

**iScience, Volume 25**

## **Supplemental information**

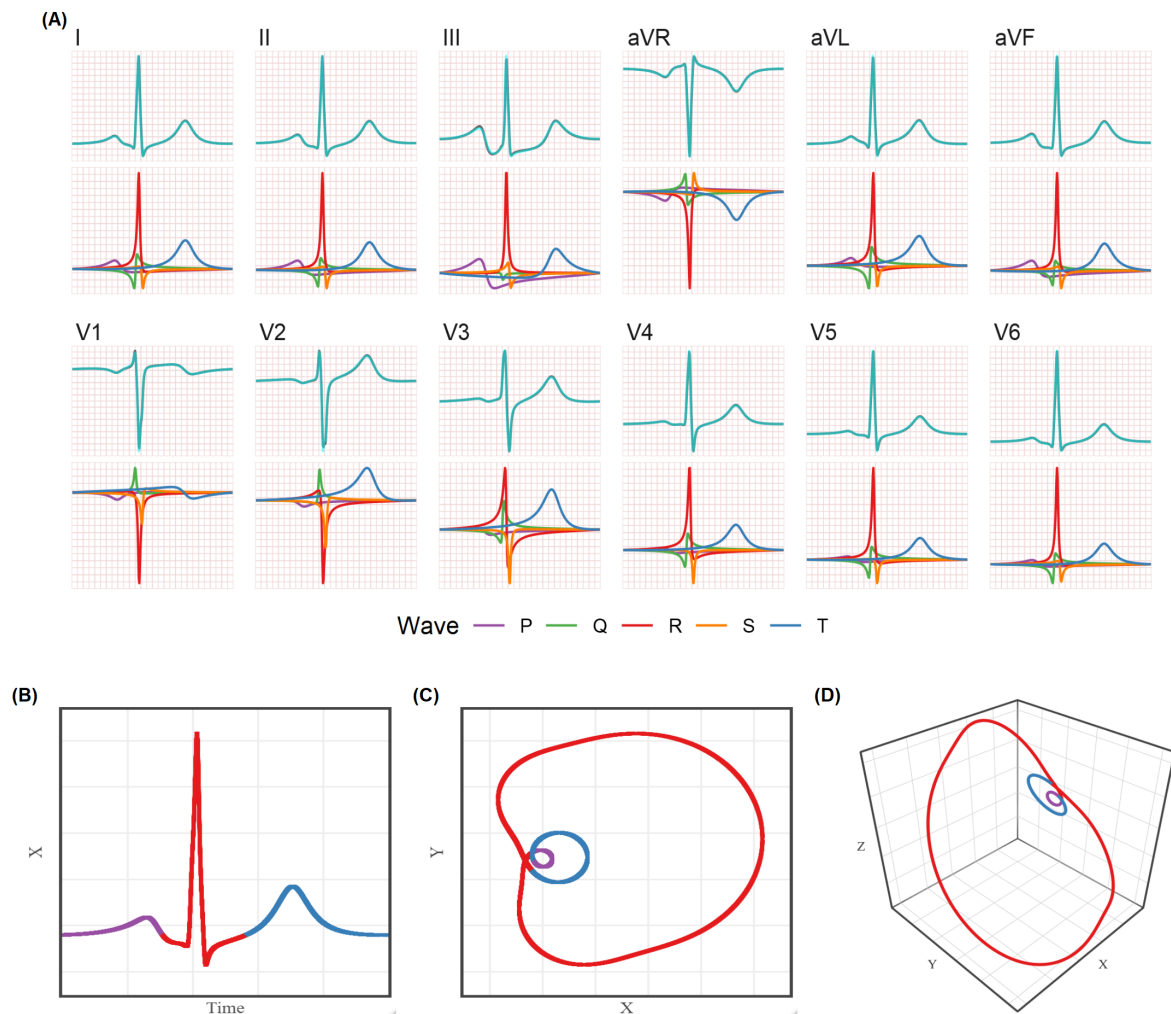
**A unique cardiac electrocardiographic**

