APCN x TSN 2025
23rd Asian Pacific Congress of Nephrology
Gene, Immunology, Vast, MEtabolism at its Finest!

Dyskalemia: From bedside to AI-ECG

Shih-Hua Lin, MD.

Division of Nephrology, Department of Medicine
Tri-Service General Hospital
National Defense Medical University
Taipei, Taiwan

台灣腎臟醫學會
T.S.N.
Taiwan Society of Nephrology

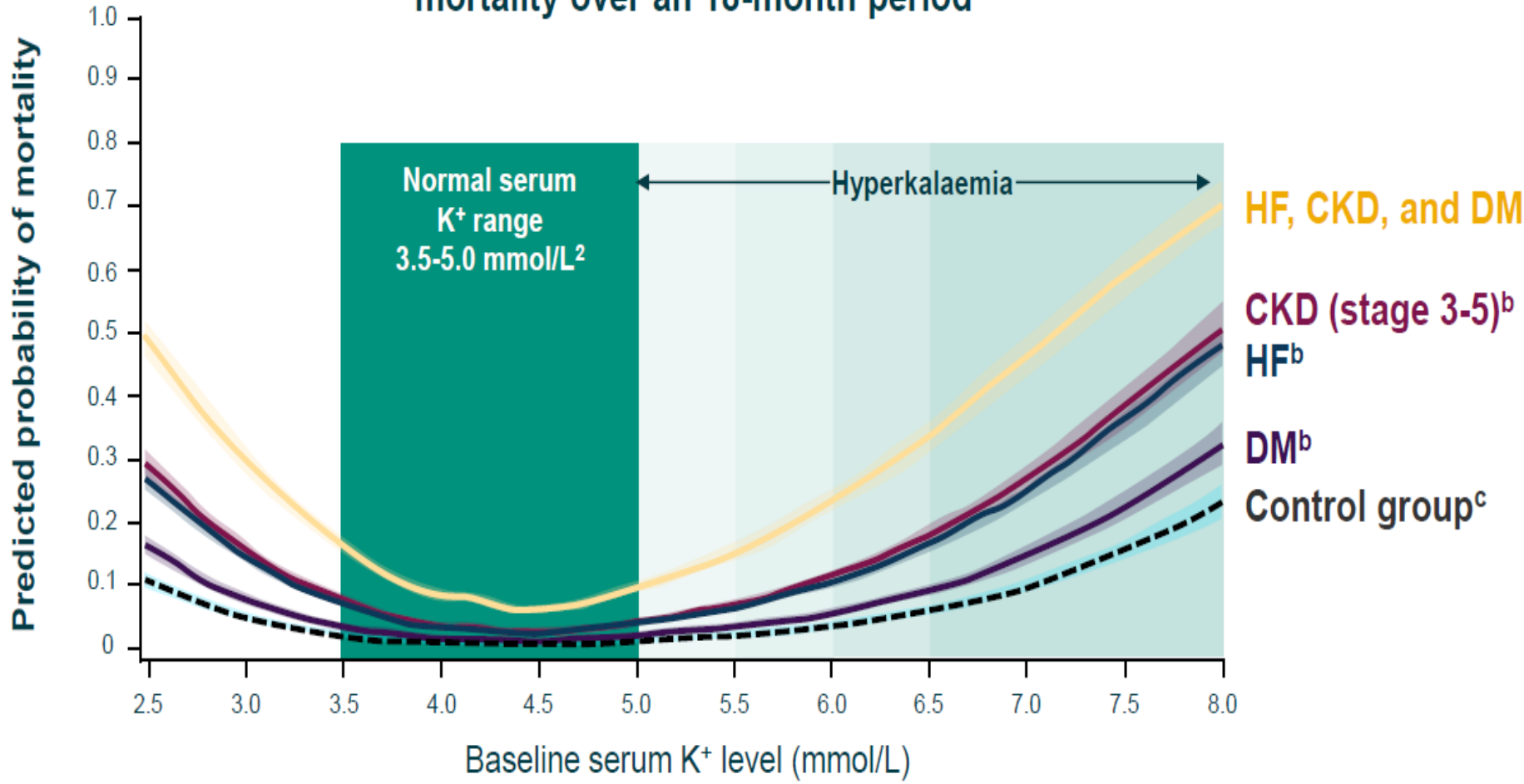
Lab-Dyskalemia

- Assessment of blood acid-base state and spot urine electrolytes help identify the underlying causes of dyskalemia.
- High urine K^+ excretion rate did not indicates renal tubular diseases. However, urine Na^+ vs Cl^- helps reveal the underlying causes of hypokalemia.
- 24 hour urine with electrolyte excretion reflects therapeutic course and help identify the co-existing K^+ shift and K^+ deficit with balance analysis
- To make genetic causes of dyskalemia should exclude other identifiable causes.
- Negative genetic diagnosis should think the possibility of autoimmune antibody to target protein

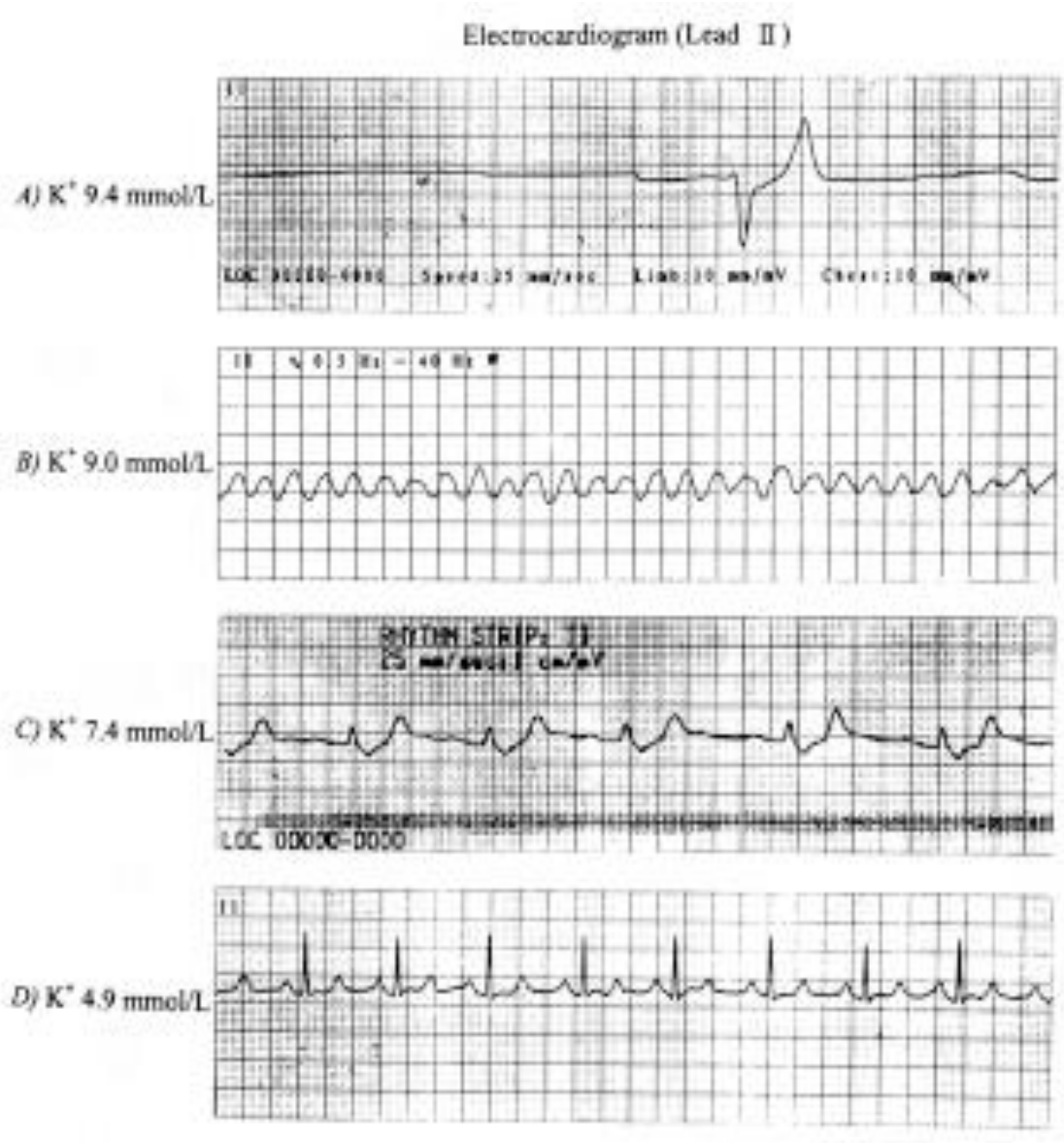
AI-ECG Dyskalemia

- Early recognition of severe dyskalemia, faster than laboratory testing
- Rapid exclusion of pseudodyskalemia to avoid inappropriate management
- Bloodless monitoring of serum potassium (K^+) changes during Rx of severe dyskalemia.
- The identification of the underlying causes for dyskalemia (HP, TPP paralysis, digoxin intoxication)
- Prediction of adverse cardiovascular outcomes (previvor).

