ACC.25

Development and External Validation of a Deep Learning ECG Model for Risk Stratification of Coronary Revascularization Need in the ED

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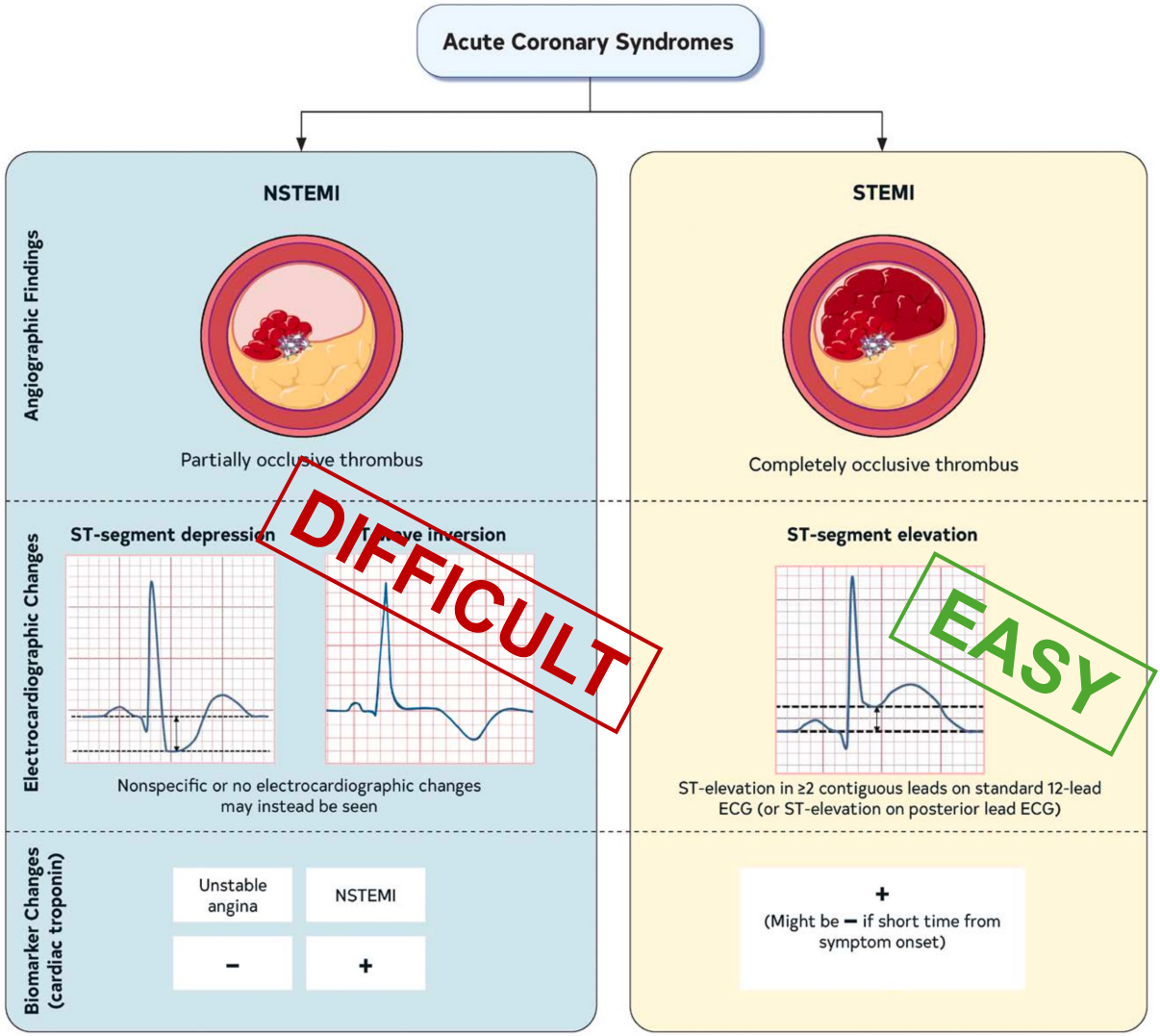
AMERICAN COLLEGE of CARDIOLOGY