**3D model. Toward interpretable AI diagnosis**

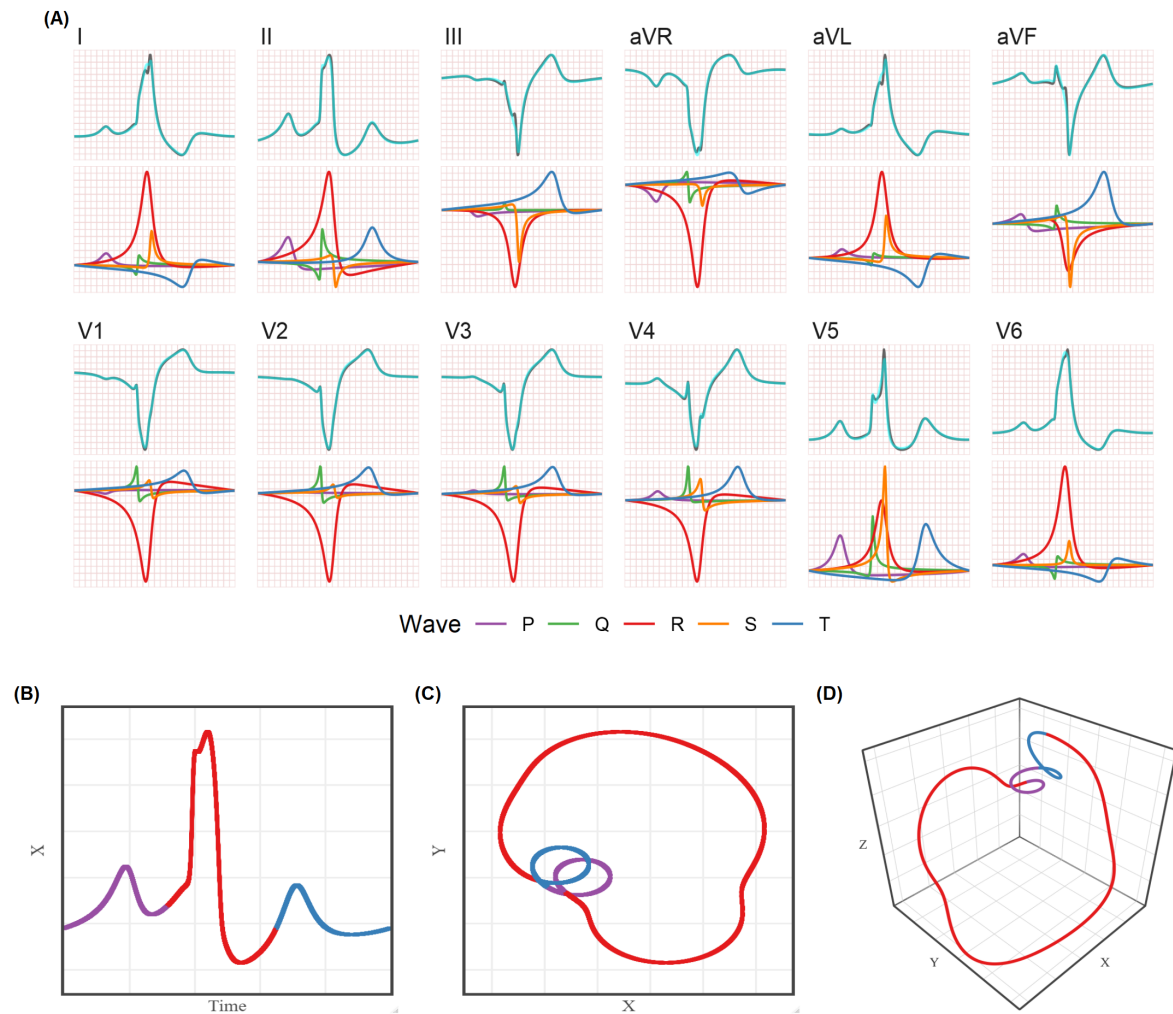
**Cristina Rueda, Alejandro Rodríguez-Collado, Itziar Fernández, Christian Canedo, María Dolores Ugarte, and Yolanda Larriba**

# 1 Supplemental Figures

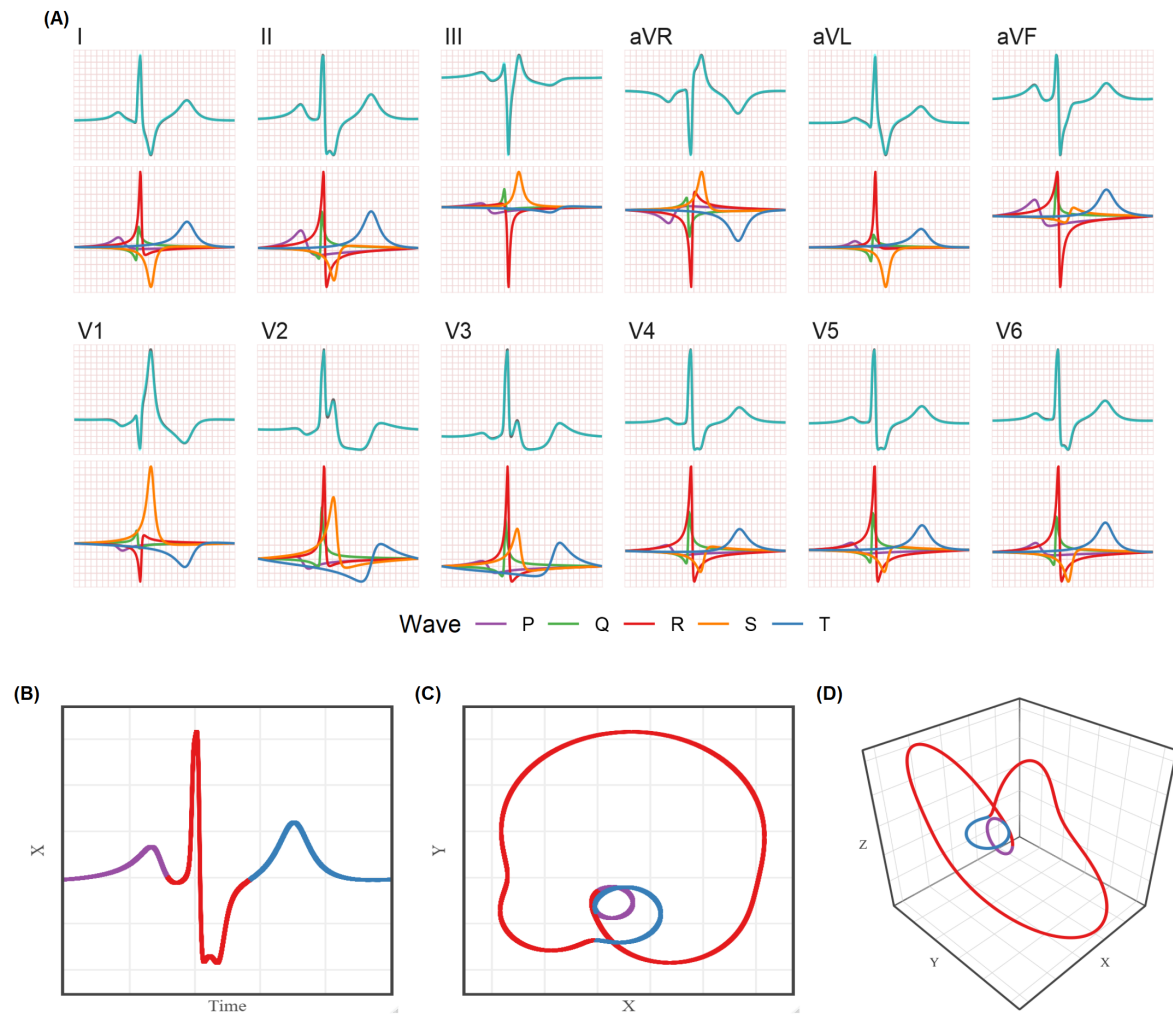
**Figure S1. ECG signal from a NORM heartbeat generated by the  $3DFMM_{ecg}$  model, related to STAR Methods and a section of Results.** (A) Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns. (B), (C), (D): 1D, 2D and 3D representation of the predicted signal, respectively, where  $X = LeadII$ ;  $Y = LeadII^{(i)}$ ;  $Z = LeadV2 - 2 * Y$ . The colours differentiate the  $P$  (purple),  $QRS$  (red) and  $T$  loops (blue).



