ResNet-based ECG Diagnosis of Myocardial Infarction in the Emergency Department

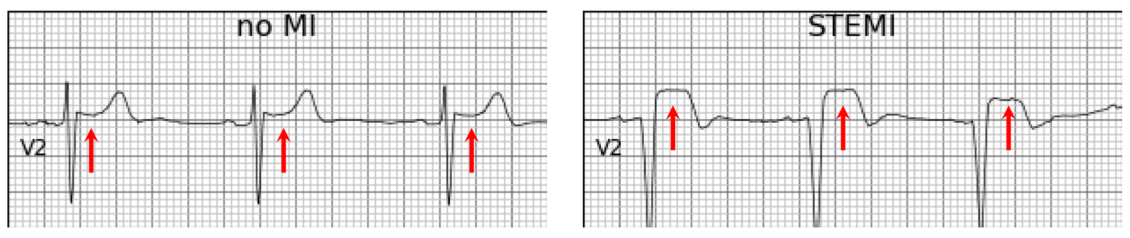
UPPSALA UNIVERSITET

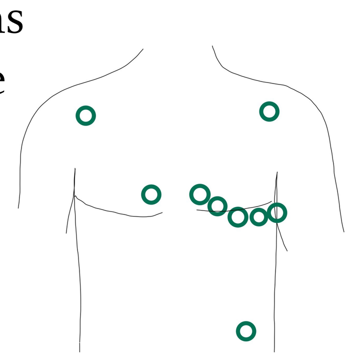
Daniel Gedon[1], Stefan Gustafsson[1,2], Erik Lampa[1], Antônio H. Ribeiro[1], Martin J. Holzmann[3], Thomas B. Schön[1], Johan Sundström[1,4]

[1]Uppsala University, Sweden; [2]Sence Research AB, Sweden;
[3]Karolinska University Hospital and Karolinska Institutet, Sweden;
[4]University of New South Wales, Australia.

Background

- Emergency Department (ED): chaotic environment; need for decision support.
- Myocardial Infarctions (MIs):
  - High burden on public health.
  - False negatives: Significant number of MIs missed yearly.
  - False positives: Many hospitalized for suspected MI do not have the condition.
- Electrocardiogram (ECG).
  - ST-elevation MI (STEMI) → detect clearly in ECG by humans
  - non-ST-elevation-MI (NSTEMI) → unknown pattern; require





Goal: Provide well-calibrated probabilities for STEMI/NSTEMI from ECGs at the ED.

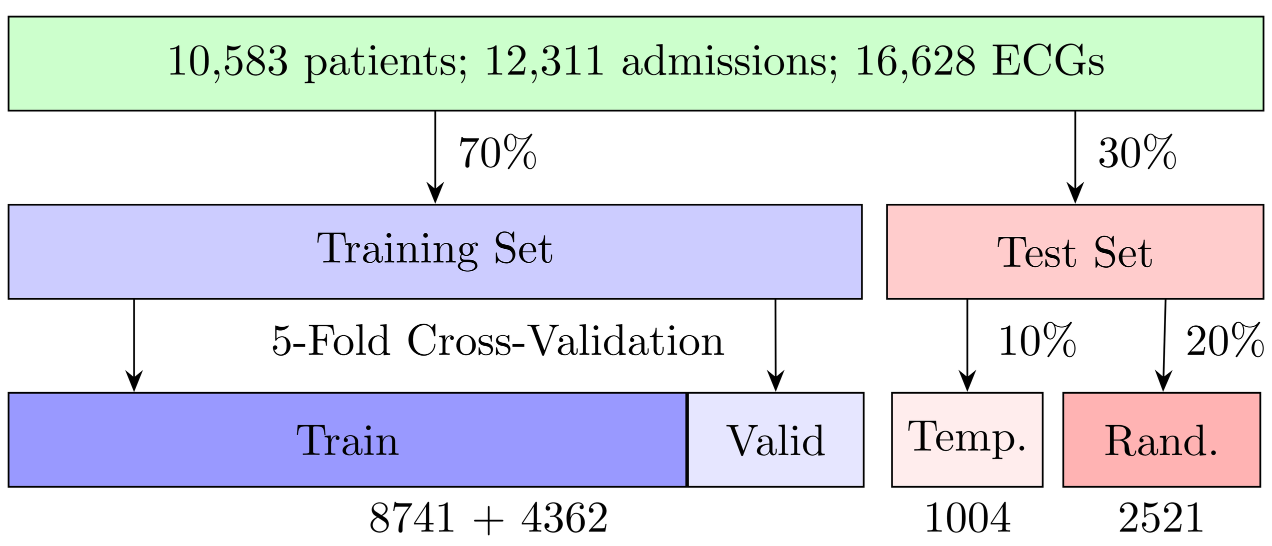
Our contribution:
- Extract a novel data set resembling the real-world setup.
- Deep learning based model for diagnosing MIs in the ED.