Introduction

- Acute Coronary Syndrome (ACS) is one of the **most frequent causes** for emergency department (ED) visits across the globe
- The electrocardiogram (**ECG**) is the **most important diagnostic tool** in the initial assessment of patients with suspected ACS
- Patients with **ST elevation** (STE) undergo **immediate coronary angiography** to reduce reperfusion delay
- ECG changes in **Non-STE** ACS are **heterogenous**, **nonspecific**, and have high **inter-rater variability**



Rao et al. Circulation. 2025;151:e00–e00

Introduction

- Further diagnostic workup of **Non-STE ACS** patients heavily relies on biomarker changes (**high-sensitivity cardiac troponins**)
- Troponin **turnaround time** can be **prolonged** due to delayed ordering of the test, blood sampling, sample transport, laboratory processing, and reviewing results
- **Troponin elevation** occurs in many conditions **other than type 1 MI** (e.g., renal dysfunction, respiratory failure, hypotension, anemia, arrhythmia, heart failure)

Myocardial injury related to acute myocardial ischaemia because of oxygen supply/demand imbalance (Type 2 MI)
Reduced myocardial perfusion, e.g.:
• Coronary artery spasm, microvascular dysfunction
• Coronary embolism
• Non-atherosclerotic coronary artery dissection
• Sustained bradyarrhythmia
• Hypotension or shock
• Respiratory failure
• Severe anaemia
Increased myocardial oxygen demand, e.g.:
• Sustained tachyarrhythmia
• Severe hypertension with or without left ventricular hypertrophy

Other causes of myocardial injury
Cardiac conditions:
• Heart failure
• Myocarditis[a]
• Cardiomyopathy (any type)
• Takotsubo syndrome
• Cardiac contusion or cardiac procedures (CABG, PCI, valvular interventions, ablation, pacing, cardioversion, or endomyocardial biopsy)

CABG, coronary artery bypass grafting; MI, myocardial infarction; PCI, percutaneous coronary intervention.
[a]Includes myocardial extension of endocarditis or pericarditis.

Systemic conditions:
• Sepsis, infectious disease
• Chronic kidney disease
• Stroke, subarachnoid haemorrhage
• Pulmonary embolism, pulmonary hypertension
• Infiltrative diseases (e.g. amyloidosis, sarcoidosis, haemochromatosis, scleroderma)
• Myocardial drug toxicity or poisoning (e.g. doxorubicin, 5-fluorouracil, trastuzumab, snake venoms)
• Critically ill patients
• Hypo- and hyper-thyroidism
• Strenuous exercise
• Rhabdomyolysis

Byrne et al. Eur Heart Journal (2023) 44, 3720–3826

Objective

- Identify **ECG patterns** that are **indicative** of whether a patient is likely to require **coronary revascularization**
- Provide an **objective screening tool** to guide further clinical assessment and **reduce diagnostic uncertainty**
- Help **identify patients** who might benefit from an early **invasive management strategy**