Relationship between serum K^+ value and mortality over an 18-month period[a]

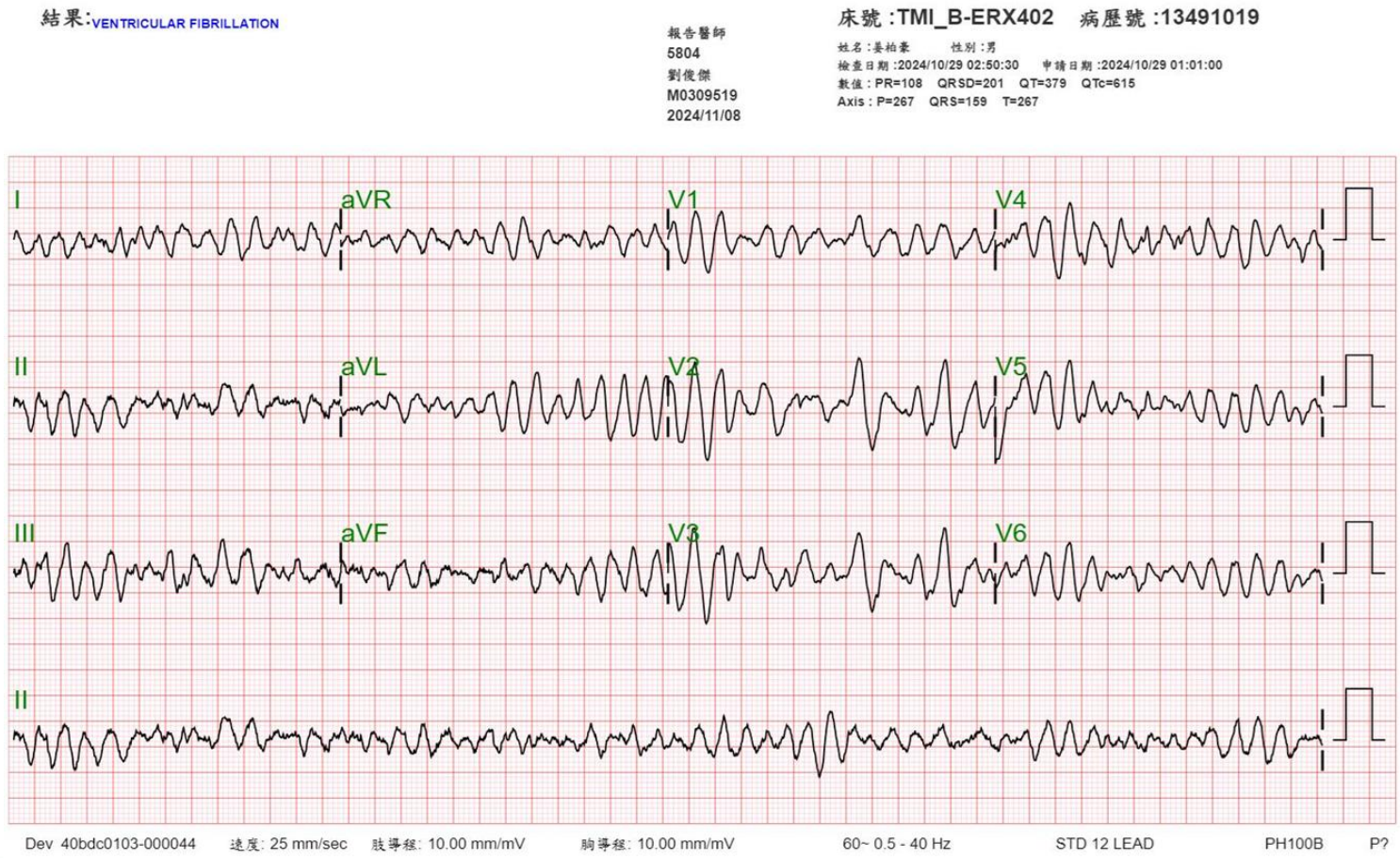


Simultaneous Hemodialysis and Cardiopulmonary Resuscitation in Successfully Terminating Life-threatening Hyperkalemic Cardiac Arrest



Lin SH, et al. JMS 2001

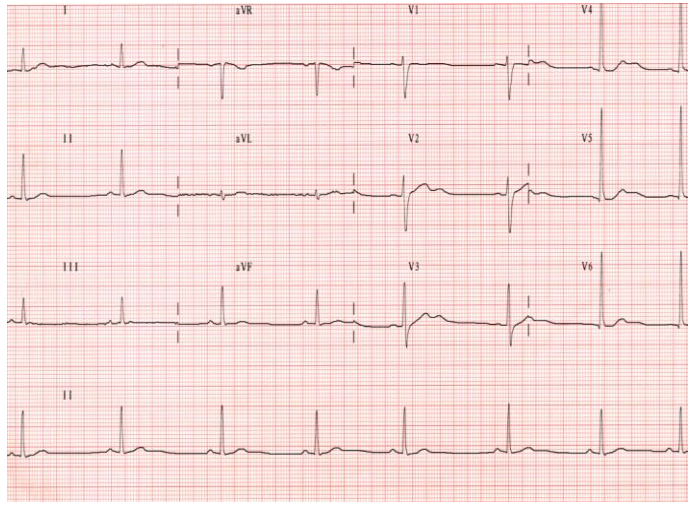
A 33 Y/O Male with hyperthyroidism presented with palpitation and muscle paralysis

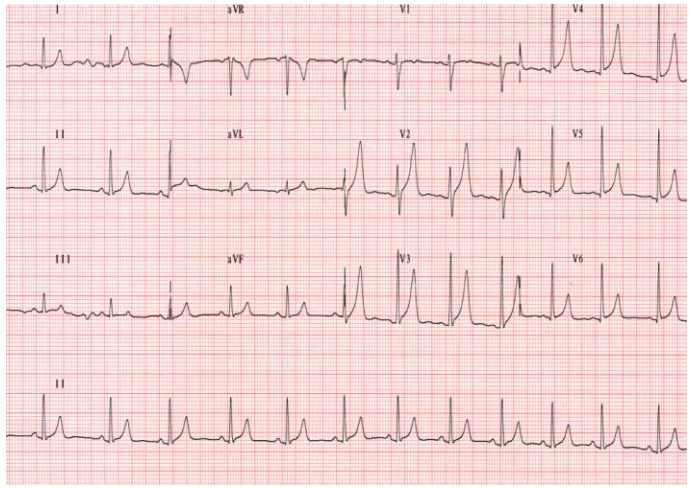


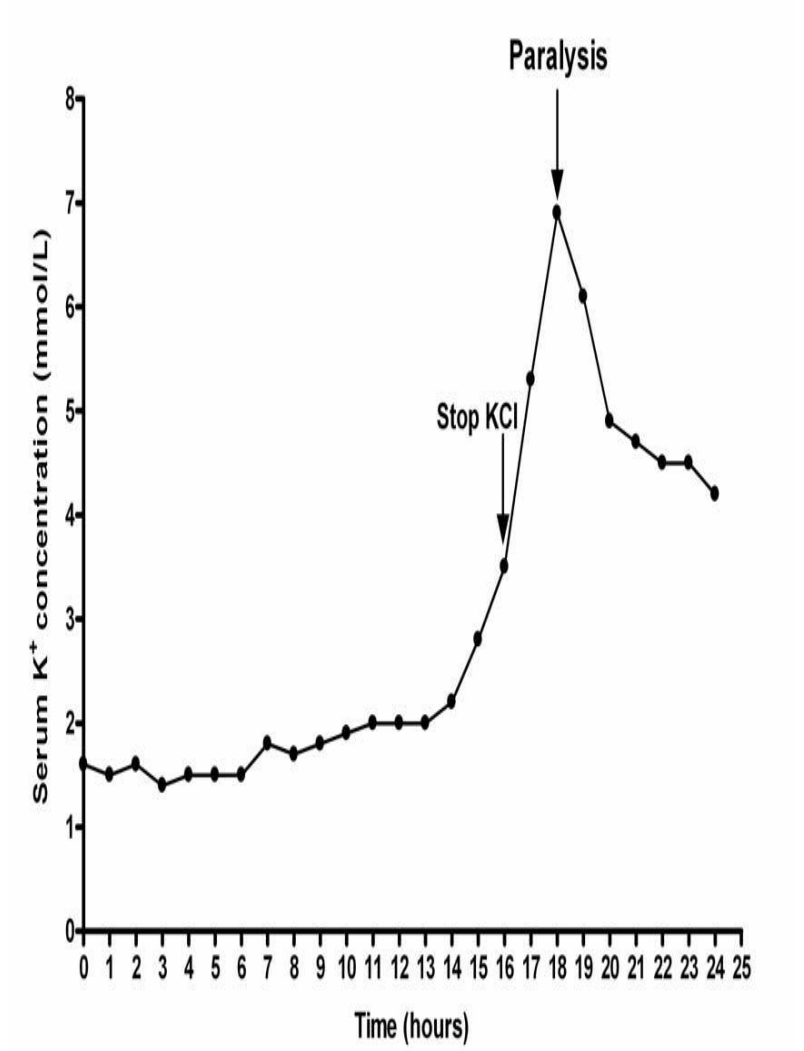
PK 2.0 to **1.4** mmol/L in 2 hours despite IV KCl 20 mmol

Recurrent Paralysis in SPP

Lin SH, et al. BMJ Case Report 2009







How Rapid is “Rapid” to Detect Severe Dyskalemia

- Detection of dyskalemia relies on laboratory tests.
- Since cardiac tissue is sensitive to dyskalemias, electrocardiography (ECG) may be able to uncover clinically important dyskalemias before laboratory.
- Even experienced clinicians frequently do not recognize the ECG morphologic changes associated with dyskalemias.
- Using ECG-based DLM with large annotated data, we successfully developed ECG-12Net to help predict severe dyskalemia in seconds.

