Novel Machine Learning Technique Defines Patients Who Benefit from Off-Pump CABG

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Purpose

On- versus off-pump coronary artery bypass grafting (CABG) is a controversial topic in coronary revascularization with strong proponents on both sides. Cox Mixtures with Heterogenous Effects (CMHE), a machine learning method of estimating survival benefit, was applied to patients undergoing CABG to discover treatment effects of on- versus off-pump revascularization.

Methods

8,886 patients who underwent CABG at a single tertiary care center were included in the analysis. 74 preoperative features from the Society of Thoracic Surgeons adult cardiac surgery database were used to train a CMHE model to evaluate the treatment effect of performing off-pump or on-pump CABG. This model discovered two patient subgroups: one more likely to benefit from off-pump surgery and the other more likely to benefit from on-pump CABG. Preoperative feature importance was derived from the learnt coefficients. Baseline characteristics between subgroups were evaluated. Kaplan-Meier survival analysis was performed with bootstrapping to construct 95% confidence intervals.

Results

Amongst all patients, 812 (9.1%) were more likely to benefit from off-pump CABG with a hazard ratio of 1.64±0.83, indicating increased long term mortality with on-pump surgery. In contrast, 8,074 patients (90.9%) were in subgroup B, with a hazard ratio of 0.75±0.16, indicating decreased mortality with on-pump surgery. Subgroup A had a net benefit of 5.51±6.05 months from off-pump CABG, while subgroup B had a net benefit of 1.85±1.29 months with use of

cardiopulmonary bypass. The top five model features favoring off-pump CABG were increased age, presence of severe mitral regurgitation, infective endocarditis, preoperative cardiogenic shock, and second-time redo cardiac surgery. The top five model features favoring on-pump CABG were preoperative steroid use, hyspanic or latino ethnicity, preoperative syncope, Native Hawaiian or Pacific Islander, and history of intravenous drug abuse.

Conclusion

Novel machine learning techniques, such as CMHE, have the potential to elucidate novel insights into which patients benefit from on- versus off-pump CABG. Rather than apply a single treatment to all patients, these methods may help guide patient management decisions and optimize care for all patients requiring surgical revascularization.

References

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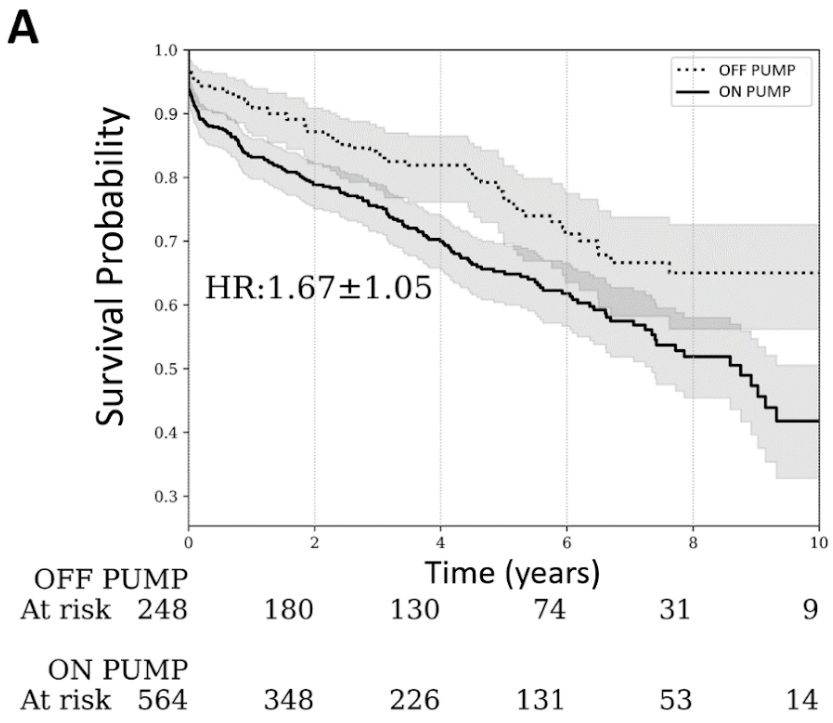
Figure 1. Kaplan-Meier curves of patients in subgroup A who are more likely to benefit from off-pump surgery and subgroup B, who are more likely to benefit from on-pump CABG.