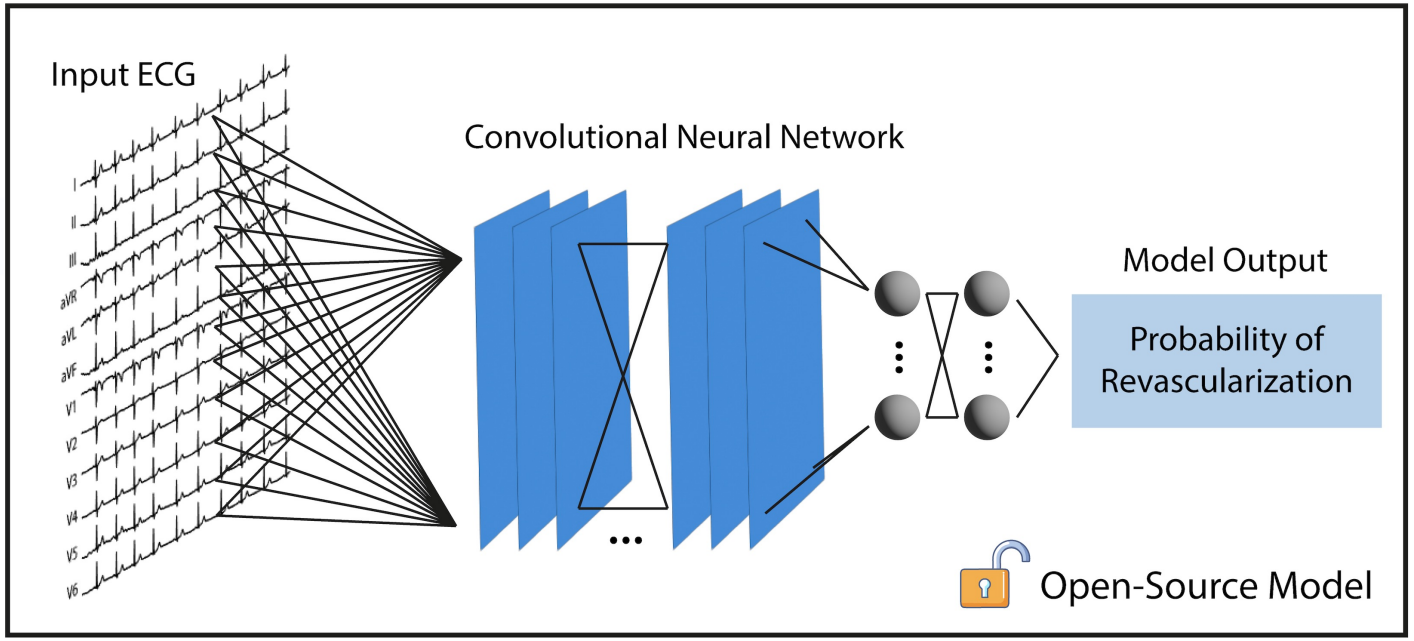
Study design

Target Population: Patients presenting to the emergency department (ED)

Training Outcome: Coronary Revascularization with PCI or CABG

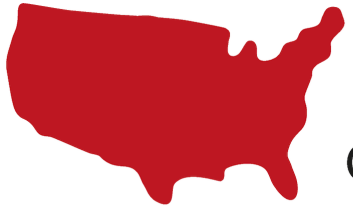
Input Data: 12-lead ECG at ED admission

Inclusion of a total of **n = 199,359** ED visits from two international cohorts



- Pragmatic choice of training outcome:
  - Undergoing a revascularization procedure was **clearly defined** in the datasets
  - Clinical revascularization decisions capture a **comprehensive clinical decision-making** pathway, including patient evaluation, risk assessment, and diagnostic investigations
- Detection of **Type 1 MI** was evaluated during external validation

Patient cohorts



US Cohort

n = 180,686 ED visits at Beth Israel Deaconess Medical Center between 2008 and 2022 (MIMIC-IV dataset)