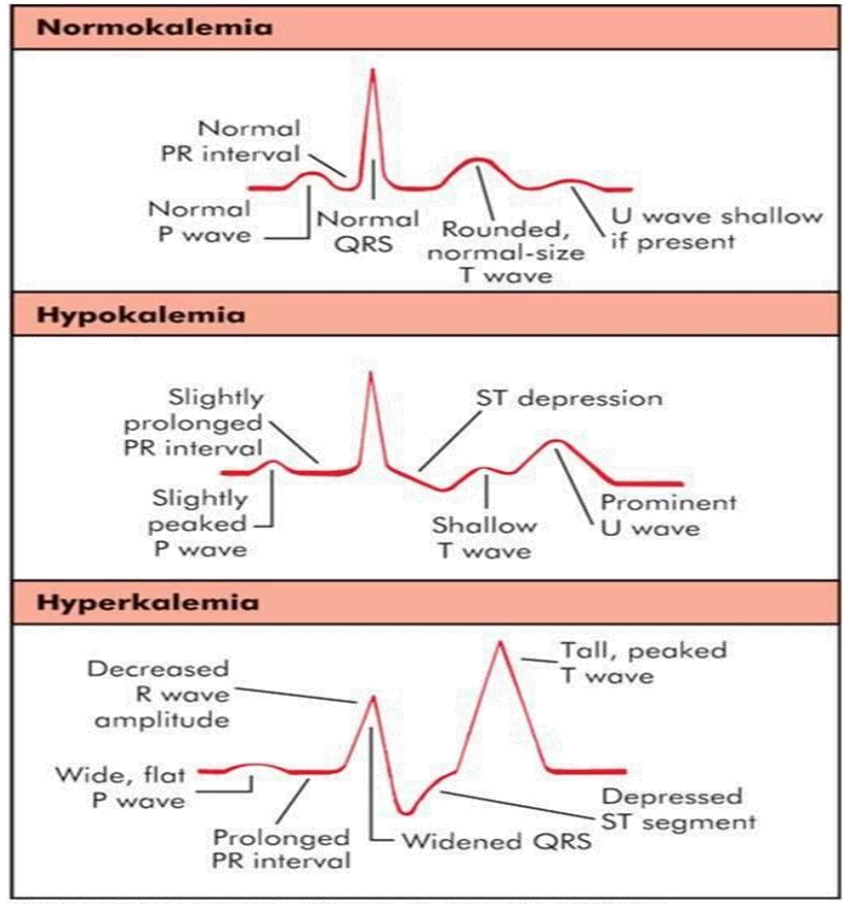
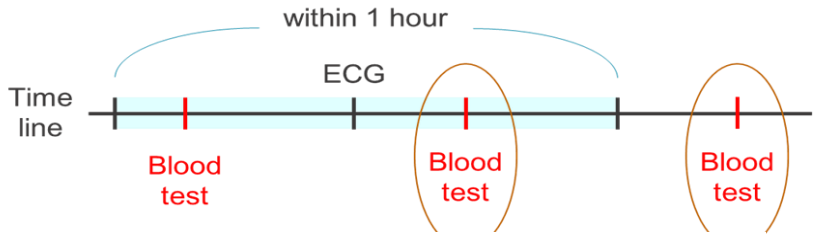
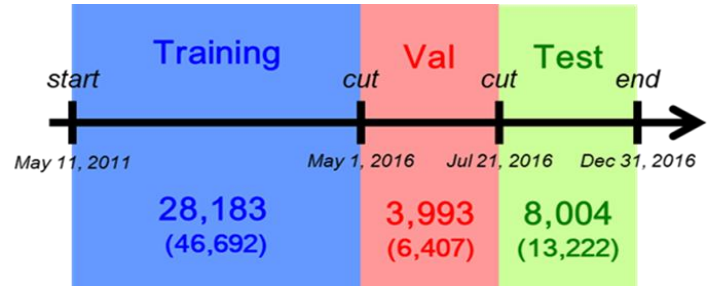
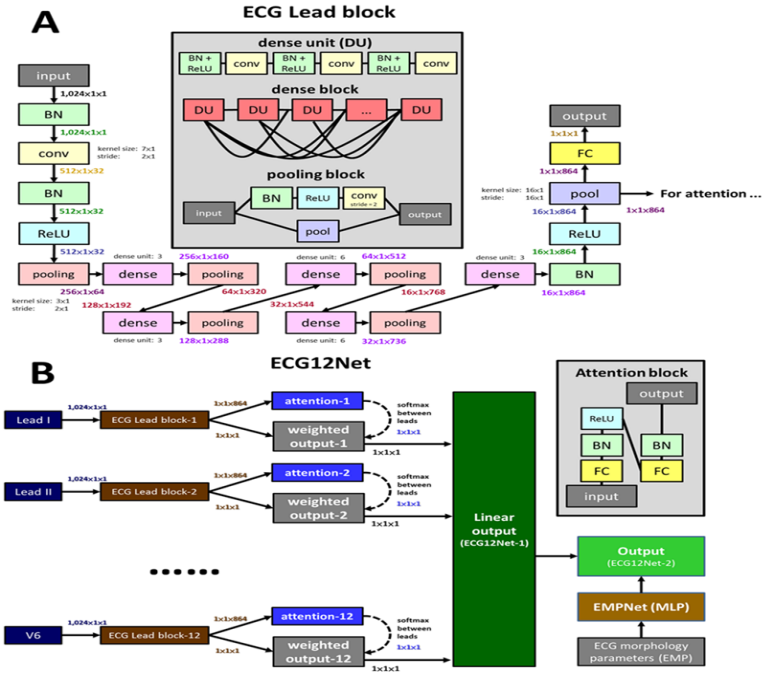


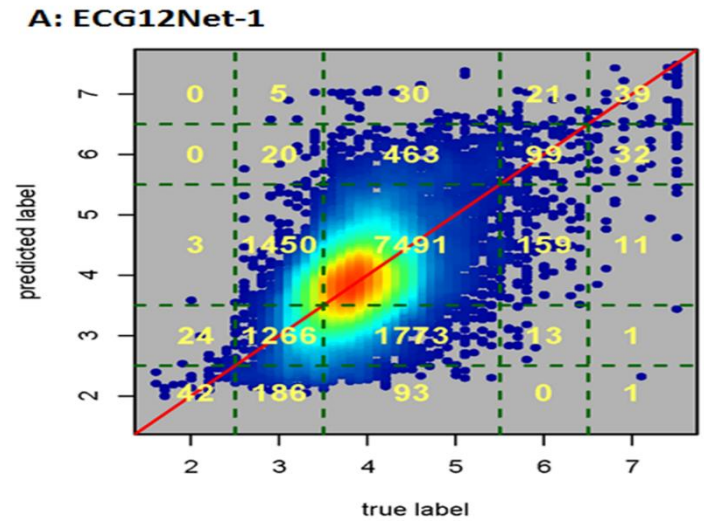
Fig. 4-7. Electrocardiogram Changes with Potassium Imbalance

Bloodless AI-ECG for the detection of Dyskalemia using large annotated serum K^+







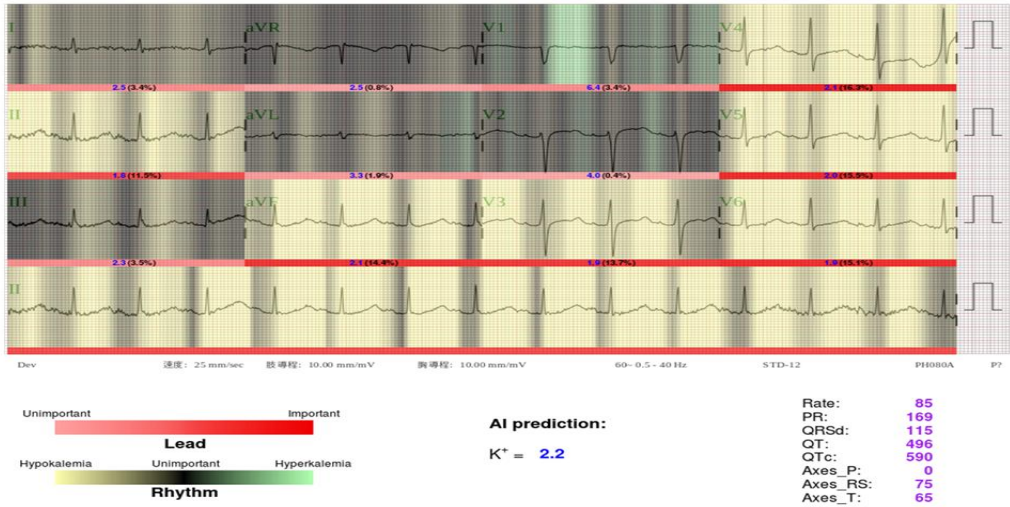


Sens (severe-hypoK): 95.6%
(severe hyperK): 84.5%

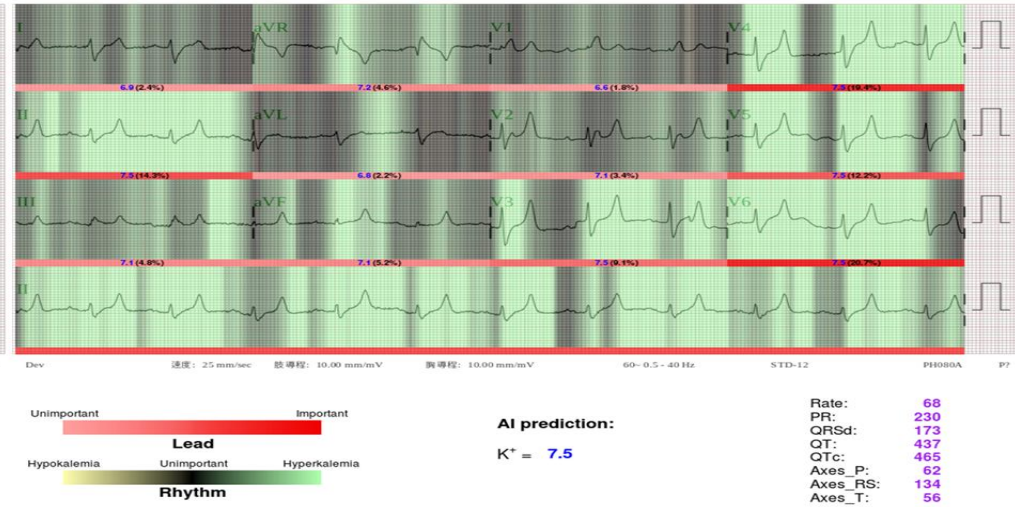
Lin CS et al, JMIR Med Inform 2020

Visualization analysis for ECG12Net in selected severe hypokalemia and hyperkalemia.