**Figure S2. ECG signal from a CLBBB heartbeat generated by the 3DFMM<sub>ecg</sub> model, related to STAR Methods and a section of Results.** (A) Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns. (B), (C), (D): 1D, 2D and 3D representation of the predicted signal, respectively, where  $X = \text{LeadII}$ ;  $Y = \text{LeadII}^{(i)}$ ;  $Z = \text{LeadV2} - 2 * Y$ . The colours differentiate the  $P$  (purple),  $QRS$  (red) and  $T$  loops (blue).

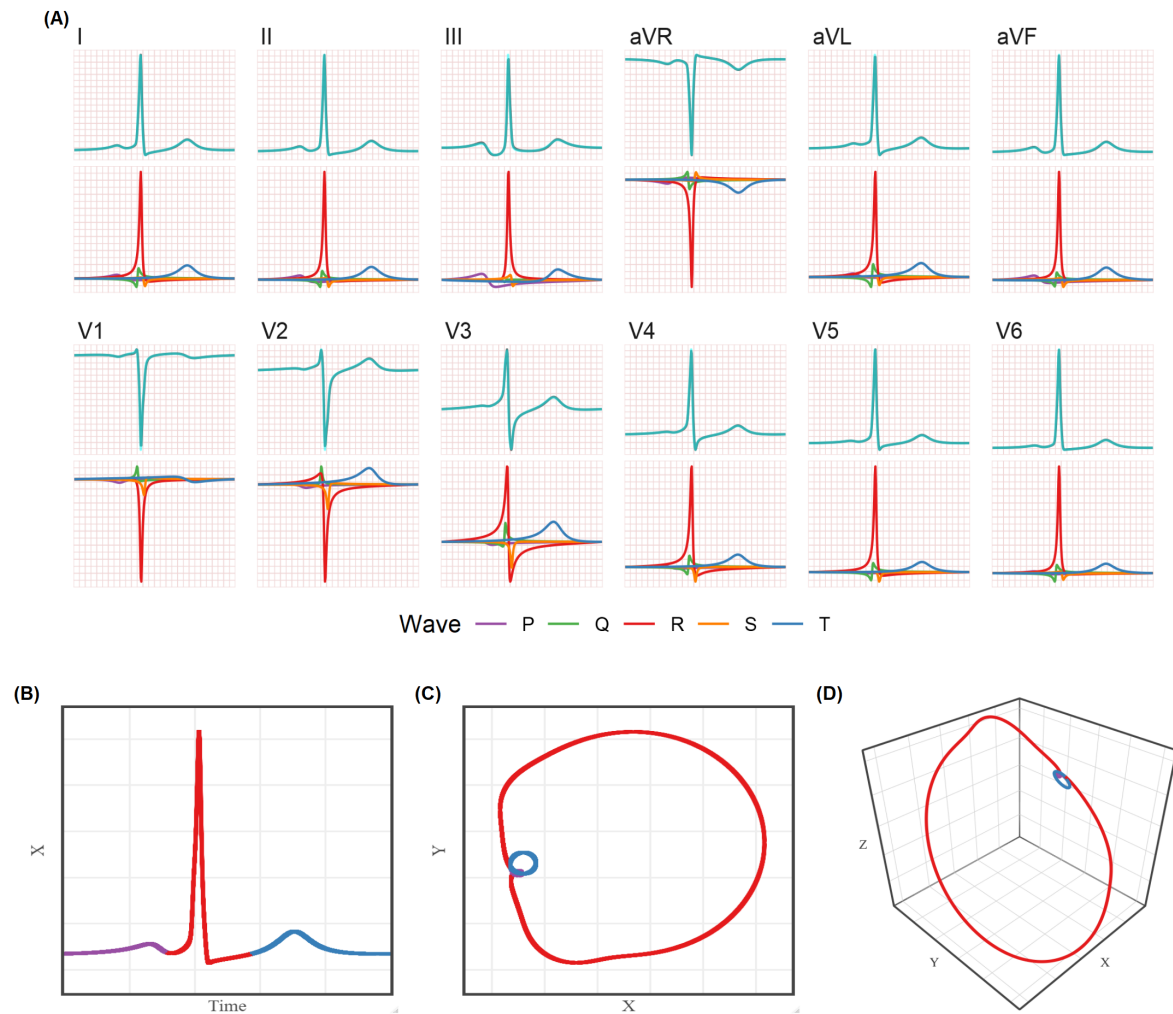


**Figure S3. ECG signal from a CRBBB heartbeat generated by the  $3DFMM_{ecg}$  model, related to STAR Methods and a section of Results.** (A) Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns. (B), (C), (D): 1D, 2D and 3D representation of the predicted signal, respectively, where  $X = LeadII$ ;  $Y = LeadII^{(i)}$ ;  $Z = LeadV2 - 2 * Y$ . The colours differentiate the  $P$  (purple),  $QRS$  (red) and  $T$  loops (blue).