0.6% Coronary Revascularization

80% Training Cohort
n = 144,691

20% Test Cohort
n = 35,995

European Cohort

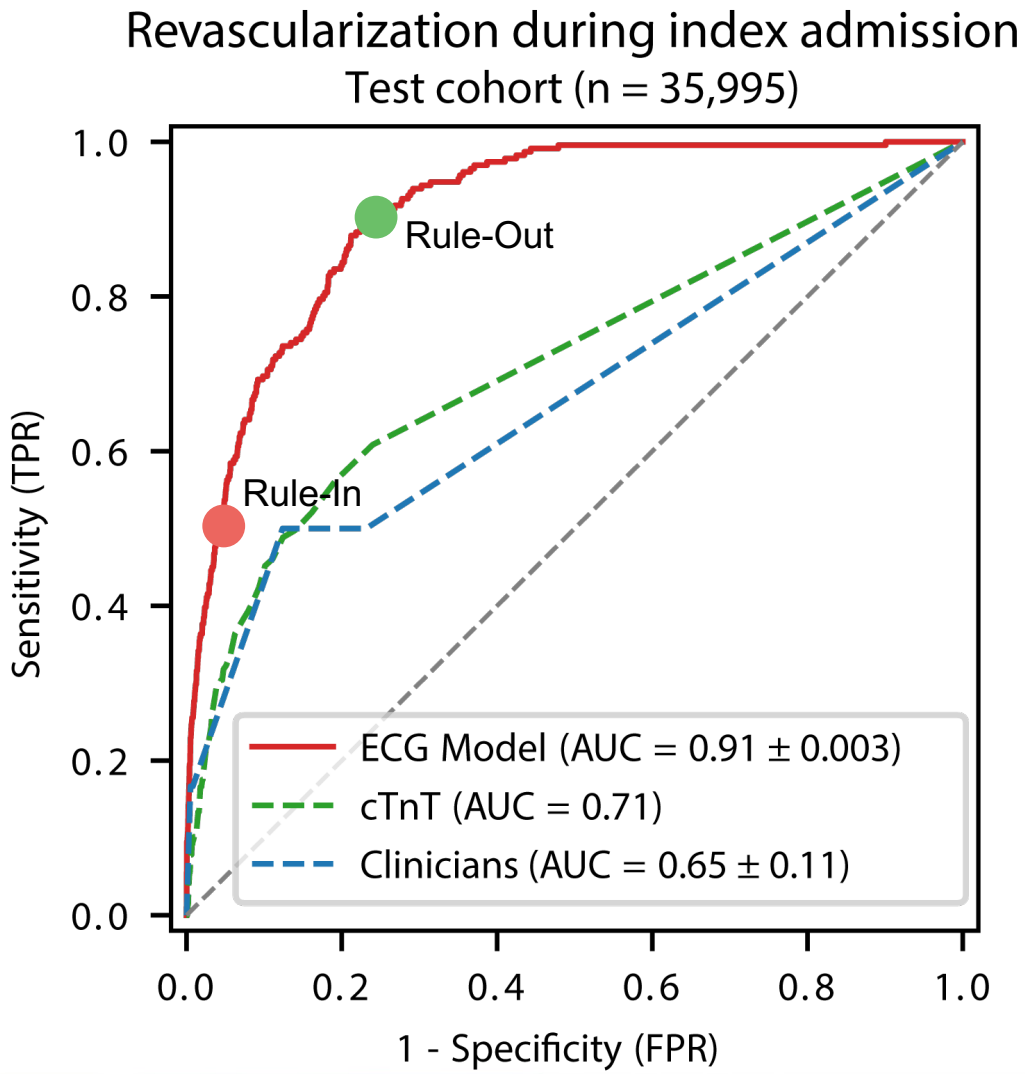
n = 18,673 ED visits at University Hospital Münster between 2018 and 2023

