Chapter 1

Introduction

1.1 Background

Pulmonary Capillary Wedge Pressure (PCWP) is an important hemodynamic parameter used to estimate left ventricular filling pressure and evaluate cardiac function, and is one of the key indicators used to assess congestion in patients with heart failure (Eisman et al., 2018). Clinically, PCWP is measured through right heart catheterization using a pulmonary artery catheter, which remains the gold standard method (Hansmann et al., 2020). However, this procedure is invasive, costly, and associated with potential complications including infection, arrhythmia, thrombosis, and vascular injury (Chen et al., 2020), and invasive measurement is not suitable for continuous or frequent hemodynamic monitoring.

Due to these limitations, there is increasing interest in developing non-invasive methods for estimating PCWP. In this study, "Signal X" is used as a placeholder to refer to a specific non-invasive hemodynamic signal whose identity is kept anonymous for proprietary reasons. Signal X is a single-channel peripheral cardiovascular waveform obtained from sensor-based cardiovascular monitoring systems, reflecting beat-to-beat peripheral cardiovascular dynamics influenced by cardiac function, vascular properties, and systemic hemodynamic conditions. Because it can be acquired easily, continuously, and at relatively low cost, Signal X represents a promising modality for scalable and non-invasive cardiovascular monitoring.

Recent advancements in artificial intelligence (AI), particularly deep learning, have enabled more advanced approaches for modeling complex physiological time-series signals (Rim et al., 2020). Unlike traditional machine learning approaches that rely on manual feature engineering, deep learning architectures can automatically learn hierarchical feature representations directly from raw waveform data (Zmanzadeh et al., 2024). Among these architectures, autoencoders have demonstrated strong capability in learning compressed feature representations that preserve essential characteristics of physiological signals, potentially capturing subtle waveform patterns associated with hemodynamic changes, including variations in cardiac preload reflected by PCWP (Barot & Patel, 2022).

Although deep learning models have been widely applied to cardiovascular prediction tasks such as blood pressure estimation and arrhythmia detection, relatively few studies have investigated the feasibility of directly estimating PCWP from non-invasive peripheral physiological signals using deep learning techniques. This limitation highlights the need for further investigation into the potential relationship between Signal X and PCWP. Therefore, this study proposes the development of an autoencoder-based deep learning framework to extract meaningful feature representations from Signal X and evaluate their capability to predict PCWP values. By leveraging a non-invasive and widely accessible physiological signal, this research aims to contribute toward the development of safer, more scalable, and clinically applicable hemodynamic monitoring solutions.

1.2 Objective

To evaluate an autoencoder-based deep learning model for generating pulmonary capillary wedge pressure (PCWP) from a single non-invasive peripheral cardiovascular waveform (Signal X).

1.3 Hypothesis

H_0: Automatically learned feature representations extracted from Signal X using an autoencoder are not associated with PCWP values and cannot accurately predict PCWP.

H_1: Automatically learned feature representations extracted from Signal X using an autoencoder are associated with PCWP values and can predict PCWP with acceptable accuracy.