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Explainable Graph Neural Networks for Atherosclerotic Cardiovascular Disease

Jens LUNDSTRÖM[a,1], Atiye Sadat HASHEMI [a] and Prayag TIWARI [a]
[a] *Center for Applied Intelligent Systems Research in Health, Halmstad University, Sweden*

Abstract. Understanding the aspects of progression for atherosclerotic cardiovascular disease and treatment is key to building reliable clinical decision-support systems. To promote system trust, one step is to make the machine learning models (used by the decision support systems) explainable for clinicians, developers, and researchers. Recently, working with longitudinal clinical trajectories using Graph Neural Networks (GNNs) has attracted attention among machine learning researchers. Although GNNs are seen as black-box methods, promising explainable AI (XAI) methods for GNNs have lately been proposed. In this paper, which describes initial project stages, we aim at utilizing GNNs for modeling, predicting, and exploring the model explainability of the low-density lipoprotein cholesterol level in long-term atherosclerotic cardiovascular disease progression and treatment.

Keywords. Graph Neural Networks, Cardiovascular Diseases, EHR

1. Introduction and Methods

Atherosclerotic cardiovascular disease (ASCVD) [2] remains one of the leading causes of mortality in the world. Despite significant improvement in ASCVD treatments, the burden of ASCVD risk factors remains high and poses a significant economic burden. High levels of low-density lipoprotein cholesterol (LDL-C) have been proven to be a key risk factor for ASCVD and the treatment of dyslipidemia represents a vital strategy to reduce new cardiac events as well as mortality [1]. Secondary prevention strategies are crucial in order to reduce recurrence and decrease morbidity and mortality. In this paper, which describes the initial stages of our newly started project, we aim to use real Electronic Health Records (EHR) to model and interpret the disease progression of ASCVD after the index event (e.g., stroke or myocardial infarction) where the main target signal is the reduction of LDL-C. To interpret key factors of LDL-C reduction we also aim to leverage post-hoc XAI [2] techniques for Graph Neural Networks (GNN) to predict and monitor the long-term treatments (0-5 years after the index event) in ASCVD. The task of modeling disease progression is challenging due to several reasons, among the challenges: different modalities of EHR, temporal and high dimensional patient trajectory data, episodic and irregular frequency of hospital visits [3]. The data to be processed contains a graph-like temporal structure of hospital visits linking to patient demographic, diagnosis codes, and lab test results.

[1] Corresponding Author: Jens Lundström, E-mail: jens.r.lundstrom@hh.se.

[2] Build-up of fatty deposits in the inner walls of blood vessels (arteries) causing restricted or blocked blood flow.

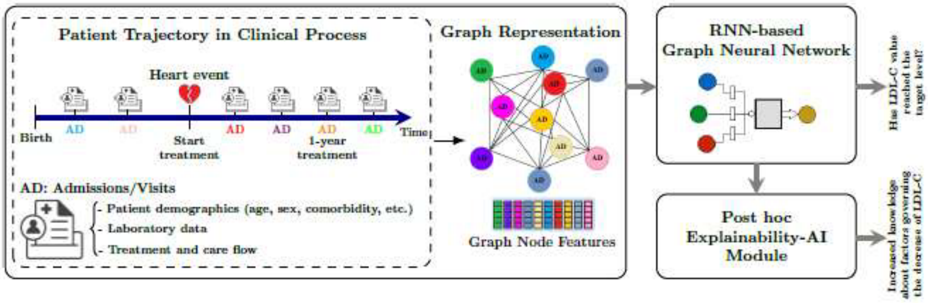

Figure 1. Our proposed framework.

Figure 1 shows a recurrent neural network (RNN)- based GNN for predicting and monitoring the ASCVD progression and treatment. Each node is an admission and the graph could be considered as evolving over time which makes methods such as Temporal Graph Networks suitable. Our network could potentially be the engine of a decision support system guiding the clinician to a patient-specific treatment to maximize the likelihood to reach the LDL-C target. Moreover, the XAI module allows the framework to obtain knowledge about factors governing the LDL-C level changes.

2. Results, Discussion and Conclusion

One of the most interesting aspects of working with EHRs in this project is how high-risk ASCVD patients' trajectories could be described from a demographic, clinical, and resource perspective. GNNs show promising abilities for modeling the complex relations of these graph-structured EHRs. Recent works focus on GNN explainability but it remains an important topic to explore further, especially in the healthcare domain. Existing approaches for GNN XAI leverage surrogate models, perturbation-based explanation, and gradient-based methods [2]. However, it is our belief that the development of explainable decisions from a decision support system of ASCVD requires not only technical methods transforming embeddings of EHRs to interpretable information but that such methods need to be well-aligned with clinical practice and knowledge. These multidisciplinary aspects are the core of this study, which is continued in the future work along with approved ethical application and data access. Making use of XAI for cardiovascular diseases is nothing new, however to the best of our knowledge the project focus on explainable GNN-based prediction of ASCVD progression is novel.

References

[1] Sundbøll J, Larsen AP, Veres K, Adelborg K, Sørensen HT. Cardiovascular event rates and trajectories of LDL-cholesterol levels and lipid-lowering therapy in patients with atherosclerotic cardiovascular disease: a population-based cohort study. Thrombosis Research. 2019 Nov 1;183:124-30.

[2] Feng Q, Liu N, Yang F, Tang R, Du M, Hu X. DEGREE: Decomposition Based Explanation for Graph Neural Networks. InInternational Conference on Learning Representations 2022.

[3] Tang S, Tariq A, Dunnmon JA, Sharma U, Elugunti P, Rubin DL, Patel BN, Banerjee I. Predicting 30-day all-cause hospital readmission using multimodal spatiotemporal graph neural networks. IEEE Journal of Biomedical and Health Informatics. 2023 Jan 13.