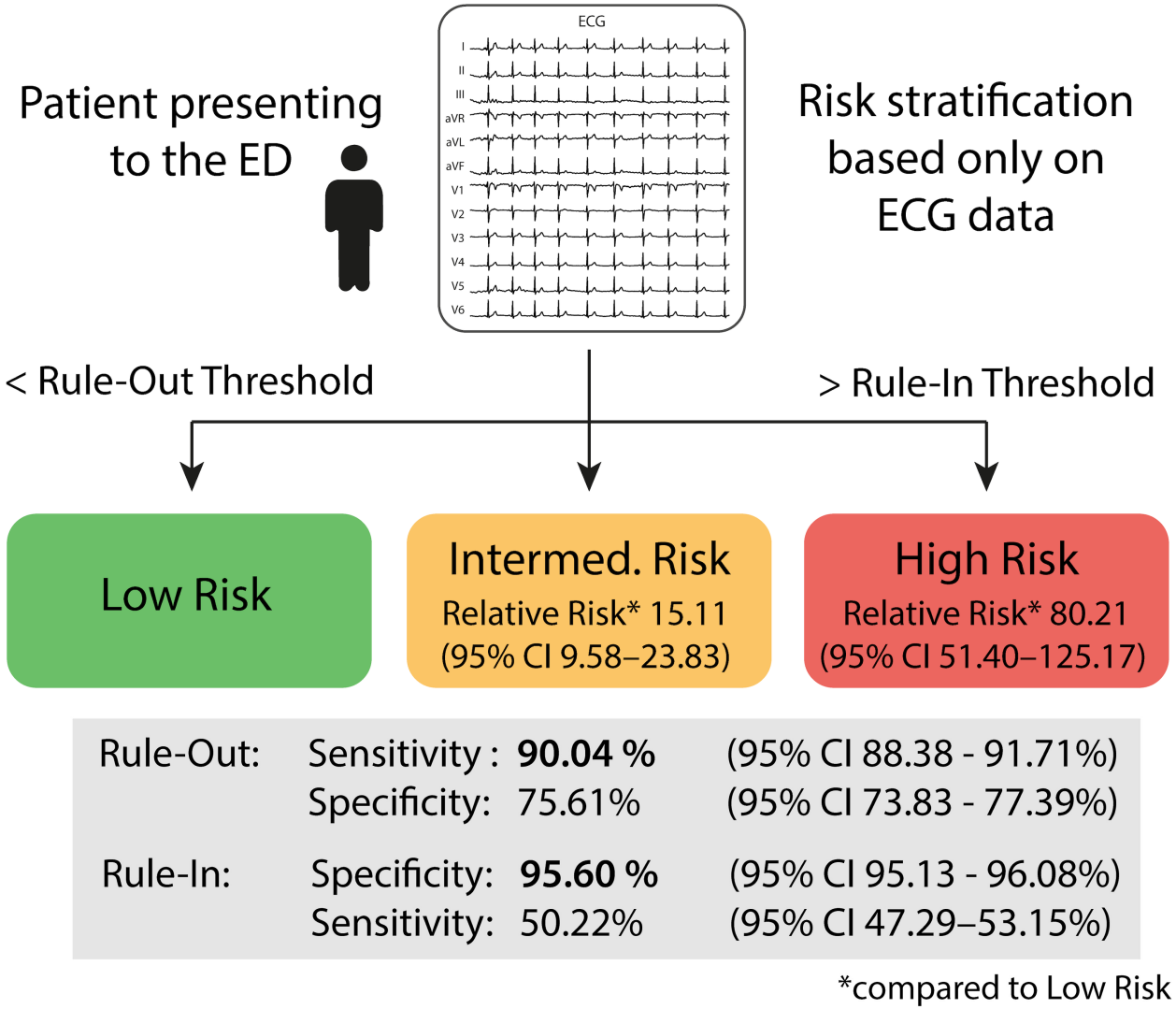
1.5% Coronary Revascularization
n = 274

1% Type 1 myocardial infarction (MI)
n = 185

External validation cohort

Model performance

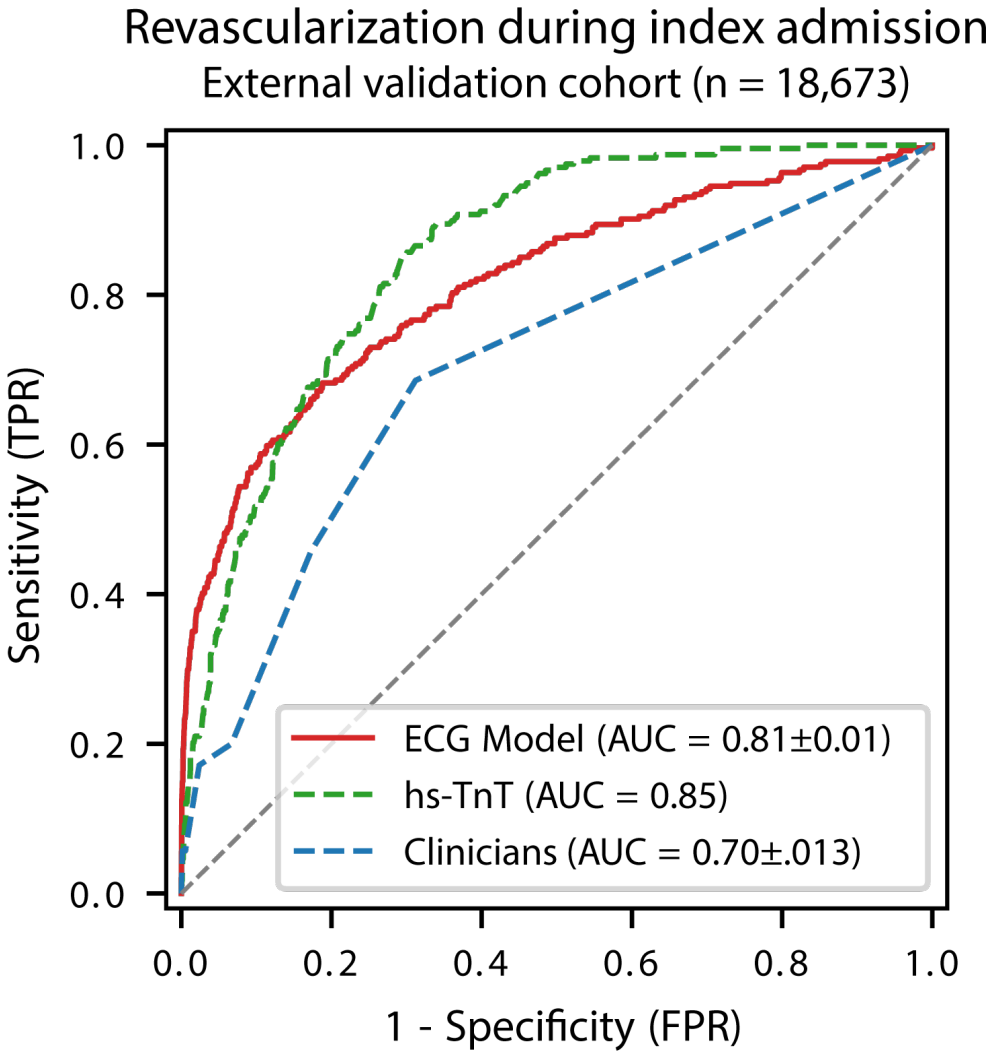