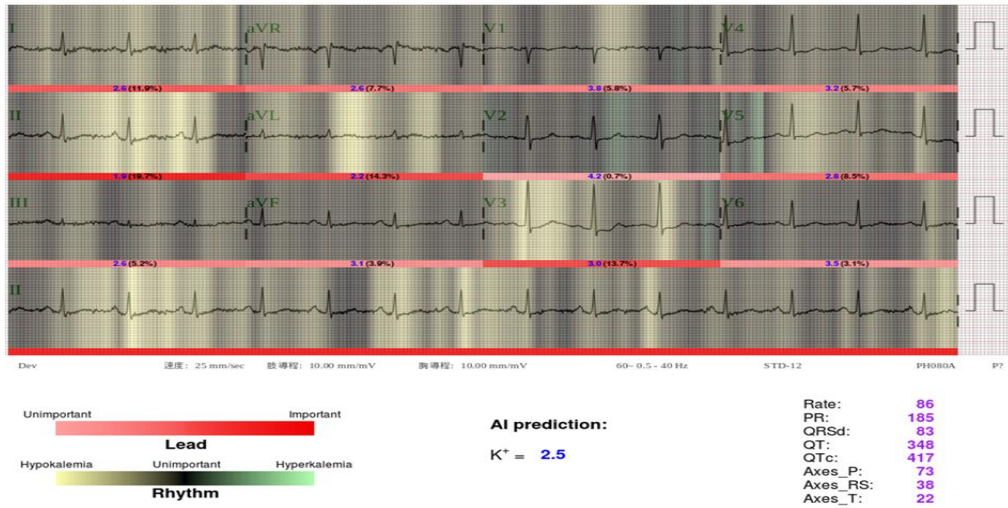
A [K⁺] 2.3



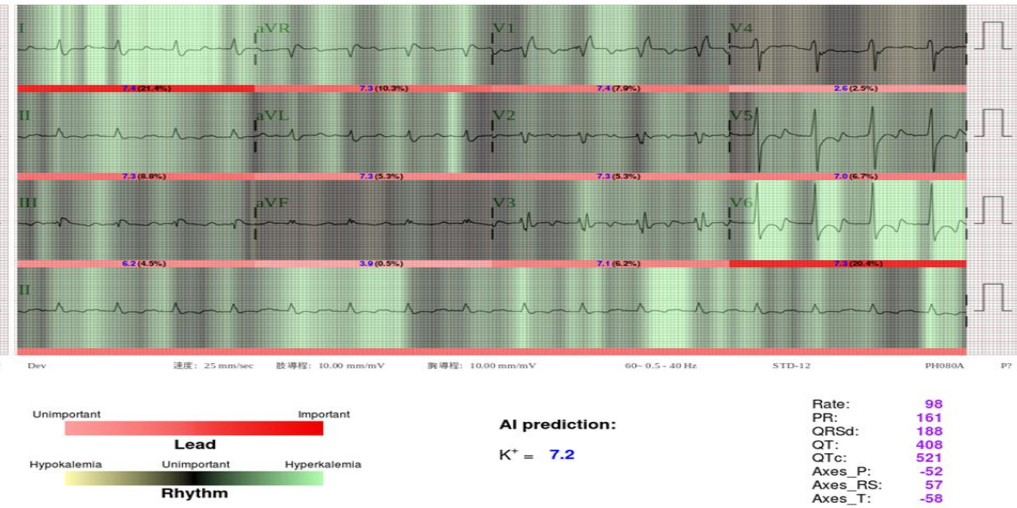
C [K⁺] 9.1



B [K⁺] 2.5



D [K⁺] 7.1

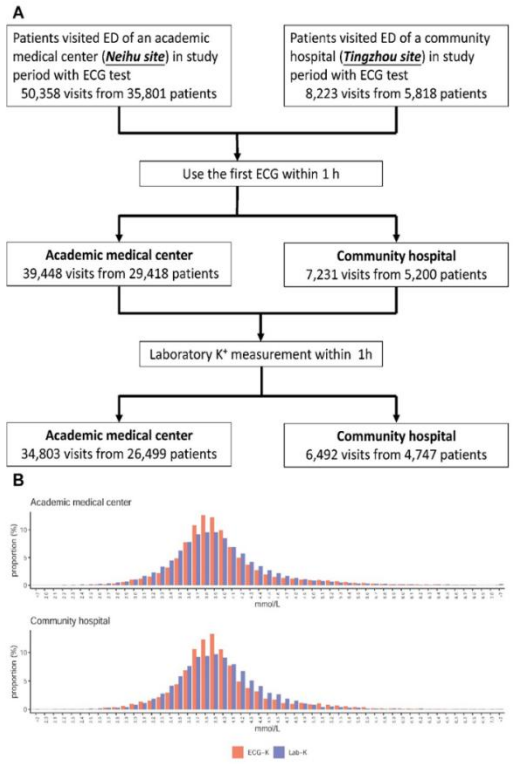


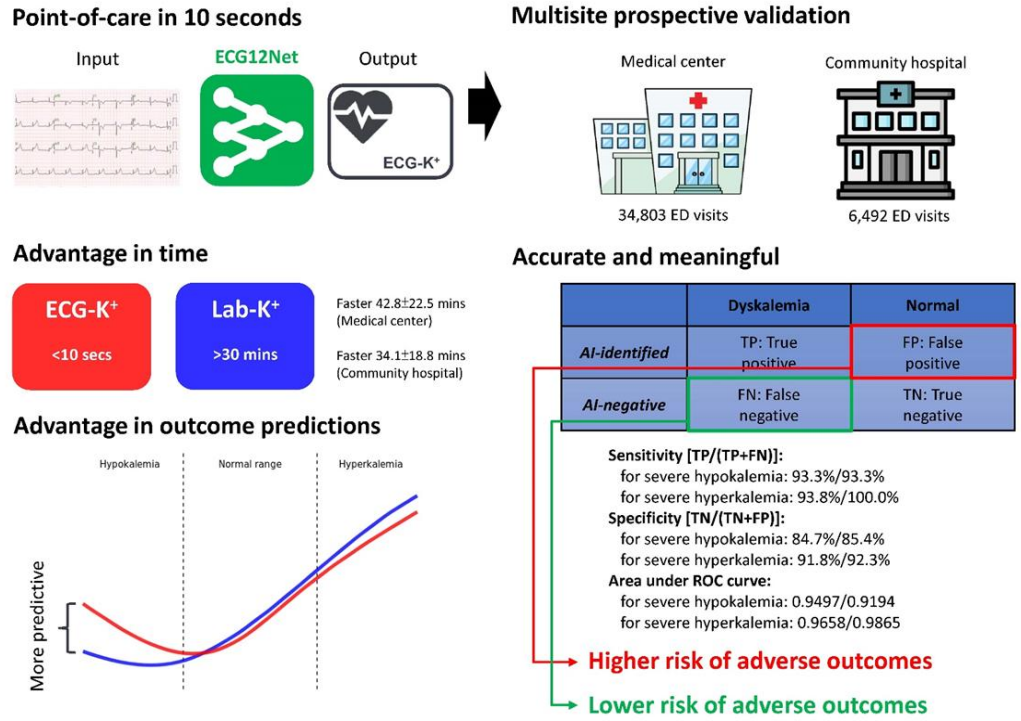
Comparison with Previous Studies

	This study	Galloway et al.
Sample size	66,321	1,576,581
Patients	**ED**	**CKD, stage ≥III**
Blood K^+	**Dyskalemia**	**Hyperkalemia**
Blood K^+ and ECG recording	**1hr < ECG < 1hr**	**<12 hrs**
Prediction type	**Continuous**	Binary
ECG lead	**12 leads**	**2 (I,II) or 4 leads**
Hyperkalemia ($K^+ \geq 5.5$)		
AUCs	0.911	0.853-0.883
Sensitivity	41.1-**84.5%**	81.3-84.0%
Specificity	**96.0%**	77.0-84.2%
Positive predictive value	26.9%	11.9-15.4%
Negative predictive value	98.5%	99.0-99.4%
Hypokalemia ($K^+ \leq 3.5$)		
AUCs	0.750	NA
Sensitivity	49.6-**95.6%**	NA
Specificity	**81.6%**	NA
Positive predictive value	44.7%	NA
Negative predictive value	85.0%	NA
Human-Machine Competition	Yes	No

Bloodless AI-ECG K^+ Helps Predict the Outcome

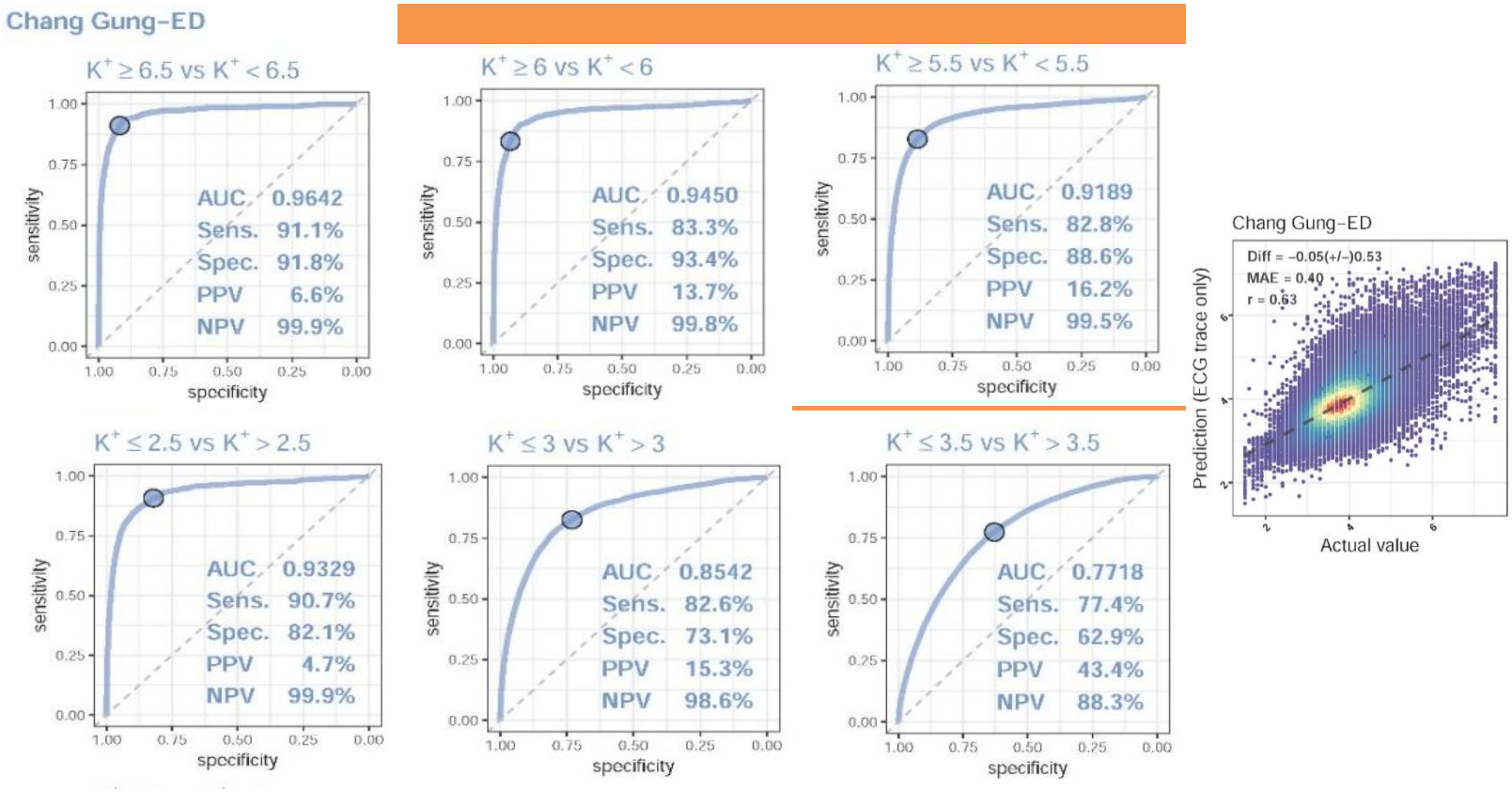
Black-Box Validation after May, 2019





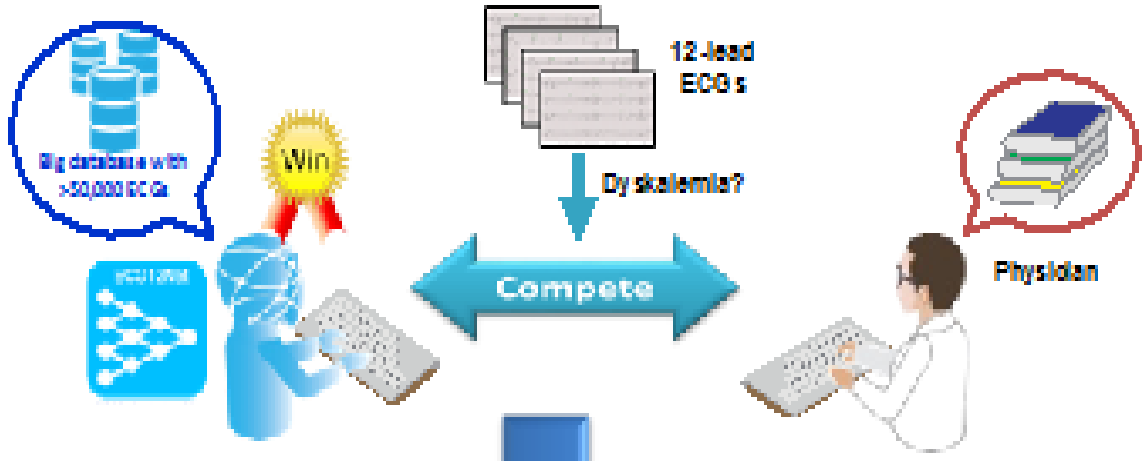
NPJ Digital Med 2022; 5: 8 (1-12)