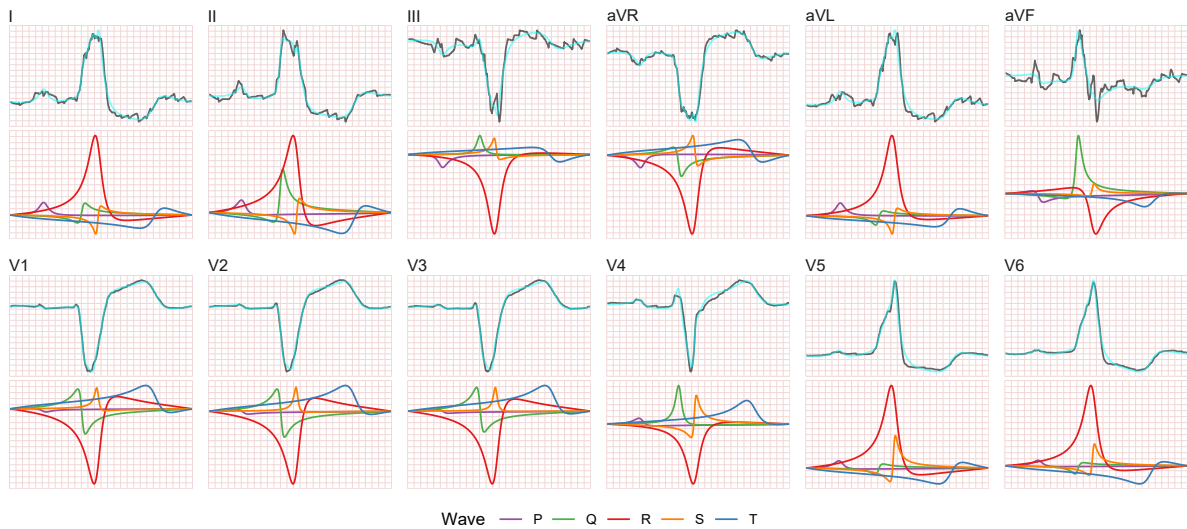




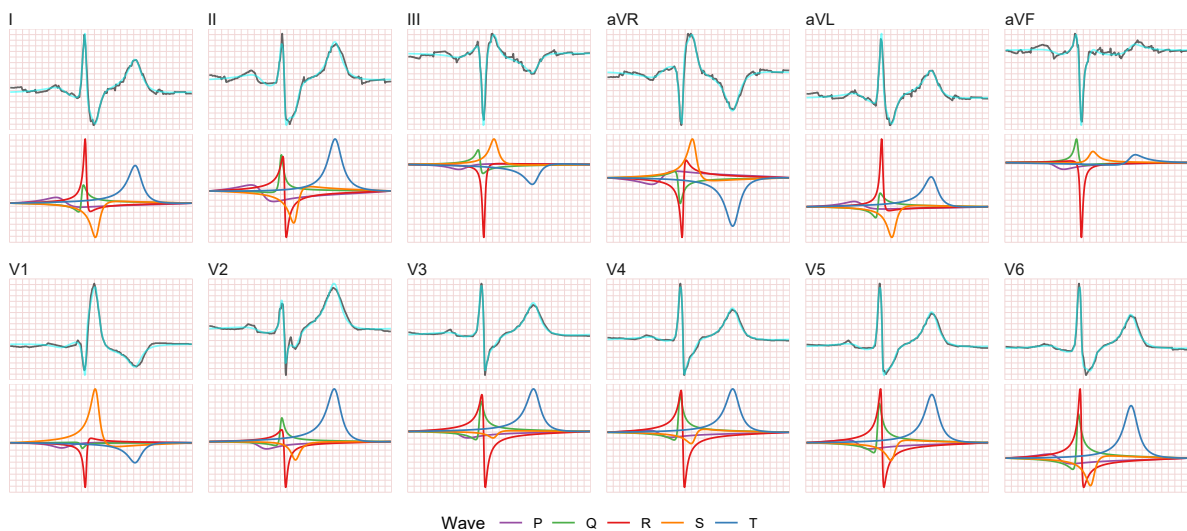
**Figure S4. ECG signal from a HYP heartbeat generated by the  $3DFMM_{ecg}$  model, related to STAR Methods and a section of Results.** (A) Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns. (B), (C), (D): 1D, 2D and 3D representation of the predicted signal, respectively, where  $X = LeadII$ ;  $Y = LeadII^{(i)}$ ;  $Z = LeadV2 - 2 * Y$ . The colours differentiate the  $P$  (purple),  $QRS$  (red) and  $T$  loops (blue).



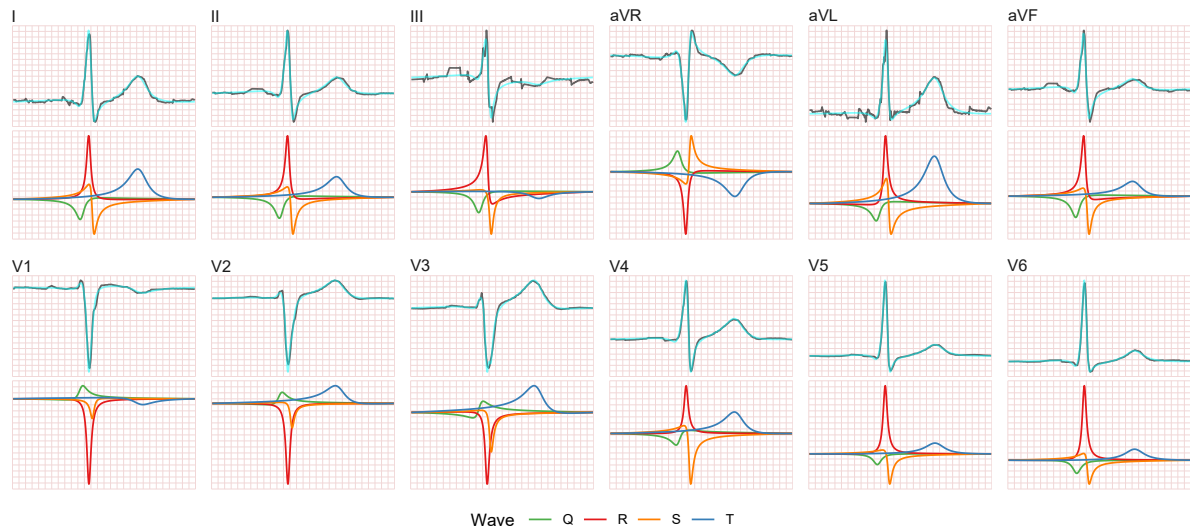
**Figure S5. 12-lead ECG signal from patient id 1710 in PTB-XL database, beat n° 3. Cardiological diagnostic: CLBBB. Related to STAR Methods, Introduction and a section of Results.** Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns.



