Artificial intelligence methodology: multi-label classification of abnormal EKG records

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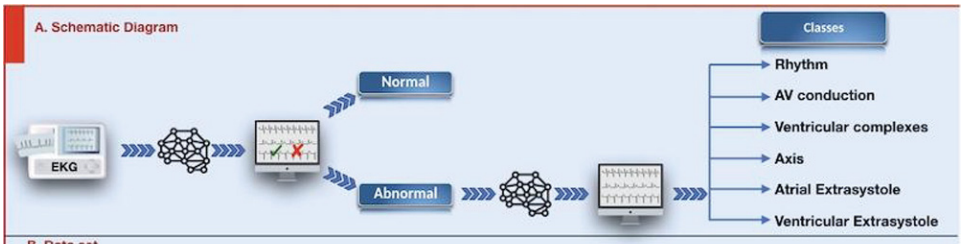
Background: Our previous experience with Artificial Intelligence (AI)-conducted EKG characterization displayed outstanding results in fast and reliable identification of Normal EKGs within the International Telemedical System (ITMS)'s massive record repository. By expanding the array of recognizable cardiovascular entities, we upgraded our methodology to accurately discriminate an anomaly amongst a highly complex database of EKG records.

Purpose: To present a feasible AI-guided filter that can accurately discriminate and classify Normal and Abnormal EKG records within a multilabeled cardiologist-annotated EKG database.

Methods: ITMS developed and tested the "One Click"' process, a "Normal/Abnormal" EKG assessing AI algorithm, by incorporating it into their digital EKG reading platform where cardiologists continuously report their findings remotely in real time. To ameliorate the diagnostic range of the algorithm, a separate dataset of 121,641 12-lead EKG records was consolidated from the ITMS database from October 2011 to January 2019. Only de-identified data was used. Preprocessing: The first 2s of each short lead and 9s of the long lead were considered. Limb leads I, II and III; and precordial leads V1, V2, V3, and V5 were used. The mean was removed from each lead. AI models/Classification: Two models were created and tested independently based on the method of EKG acquisition (69,852 records transtelephonic [TTP]; 52,259 mobile transmission [MOB]). Each record is categorized into six disjoint classes based on the most common types of cardiac disorders (Low/null co-occurrence pathologies in these datasets were grouped into analogous groups). Training/Testing: Distribution of both sets per transmission type was performed through a greedy algorithm, which identified multiple diagnoses per EKG record and labeled it separately to the corresponding group, ensuring sufficient samples per class. Detailed class distribution is shown below. An inception convolutional neural network was implemented; "Normal" or "Abnormal" labels were assigned to each EKG record independently and were compared to cardiologists' reports; performance indicators were calculated for each model and group.

Results: MOB model accrued an average accuracy of 86.7%; sensitivity of 90.5%; and specificity of 83.9%. TTP model yielded an average accuracy of 77.2%; sensitivity of 91.1%; and specificity of 69.4% (Lower values were attributed to the "Ventricular Complexes" group, which challenged the algorithm by having a smaller ratio of abnormal exams). Detailed results of each training set are shown below.

Conclusion: Providing an effective and reliable multilabel-capable EKG triaging tool remains a challenging but attainable goal. Continuous systematic enhancement of our AI-driven methodology has led us to satisfactory, yet imperfect results which compel us to further study and improve our efforts to provide a trustworthy cardiologist-friendly triage device.



B. Data set

	MOB AI Model		TTP AI model	
	Training Set	Testing Set	Training Set	Testing Set
Number Of EKGs Used	47,199	5,060	47,773	21,609
Classes	*Number of EKGs distributed based on class			
Rhythm	14,096	1,867	20,000	5,117
AV conduction	10,000	1,049	10,000	5,000
Ventricular Complexes	14,188	1,299	27,652	9,413
Axis	10,000	914	10,000	5,000
Atrial Extrasystole	7,077	610	10,733	5,000
Ventricular Extrasystole	7,522	720	10,000	5,000

* Most EKGs have ≥ 1 abnormality and have ≥ 1 group label.

C. Results

Classes	MOB AI model (%)			TTP AI model (%)		
	Accuracy	Sensitivity (Abn)	Specificity (Nor)	Accuracy	Sensitivity (Abn)	Specificity (Nor)
Rhythm	89.2	93.7	82.8	72.58	81.22	69.98
AV conduction	81.6	94.4	78.4	82.46	90.66	79.99
Ventricular Complexes	74	92.6	64.9	51.1	96.41	*16.13
Axis	87.4	88.5	87.1	84.54	96.44	80.96
Atrial extrasystole	91.8	84.7	92.9	83.4	91.7	80.97
Ventricular Extrasystole	96.1	89.3	97.4	88.63	90.36	88.11
Overall Average	86.7	90.5	83.9	77.2	91.1	69.4

* Result of poor TTP transmission and forcing to find 4 abnormal over 1 normal finding (1:4 Nor:Abn ratio)

EKG - Electrocardiogram, AV- AtrioVentricular node, MOB - Mobile digital transmission, TTP - Trans TelePhonic transmission, AI - Artificial Intelligence, Abn - Abnormal, Nor - Normal