A Cross-system External Validation at CGMH (GE)

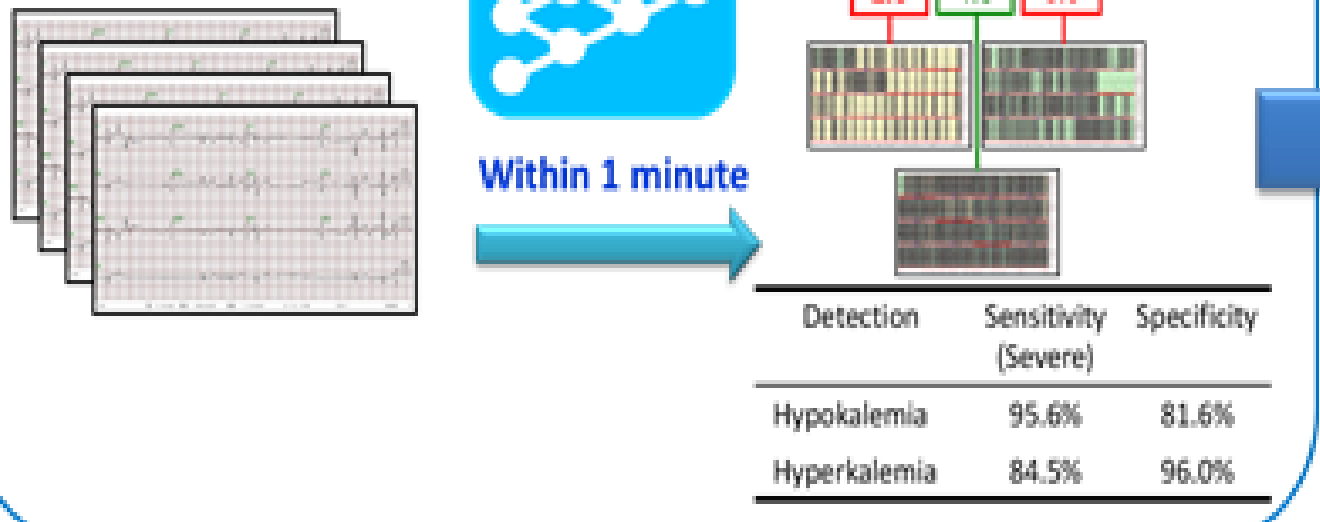


Taiwan Innovation Award 2020

Model Establishment

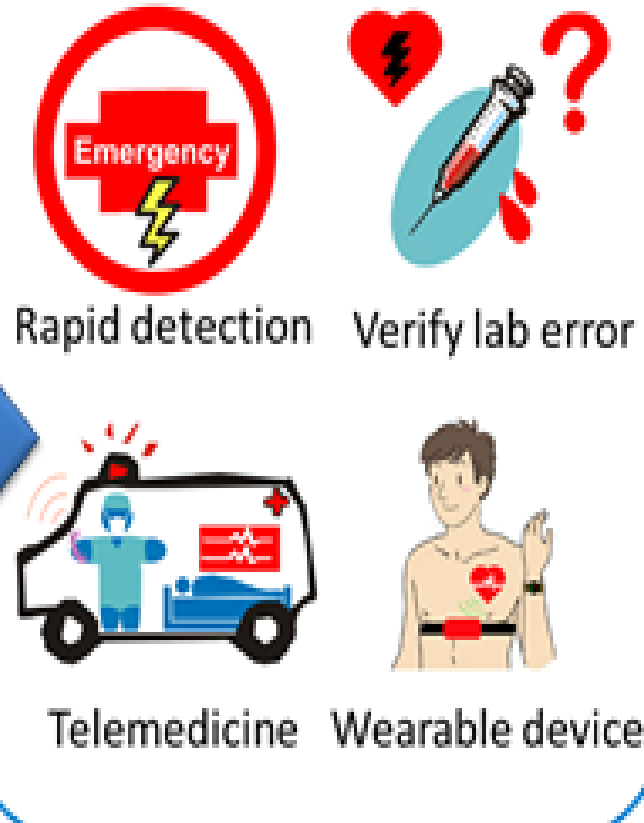


Model Validation



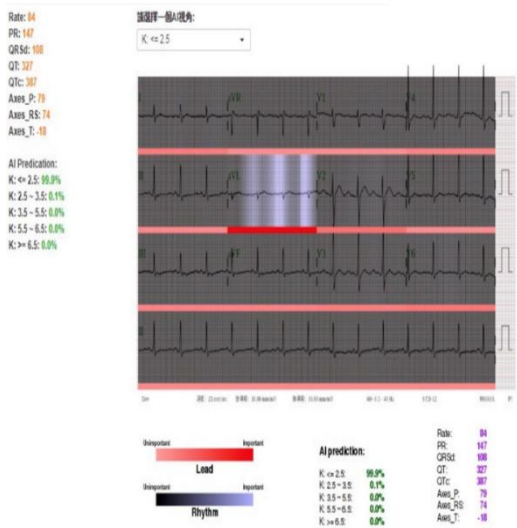
Detection	Sensitivity (Severe)	Specificity
Hypokalemia	95.6%	81.6%
Hyperkalemia	84.5%	96.0%

Future Application



Early Detection of Severe Dyskalemia and Laboratory Error

Case : **A Young Male with Muscle Paralysis**



K^+: 2.2

A 24 Y/O Male with Chronic Hypokalemia (GS) at OPD

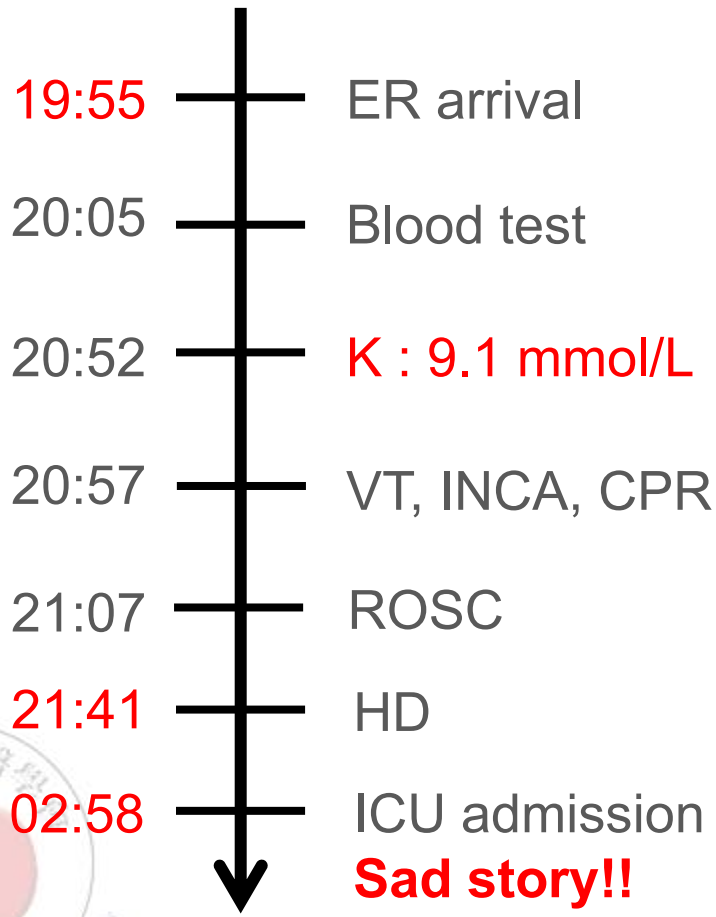
AI prediction:

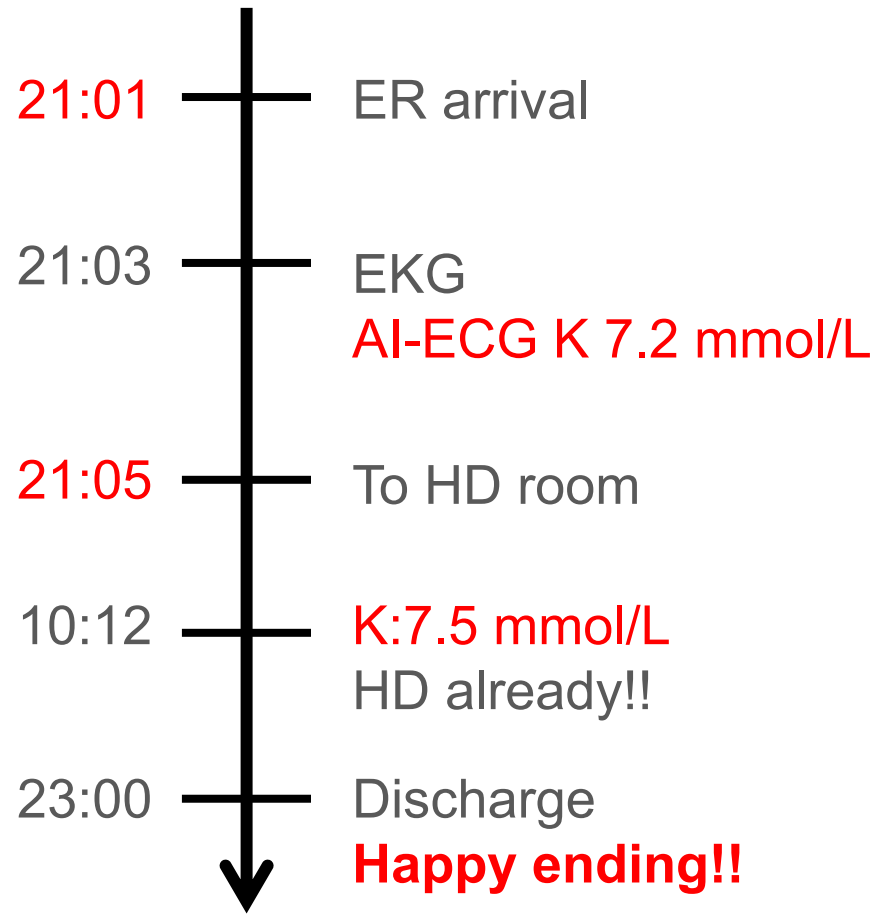
K^+ = **1.6~1.8**

檢驗代碼	檢驗結果	檢驗結果單位	最小/最大安全值
GLU(ER)	H 120	mg/dL	74 - 100
BUN	15	mg/dL	7 - 25
eGFR	86.7 Stage2		
Creatinine	1.1	mg/dL	0.7 - 1.2
Uric Acid	4.7	mg/dL	2.3 - 7.0
Total Calcium	9.6	mg/dL	8.6 - 10.2
AST	31	U/L	- 40
ALT	37	U/L	- 41
Total Protein	8.2	g/dL	6.6 - 8.7
Albumin	4.5	g/dL	3.5 - 5.7
A/G Ratio	1.2		1.2 - 2.4
Na	L 135	mmol/L	136 - 145
K	L 1.6	mmol/L	3.5 - 5.1
Cl	100	mmol/L	98 - 107
Magnesium	1.9	mg/dL	1.7 - 2.55
PANIC INFORM			
通知日期	20/08/01		
通知時間	11h03m		
通知電話	12501		
被通知人	DR.林		
通知者	申總人		

A 52-year-old: DM and CKD stage IV female with laboratory hypokalemia (2.6 mmol/L)

Lab K: 7.1 mmol/L

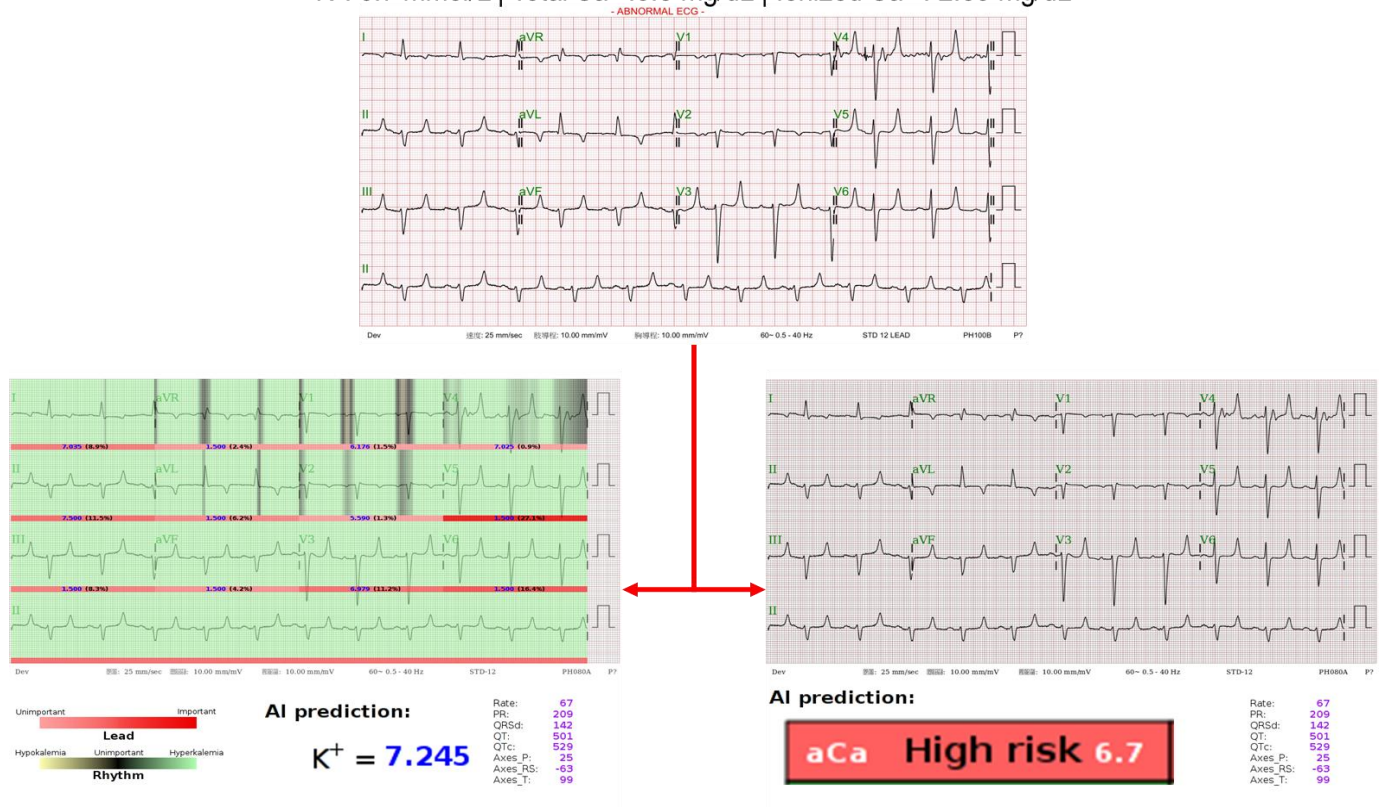




Recurrent Hyperkalemia and Persistent ECG hyperkalemia Following Parathyroidectomy with HBS

1st Episode

K^+: 6.7 mmol/L | Total Ca^{2+}:5.8 mg/dL | Ionized Ca^{2+}: 2.83 mg/dL



Lu A, et al. Best poster presentation in ASN 2024 Invited for publication

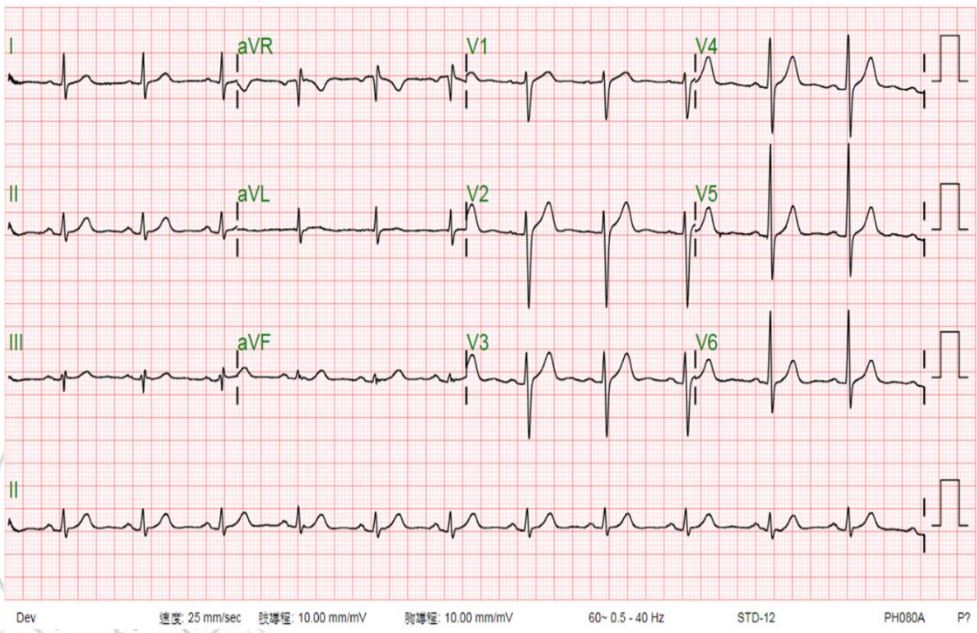
Case: **A Male with Extreme Hyperkalemia**

- A 47- year-old male , Height: 156 cm, Weight: 65 Kg
- Clinical presentation: intermittent dyspnea, lower limbs edema for days

  No muscle cramps, weakness, paralysis, paresthesias, tetany

  and no focal neurologic deficits

Other H→ leukocytosis, Hyperkalemia (>9mmol/L) noted→ Refer to TSGH.
Rx: Lab: K^+ 9.1 mmol/L, hemodialysis, yes or no?



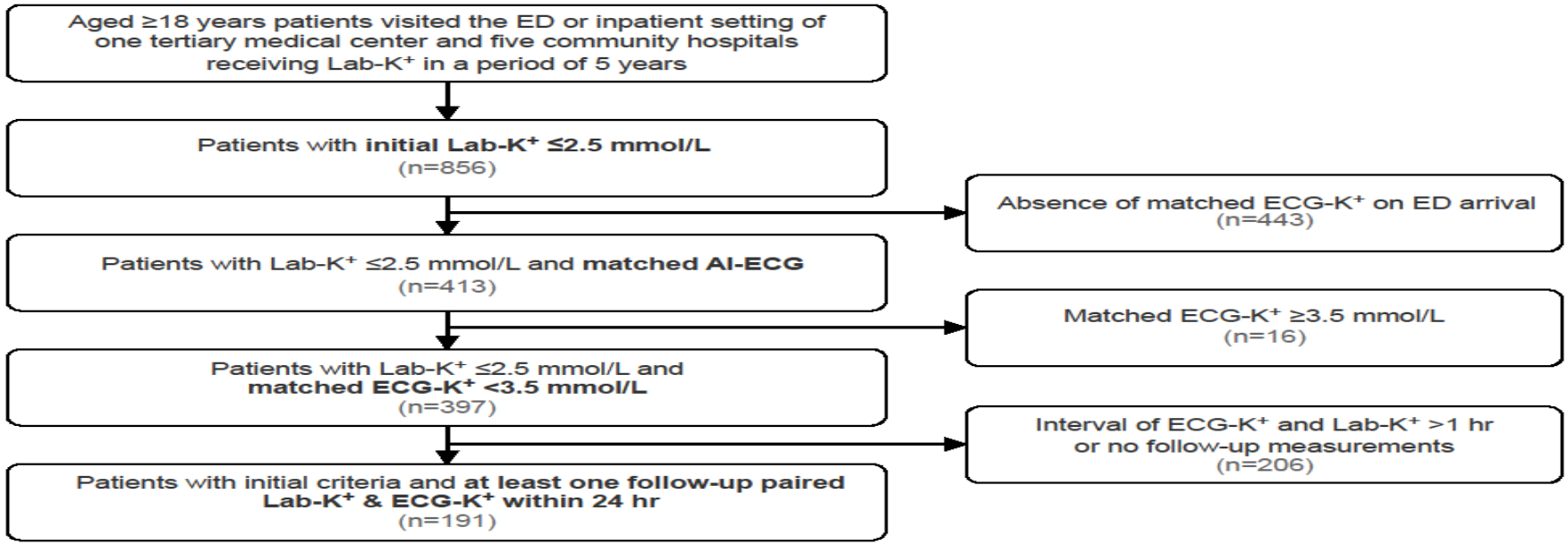
Unimportant Important
Lead
Unimportant Important
Rhythm