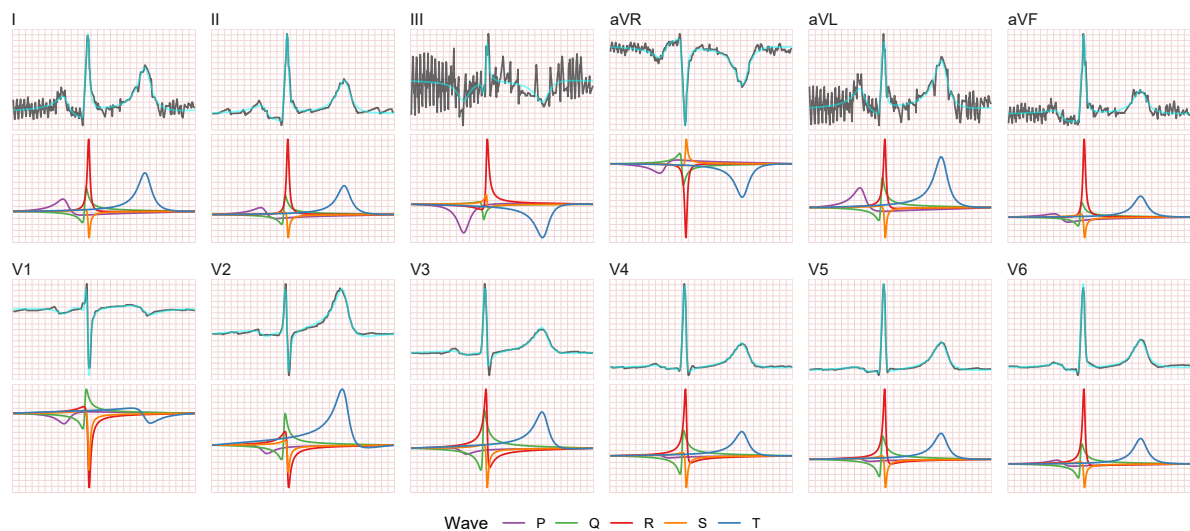
**Figure S6. 12-lead ECG signal from patient id 195 in PTB-XL database, beat n° 1. Cardiological diagnostic: CRBBB. Related to STAR Methods, Introduction and a section of Results.** Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns.



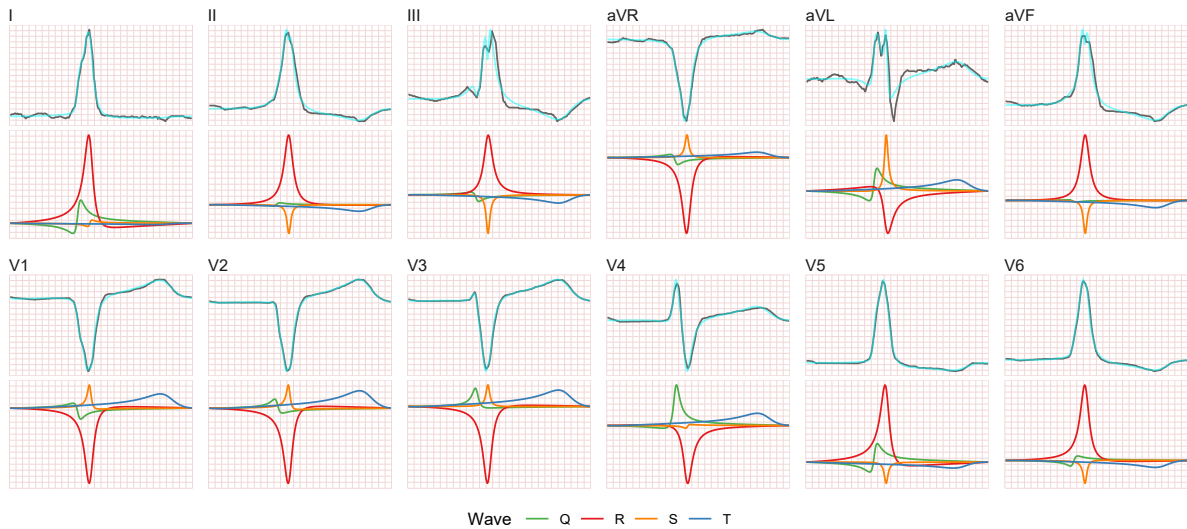
**Figure S7. 12-lead ECG signal from patient id 30 in PTB-XL database, beat n°6. Cardiological diagnostic: HYP. Related to STAR Methods, Introduction and a section of Results.** Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns.