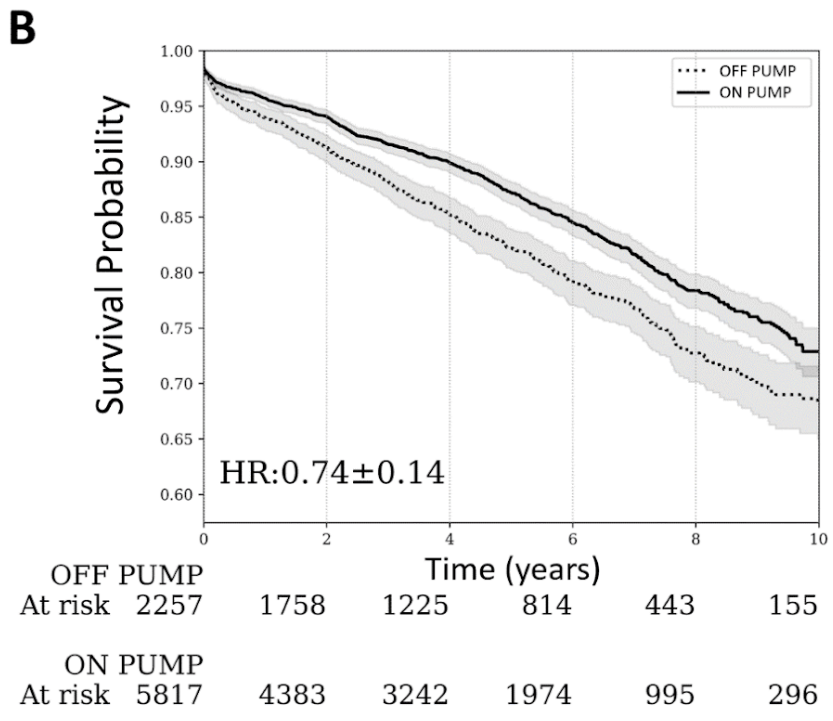


Table 1. Baseline characteristics and top five feature weights for subgroups favoring on-pump or off-pump coronary artery bypass grafting.

Baseline Characteristics/ Model Features	Entire Cohort (N = 8,886)	Group Favoring On-Pump CABG (N =8,074)	Group Favoring Off-Pump CABG (N = 812)	Feature Weights
Top 5 Features for Supporting Off-Pump CABG				
Age (years)	65.9±10.2	64.9±9.9	75.9±7.4	0.289
Severe Mitral Regurgitation	0.8% (72)	0.6% (52)	2.5% (20)	0.249
Infective Endocarditis	0.0% (4)	0.0% (3)	0.1% (1)	0.221
Cardiogenic Shock	2.3% (202)	1.3% (105)	11.9% (97)	0.191
Second-time Redo Cardiac Surgery	0.2% (16)	0.2% (13)	0.4% (3)	0.189
Top 5 Features for Supporting On-Pump CABG				
History of IV Drug Abuse	4.9% (435)	5.4% (434)	0.1% (1)	-0.174
Race - Native Hawaiian or Pacific Islander	0.1% (7)	0.1% (7)	0.0% (0)	-0.186
Preoperative Syncope	3.3% (289)	3.4% (274)	1.8% (15)	-0.206
Hispanic or Latino Ethnicity	0.5% (48)	0.6% (46)	0.2% (2)	-0.264
Preoperative Steroid Use	2.2% (195)	2.3% (188)	0.9% (7)	-0.306