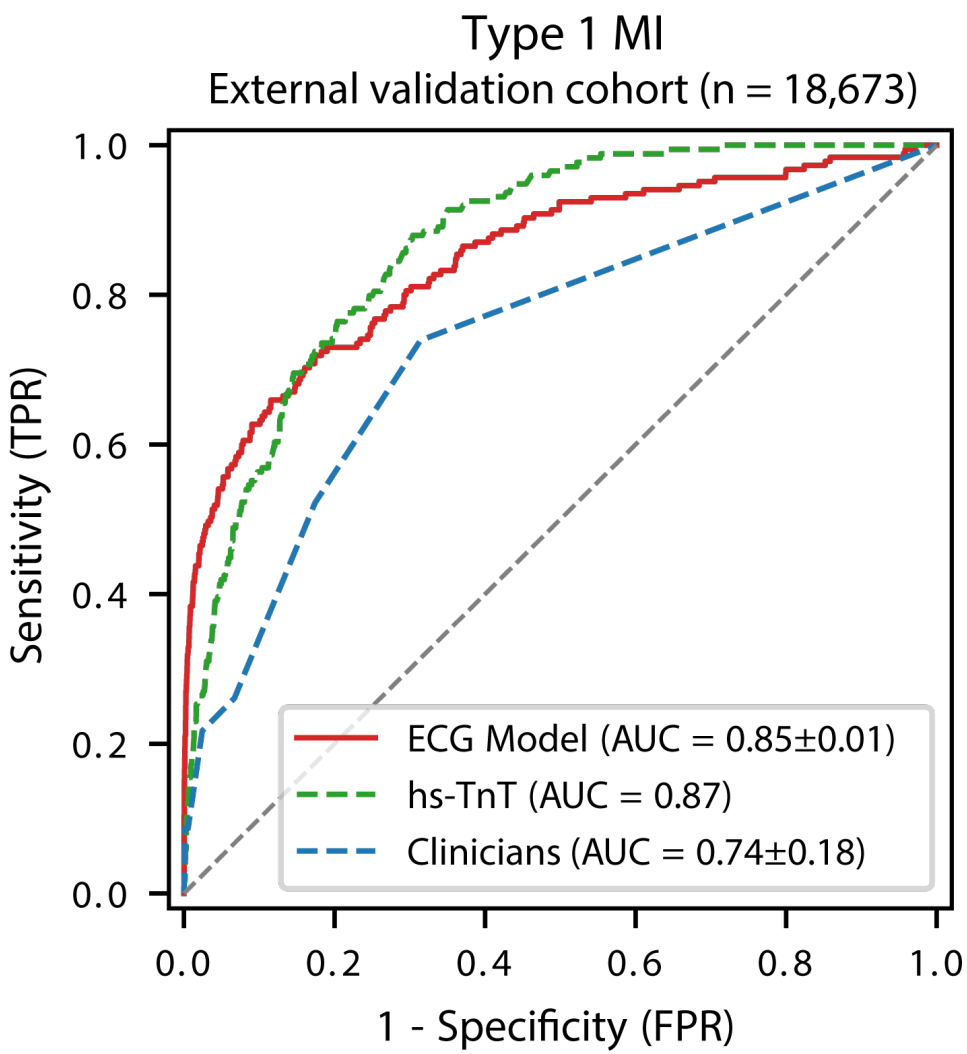


Rule-Out:	Sensitivity :	**90.04 %**	(95% CI 88.38 - 91.71%)
	Specificity:	75.61%	(95% CI 73.83 - 77.39%)
Rule-In:	Specificity:	**95.60 %**	(95% CI 95.13 - 96.08%)
	Sensitivity:	50.22%	(95% CI 47.29–53.15%)