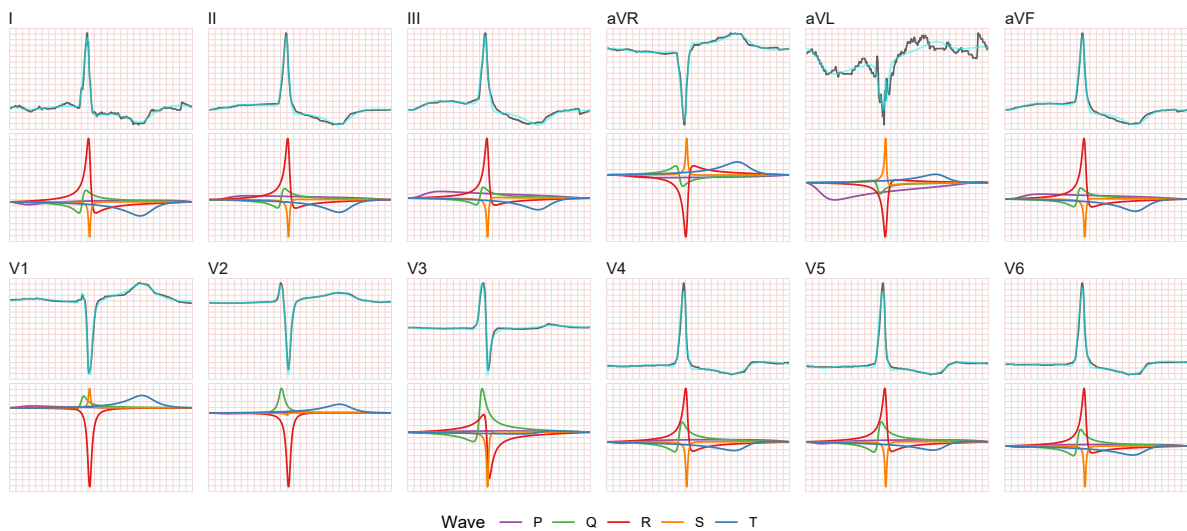
**Figure S8. 12-lead ECG signal from patient id 2838 in PTB-XL database, beat n°7. Noisy ECG signal for a NORM subject. Related to STAR Methods, Introduction and a section of Results.** Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns.



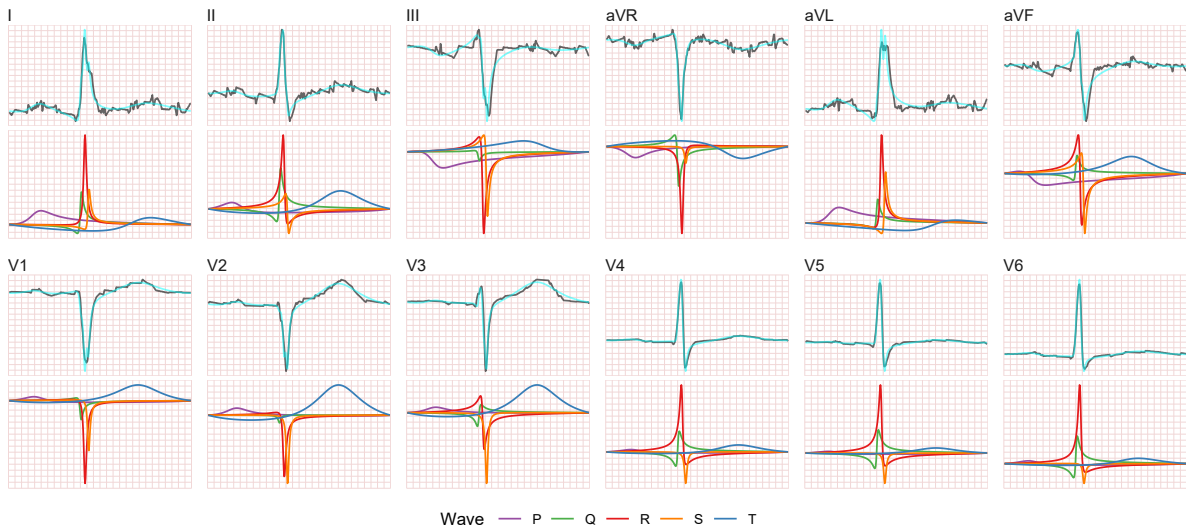
**Figure S9. 12-lead ECG signal from patient id 12507 in PTB-XL database, beat n°11. Cardiological diagnostic: Incomplete LBBB. Related to STAR Methods, Introduction and a section of Results.** Absence of *P* wave. Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns.



**Figure S10. 12-lead ECG signal from patient id 1233 in PTB-XL database, beat n°12. Cardiological diagnostic: STTC (ST/T Change). Related to STAR Methods, Introduction and a section of Results.** Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns.



**Figure S11.** 12-lead ECG signal from patient id 962 in PTB-XL database, beat n°8. Cardiological diagnostic: MI (Myocardial Infarction). Related to STAR Methods, Introduction and a section of Results. Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns.



**Figure S12.** 12-lead ECG signal from patient id 711 in PTB-XL database, beat n°5. Cardiological diagnostic: CLBBB with QRS notching. Related to STAR Methods, Introduction and a section of Results. Top panels: 12-lead observed (grey) and predicted (cyan) signals. Bottom panels: 12-lead FMM wave patterns.