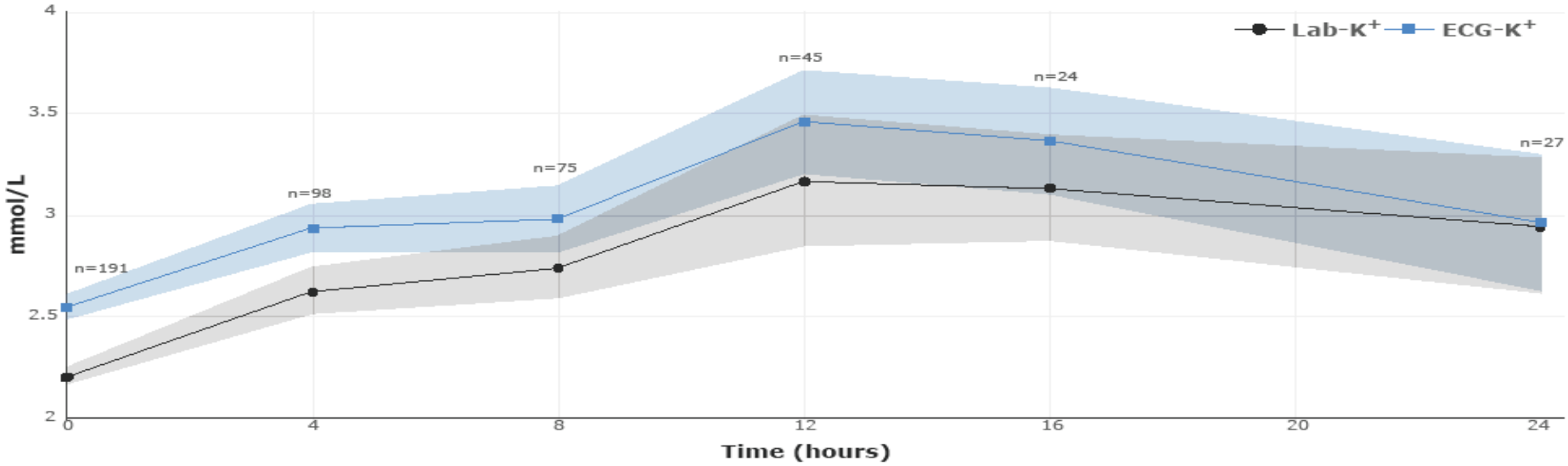
AI prediction:

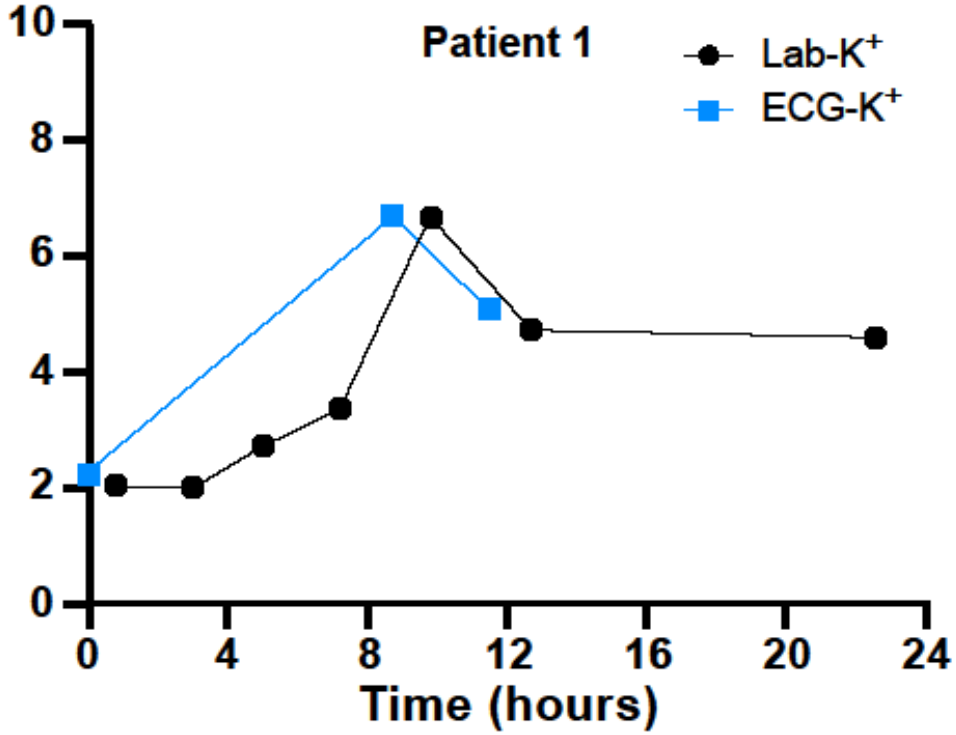
K: <= 2.5:	0.4%
K: 2.5 ~ 3.5:	28.6%
K: 3.5 ~ 5.5:	69.1%
K: 5.5 ~ 6.5:	1.8%
K: >= 6.5:	0.0%

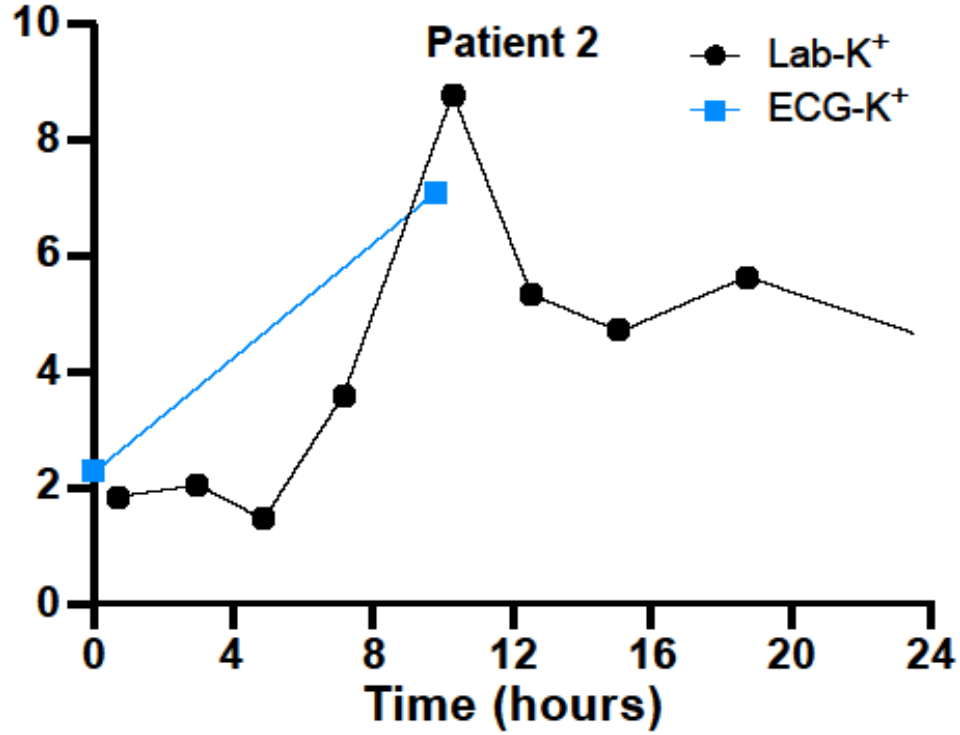
Rate:	70
PR:	186
QRSd:	93
QT:	386
QTc:	417
Axes_P:	68
Axes_RS:	54
Axes_T:	57