⇒ difficult real-world scenario with immediate benefits for practicing physicians.

Data Set

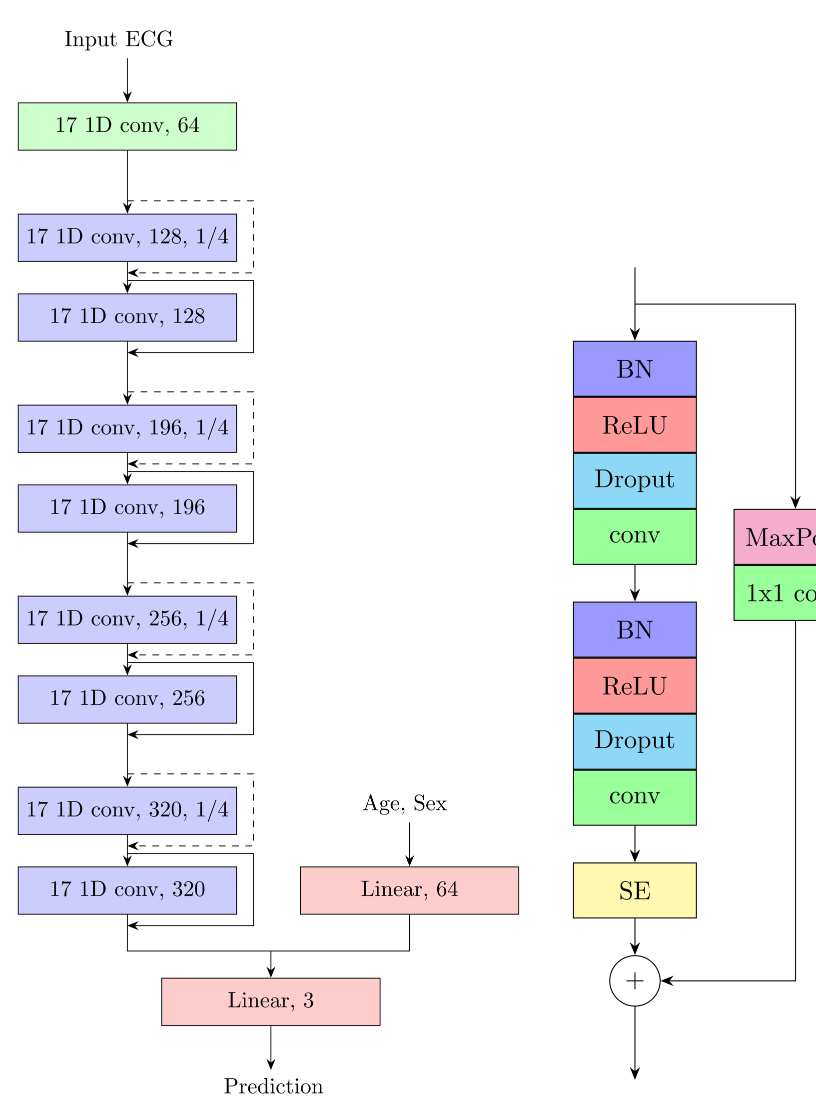
- Standard 10 seconds 12-lead ECGs.
- Adult patients at local ED visits in Stockholm region between 2007 and 2016.
- High risk patients → admitted to coronary care unit (CCU)
- Labels:
  - SWEDEHEART registry [1]: STEMI (11%), NSTEMI (33%), Control (56%)
  - By discharging physician that followed patient journey during hospitalisation.
- Filter to ensure:
  - inclusion of at event before-treatment ECGs
  - availability of outcome label
  - no missing ECG leads

⇒ real-world scenario for unsolved problem



Model Architecture

- Limit to traces, age, sex as input → high transportability of model
- Extension of [2]:
  - ResNet-based architecture.
  - Additional SE-net blocks.
  - Hyperparameter search.
  - Ensemble of 5 models.
- Model calibration.
  - Model's probability estimates reflect the ground truth empirical class frequencies.
  - Important for clinical use.