*compared to Low Risk

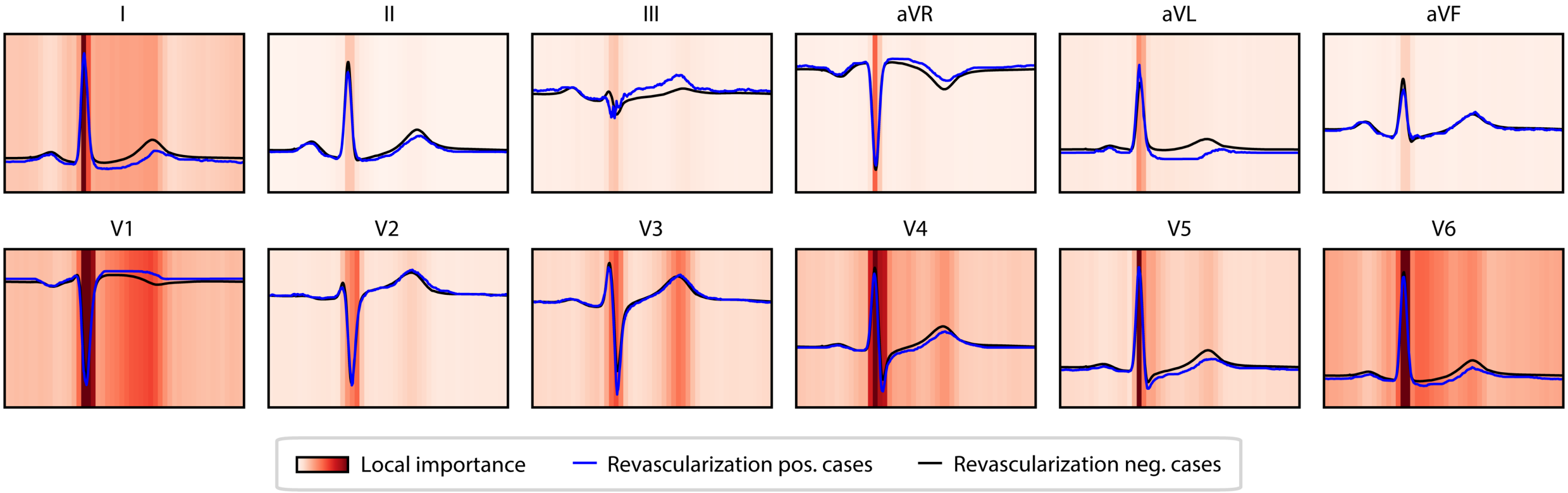
External validation





Model explainability

- Attention maps highlight **ECG segments most relevant** for the model
- Local importance averaged across the test cohort and aligned to median beats



Strengths and Limitations

Strengths

- ✅ Very **large** and **diverse** sample size of nearly **200,000 patients**
- ✅ The model is trained on a **general ED population** to ensure **broad applicability** on ED ECG machines
- ✅ Model appears to have generalized towards actual **type 1 MI detection** despite “noisy” training labels

Limitations

- ⚠️ The datasets are sourced from **only 2 centers**
- ⚠️ The **low outcome prevalence** in a general ED population (0.6-1.5%) means many **false positives**
- ⚠️ Model learns from **historical clinical decisions** that are potentially biased or have questionable clinical benefit

Conclusions

- The ECG model detected patients requiring coronary revascularization with **higher diagnostic accuracy** than clinician ECG interpretation or conventional cardiac troponin T assays
- **Type 1 MI detection** was better than clinicians and **approximated** the diagnostic accuracy of **high-sensitivity troponin T**
- **Open-Source** nature enables **continuous model improvements** by the scientific community and **fine-tuning** of model weights to distinct patient populations
- **Future research is needed** for prospective validation of the model in clinical practice, assessing its **impact on clinical workflows** and **patient outcomes**

Now online!

European Heart Journal

ESC European Society of Cardiology

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Büscher et al. (2025) *European Heart Journal.* doi:10.1093/eurheartj/ehaf254

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Thank you!

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