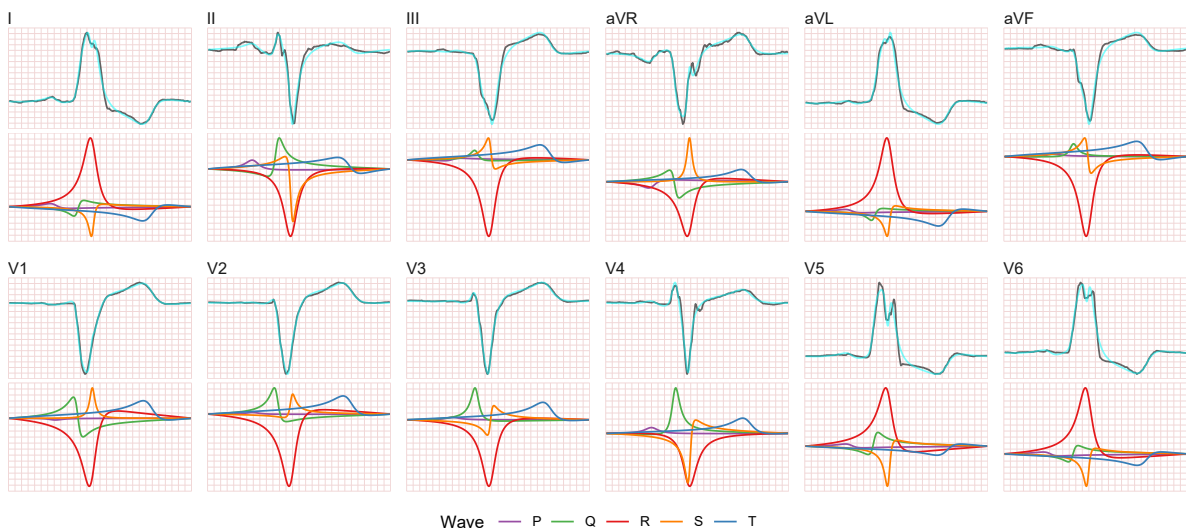




Figure S13. Four steps ECG data preprocessing outline, related to STAR Methods. Orange lines in *Step 1* show baseline drift. Red dots in *Steps 2* and *3* indicate single-lead *QRS* detections. The blue dots in *Step 3* locate multi-lead *QRS* detections. Blue dashed lines in *Step 4* illustrates heartbeat segmentation. Representatives of removed

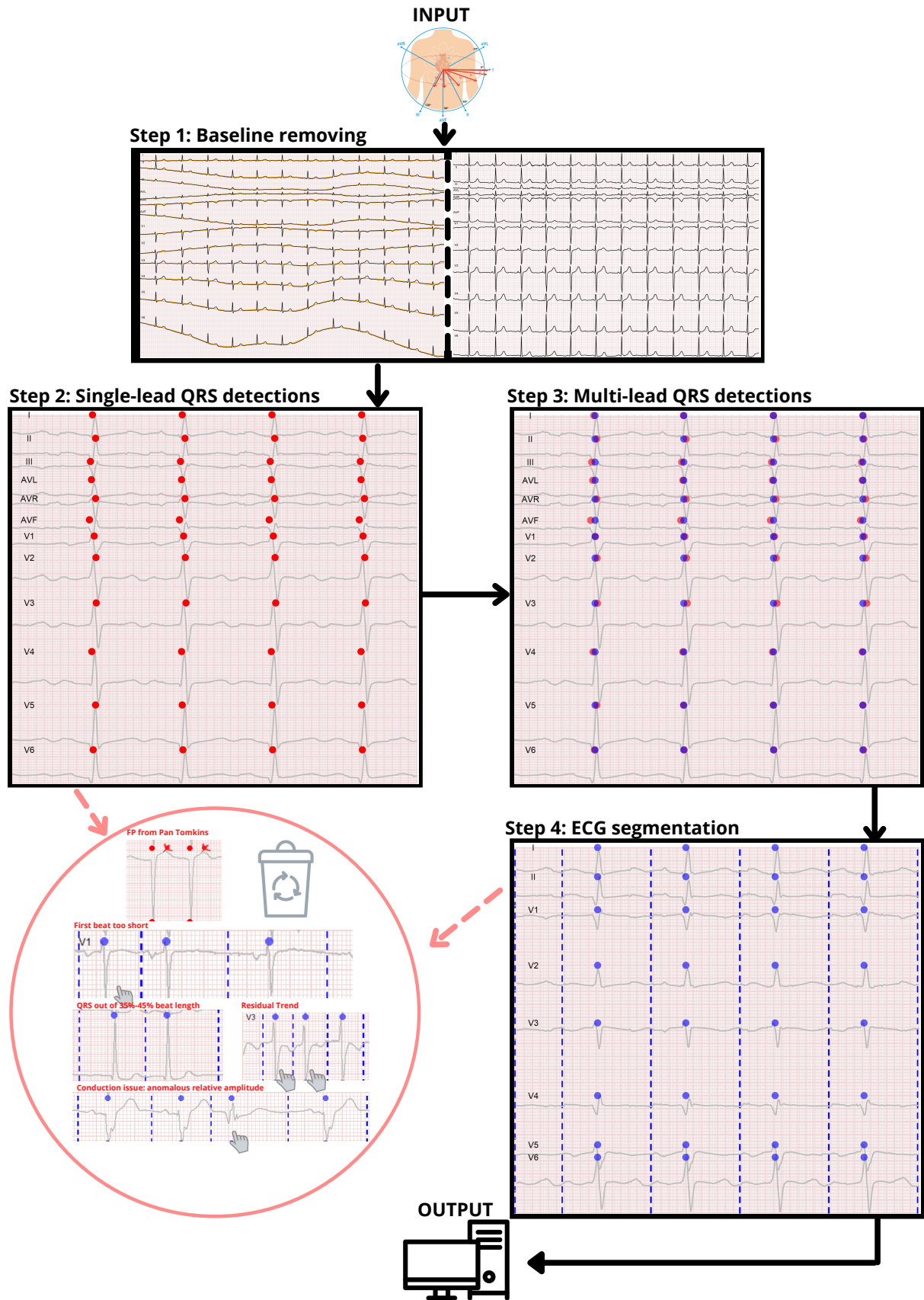
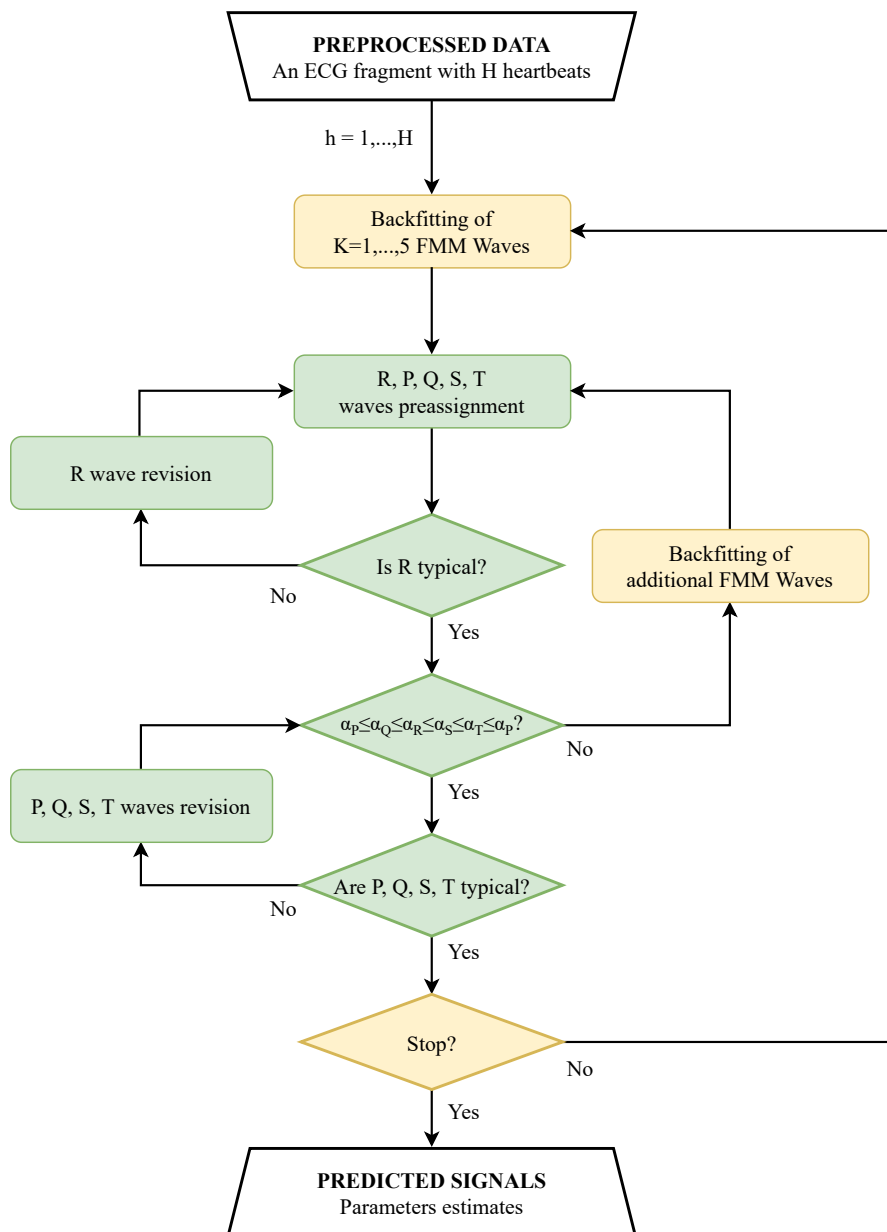