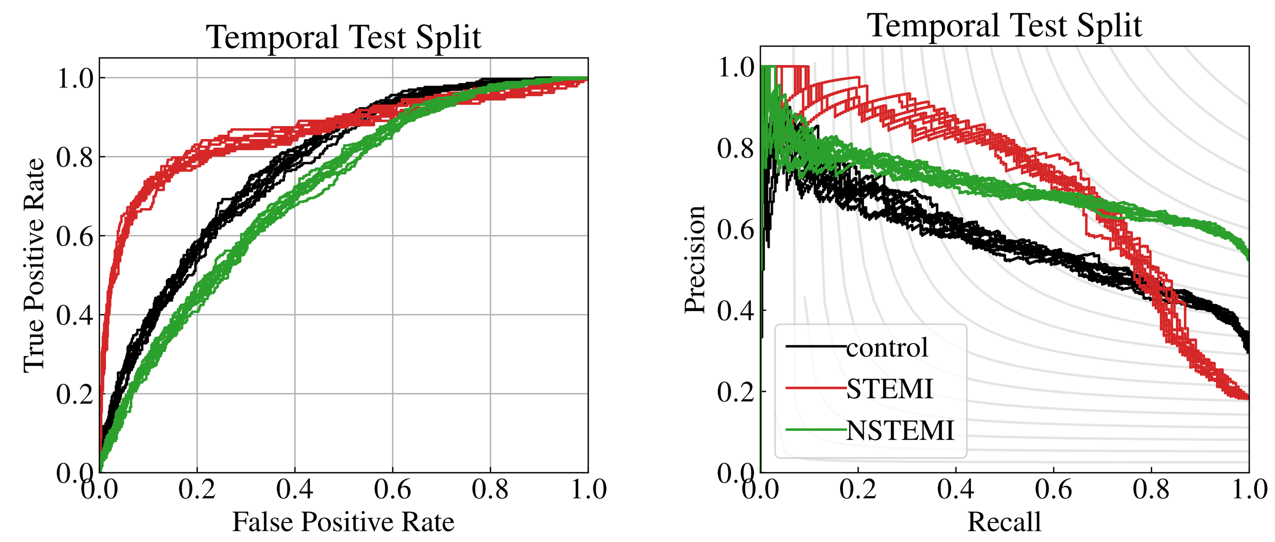


Results

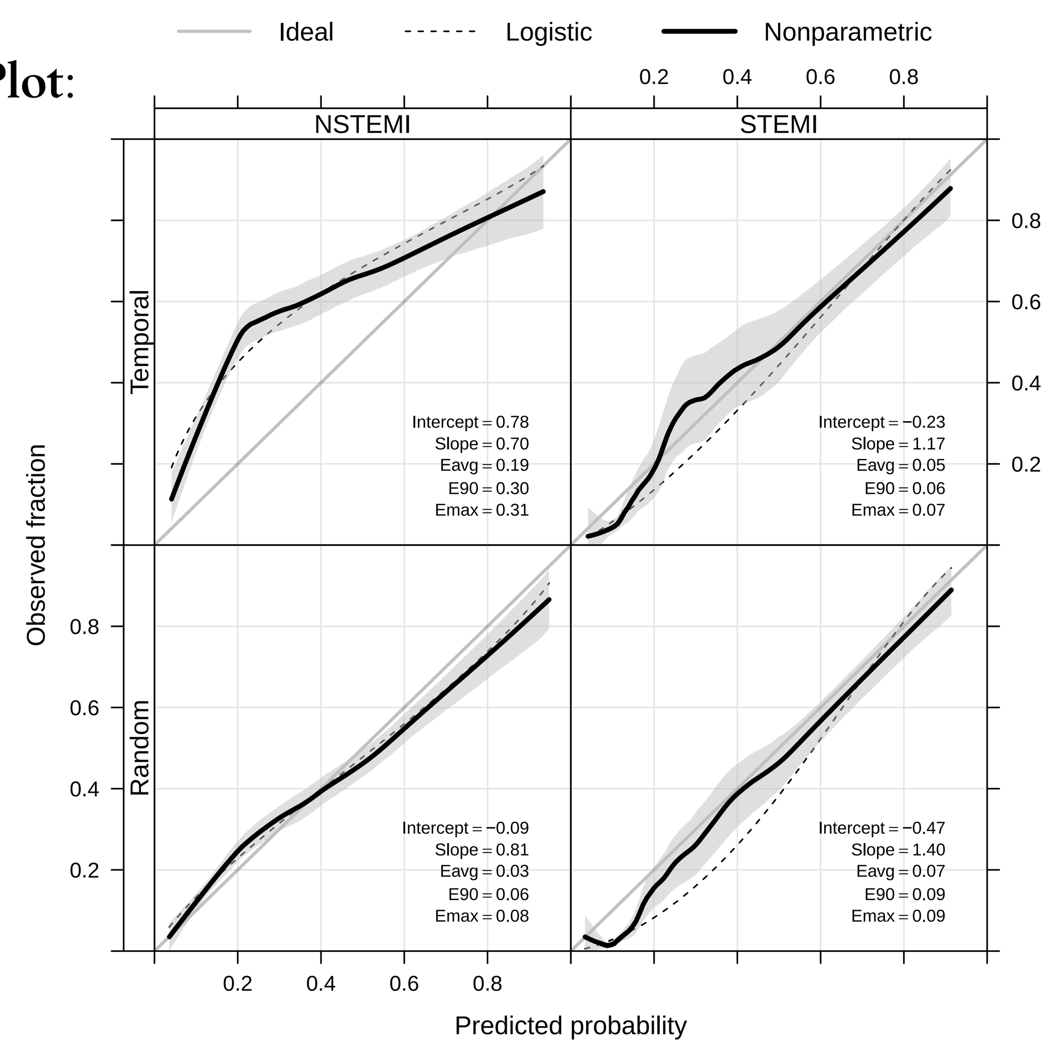
Main results over 10 models seeds:

		Random	Temporal
Accuracy	Control	0.75 (0.007)	0.44 (0.011)
	NSTEMI	0.57 (0.012)	0.72 (0.010)
	STEMI	0.71 (0.013)	0.72 (0.020)
AUROC	NSTEMI	0.76 (0.003)	0.74 (0.003)
	STEMI	0.85 (0.002)	0.82 (0.003)
AUPR	NSTEMI	0.69 (0.003)	0.64 (0.005)
	STEMI	0.76 (0.005)	0.64 (0.006)
Brier	NSTEMI	0.19 (0.001)	0.27 (0.002)
	STEMI	0.10 (0.001)	0.13 (0.001)
ECE	Multiclass	0.25 (0.004)	0.11 (0.012)

Receiver-Operator Curve and **Precision-Recall-Curve**:

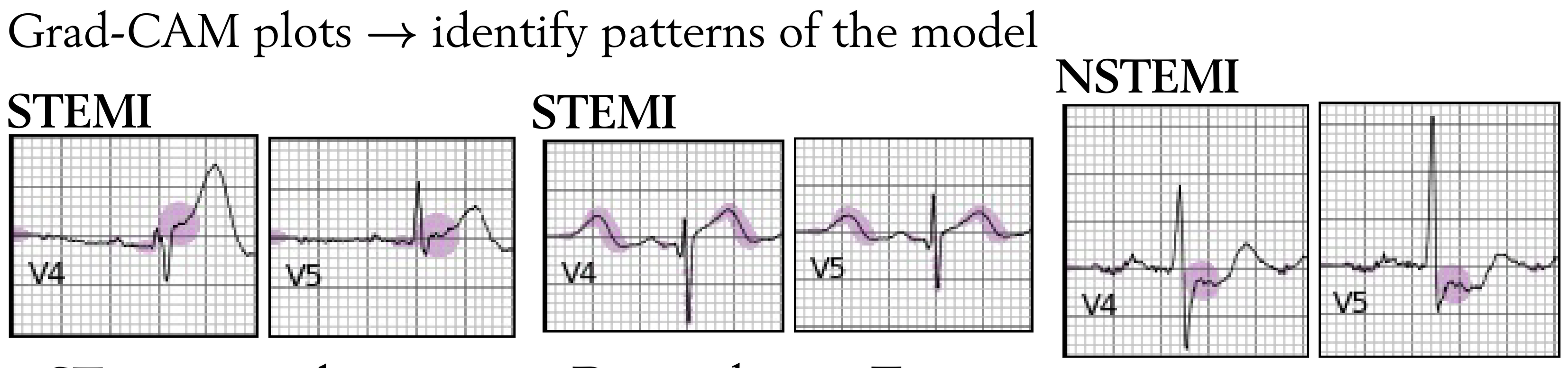


Calibration Plot:



Model Analysis

Grad-CAM plots → identify patterns of the model



STEMI:
- ST-segment elevation
- typical for humans

STEMI:
- Down-sloping T-wave
- untypical for humans

NSTEMI:
- ST-segment depression
- humans would not suspect a MI

Acknowledgment

Supported by the Kjell and Märta Beijer Foundation, Anders Wiklöf, the Wallenberg AI, Autonomous Systems and Software Program (WASP) funded by Knut and Alice Wallenberg Foundation, and Uppsala University via AI4Research.

References

[1] https://www.ucr.uu.se/swedeheart/dokument-sh/variabellista
[2] Ribeiro, A.H., Ribeiro, M.H., Paixão, G.M.M. et al. Automatic diagnosis of the 12-lead ECG using a deep neural network. Nat Commun 11, 1760 (2020).

daniel.gedon@it.uu.se, stefan.gustafsson@medsci.uu.se