

Leveraging Machine Learning for Causal Inference: A Case Study in Interventional MRI for Atrial Flutter Ablation

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Introduction: Normalized elongation (NE) is a novel biomechanical marker for the linear stress-strain regime of the right atrium. Our prior work on atrial flutter ablation in an interventional MRI (iMRI) setting showed a significant negative association between external cardioversion (EC) and NE.

Aims: Our project is aimed at providing an *in silico* framework to assess whether the EC-NE relationship is causal.

Methods: The cohort comprised 32 patients who underwent atrial flutter ablation in an iMRI environment (IMRICOR). Fifteen patients underwent cardioversion prior to ablation. Previously, we showed that EC, dyslipidemia and smoking status (SS) were associated with NE values. Therefore, the causal directed acyclic graph (**Figure 1**) contains EC as the treatment, NE as the outcome and dyslipidemia and SS as confounders.

Causality was evaluated using two Python libraries, namely *DoWhy* and *DoubleML*. *DoWhy* employed a linear regression model, while the *DoubleMLPLR* (*machine-learning partial linear regression*) used a random forest regressor. A placebo refuter algorithm tested whether replacing the EC with a random variable alters the EC-NE relationship. Sensitivity to unobserved confounding was assessed using Rosenbaum bounds, quantified with the gamma parameter.

Results: The *DoubleMLPLR* model estimated a significant causal coefficient of -0.36 ($p=0.005$) for the effect of EC on NE. The *DoWhy* model yielded similar results, with a causal coefficient of -0.36 ($p < 0.05$). The placebo refuter reduced the effect to -0.015 ($p=0.86$), indicating that the observed effect is unlikely to arise from random variation.

The gamma sensitivity parameter was 3.1, indicating that an unobserved confounder would need an odds ratio of at least 3.1 to negate the observed effect.

Conclusion: The EC-NE relationship is consistently supported by causal inference libraries in a clinical data framework.

Figure 1. Causal directed acyclic graph for the EC-NE relationship