Figure S14. Flow chart of the Identification Algorithm, related to STAR Methods. The yellow and green blocks correspond to the M-step and the I-step, respectively.



## 2 Supplemental Tables

Table S1. 3DFMM<sub>ecg</sub> parameter configurations across the different ECG signal patterns, related to STAR Methods and a section of Results.

	$\alpha_P$	$\alpha_Q$	$\alpha_R$	$\alpha_S$	$\alpha_T$	$\omega_P$	$\omega_Q$	$\omega_R$	$\omega_S$	$\omega_T$	$maxAR$
NORM	4.90	5.61	5.75	5.88	1.30	0.13	0.03	0.03	0.03	0.19	697.77
CLBBB	4.41	5.61	6.00	6.08	1.30	0.13	0.03	0.14	0.04	0.19	1366.46
CRBBB	4.90	5.61	5.75	6.15	1.30	0.13	0.03	0.03	0.08	0.19	642.96
HYP	4.90	5.61	5.75	5.88	1.30	0.13	0.03	0.03	0.03	0.19	1709.54

Table S2. Estimation performance measures across the different ECG signal patterns, related to STAR Methods.

		$\alpha_P$	$\alpha_Q$	$\alpha_R$	$\alpha_S$	$\alpha_T$	$\omega_P$	$\omega_Q$	$\omega_R$	$\omega_S$	$\omega_T$	$maxAR$
NORM	<i>bias</i>	0.023	-0.001	-0.003	0.001	-0.016	0.016	-0.004	-0.002	-0.005	0.015	22.892
	<i>empSE</i>	0.034	0.001	0.000	0.001	0.023	0.007	0.002	0.000	0.002	0.002	6.684
	<i>CV</i>	0.013	0.000	0.001	0.000	0.009	0.134	0.140	0.072	0.182	0.083	0.034
CLBBB	<i>bias</i>	-0.001	0.003	0.007	0.058	0.020	0.005	-0.001	-0.004	0.012	0.002	49.725
	<i>empSE</i>	0.007	0.000	0.001	0.002	0.002	0.003	0.000	0.000	0.005	0.001	10.458
	<i>CV</i>	0.002	0.001	0.002	0.018	0.006	0.042	0.048	0.026	0.312	0.012	0.037
CRBBB	<i>bias</i>	0.042	0.003	-0.004	-0.003	0.006	0.010	-0.003	-0.002	0.004	0.007	-20.213
	<i>empSE</i>	0.007	0.001	0.001	0.002	0.026	0.003	0.001	0.000	0.001	0.002	8.405
	<i>CV</i>	0.013	0.001	0.001	0.001	0.008	0.078	0.098	0.073	0.050	0.040	0.034
HYP	<i>bias</i>	0.047	0.004	-0.004	0.002	0.000	0.013	-0.010	-0.002	-0.005	0.016	36.318
	<i>empSE</i>	0.005	0.001	0.000	0.001	0.008	0.004	0.000	0.000	0.001	0.002	5.203
	<i>CV</i>	0.015	0.001	0.001	0.001	0.002	0.105	0.337	0.077	0.177	0.087	0.021

Table S3. Median and percentile ranges for  $\bar{R}$  across the different ECG signal patterns, related to STAR Methods.

	NORM	CLBBB	CRBBB	HYP
$p_5$	0.980	0.975	0.978	0.994
$p_{50}$	0.981	0.976	0.980	0.994
$p_{95}$	0.982	0.978	0.980	0.994