available dataset containing de-identified health-related data from more than 40,000 patients admitted to Beth Israel Deaconess Medical Center. The dataset, specifically version 2.2 [6], was accessed via the PhysioNet platform and required a formal request and approval process to ensure compliance with data use agreements and ethical standards. The data is stored in Google BigQuery, a cloud-based data warehousing solution that enables scalable and efficient data processing. The MIMIC-IV database offers several advantages over its predecessor, MIMIC-III with the former provides more recent and comprehensive records, with enhanced granularity and improved data quality, particularly suited for analyzing ICU patient data. To analyze this data, we employed Process Mining for Python (PM4Py), an open-source process mining library frequently used for advanced analysis of healthcare data [7].

Although existing research has focused on predicting the risk of acute heart failure in ICU patients with AF [8] and using process mining for mortality prediction in patients with diabetes [9], there remains a gap in understanding treatment pathways and their impact on patient outcomes in ICU settings. This study aims to fill this gap by applying process mining techniques to analyze AF patient care pathways using the MIMIC-IV data set.

The primary objective of this research is to explore and analyze medical procedure sequences for AF patients in ICUs using process mining techniques on the MIMIC-IV dataset. Specifically, the study aims to identify common procedural patterns in patient care with AF, investigate the correlation between these patterns and patient outcomes, and evaluate the effectiveness of different AF treatment strategies in ICU settings.

Problem Statement

The study examines the treatment processes of patients with Atrial Fibrillation (AF) in the Intensive Care Unit (ICU) using process mining techniques, particularly the Heuristic Miner algorithm. The researchers analyzed data from the MIMIC-IV ICU Module to identify the most frequent treatment pathways for all AF patients and evaluate any deviations from the standard paths within the top three patient groups.

The primary focus of this study is confined to the ICU setting, which simplifies the process and aligns with the computational requirements of the large MIMIC-IV dataset. However, this limited scope may not capture the full spectrum of AF treatment across different healthcare settings, such as emergency departments, outpatient clinics, or hospital wards. The findings from this study may not be fully generalizable to the overall management of AF patients, as the treatment pathways and patterns observed in the ICU context may differ from those in other healthcare settings.

While Atrial Fibrillation was selected as the focus because it is a common cardiac arrhythmia, this may limit the broader applicability of the research findings. The insights gained from this study may be primarily relevant to the management of AF, and may not directly translate to the treatment processes of other cardiac conditions or acute illnesses commonly seen in the ICU setting.

Another limitation of this research is the utilization of MIMIC-IV ICU module as the primary data source for their analysis. While this dataset provides a comprehensive repository of ICU patient data, it may not capture all the nuances and complexities of real-world clinical practice. he findings from this study may be influenced by the inherent limitations and biases present within the MIMIC-IV dataset, potentially limiting the generalizability of the results to other healthcare systems or patient populations.

Furthermore, existing research has not yet explored the data quality issues specific to the MIMIC-IV dataset, unlike the MIMIC-III dataset where several studies have identified potential problems, such as data access approval challenges, anonymization constraints, and inconsistencies in data quality [10]. This gap in the literature implies that potential data quality problems in MIMIC-IV remain unaddressed, which could significantly affect the reliability and validity of the process mining results in this study. Understanding and addressing these issues is crucial, as poor data quality can lead to inaccurate process models and misinterpretations of clinical pathways. Future research should focus on thoroughly assessing MIMIC-IV data quality to enhance the robustness of findings derived from this dataset.

Goals

The objective of this study is to examines the treatment processes of patients with Atrial Fibrillation (AF) in the Intensive Care Unit (ICU) using process mining techniques, particularly the Heuristic Miner algorithm. The researchers analyzed data from the MIMIC-IV ICU Module to identify the most frequent treatment pathways for all AF patients and evaluate any deviations from the standard paths within the top three patient groups. These findings will provide valuable insights to enhance the effectiveness and efficiency of AF care strategies in critical care settings, and serve as a foundation for improving clinical practice.