(III) Help monitor serum K^+ change during Rx

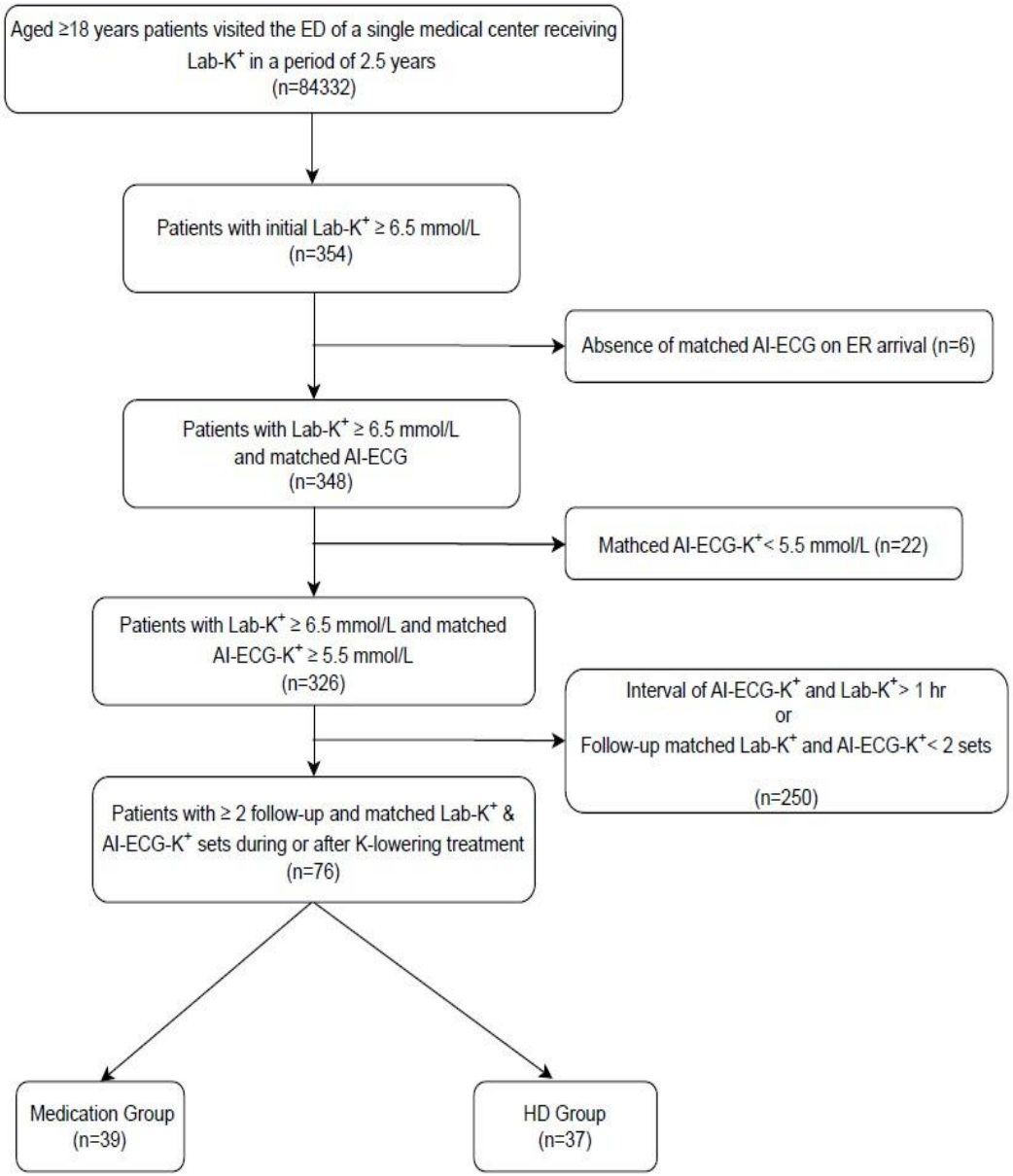


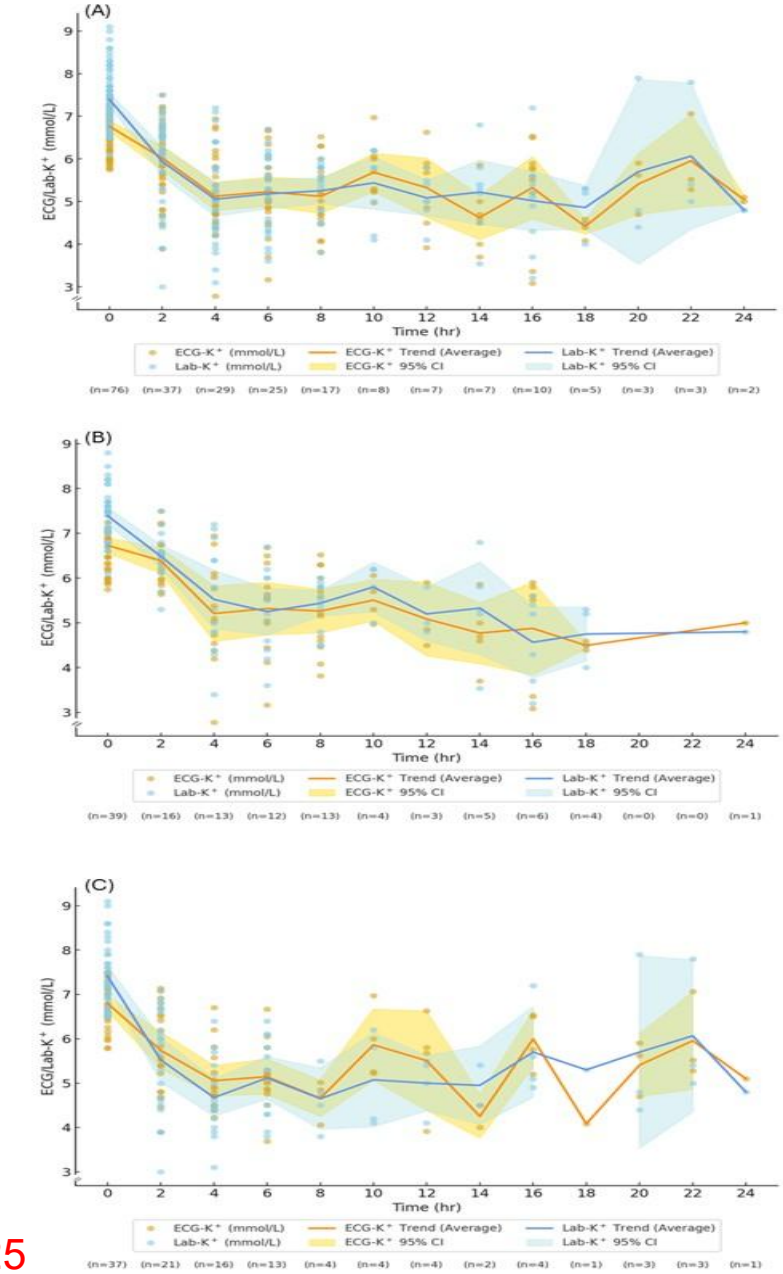



Patient 1
Lab-K+
ECG-K+
10
8
6
4
2
0
0
4
8
12
16
20
24
Time (hours)

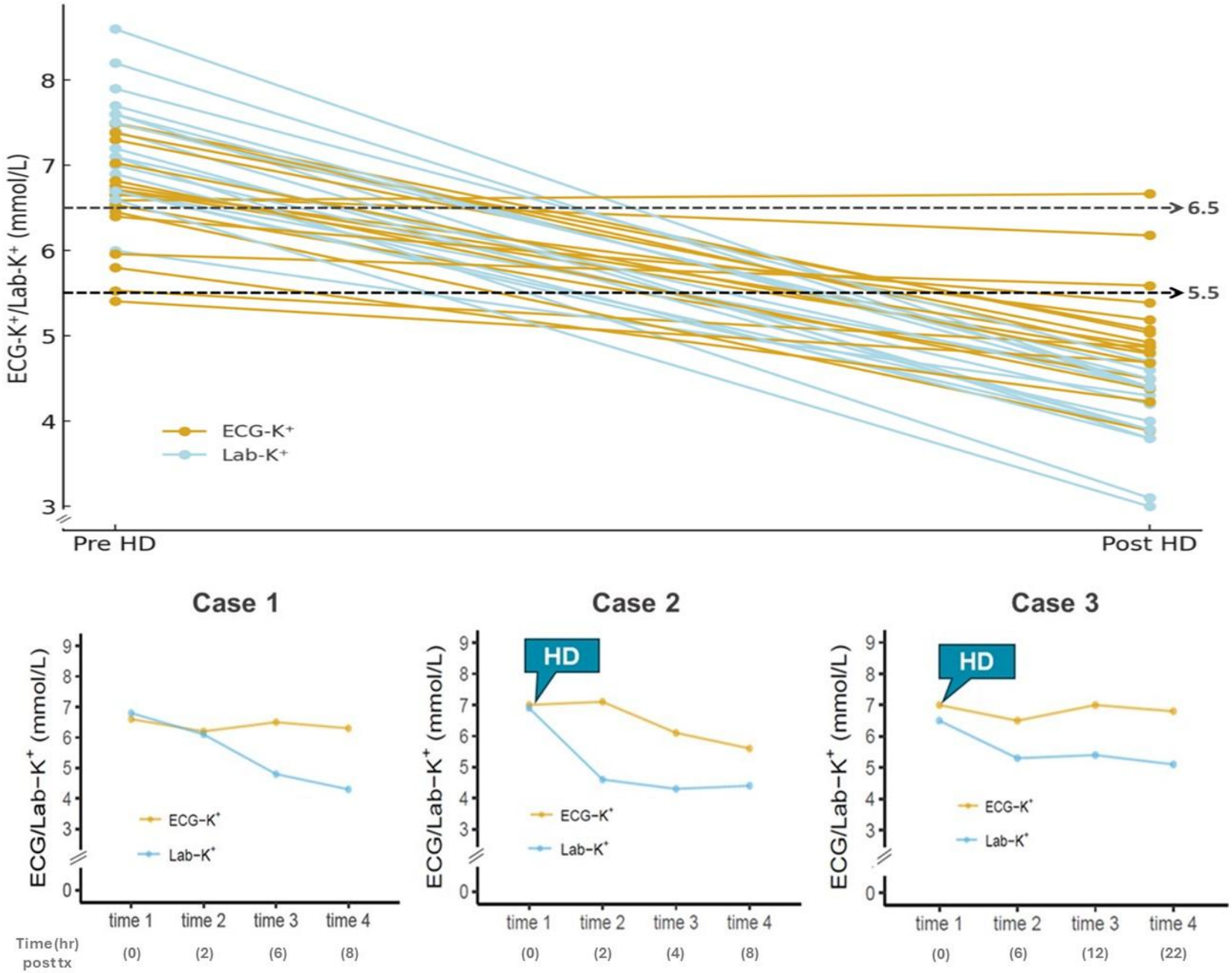

Patient 2
Lab-K+
ECG-K+
10
8
6
4
2
0
0
4
8
12
16
20
24
Time (hours)

Monitoring Serum Potassium Concentration in Patients with Severe Hyperkalemia: the Role of Bloodless AI-Assisted Electrocardiography





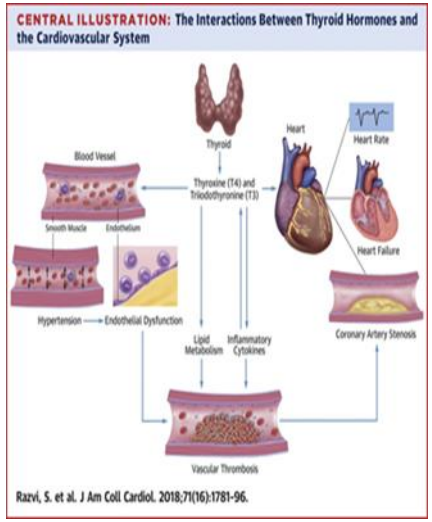
Chen CC, et al. CKJ, 2025

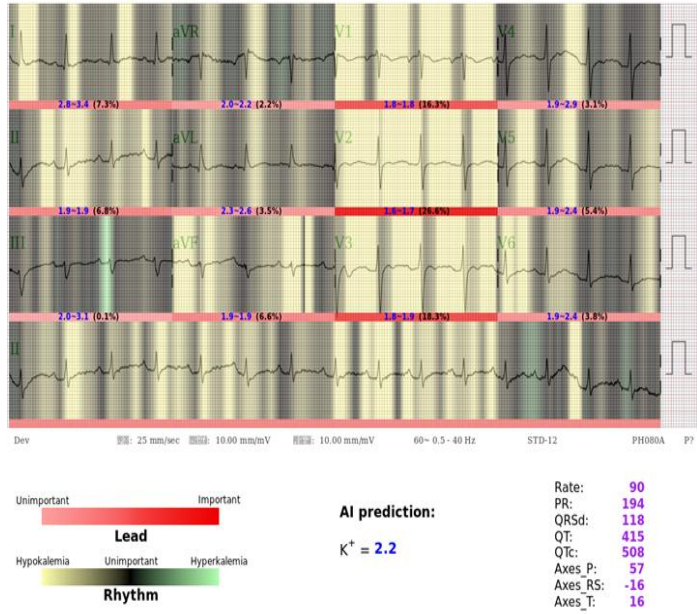


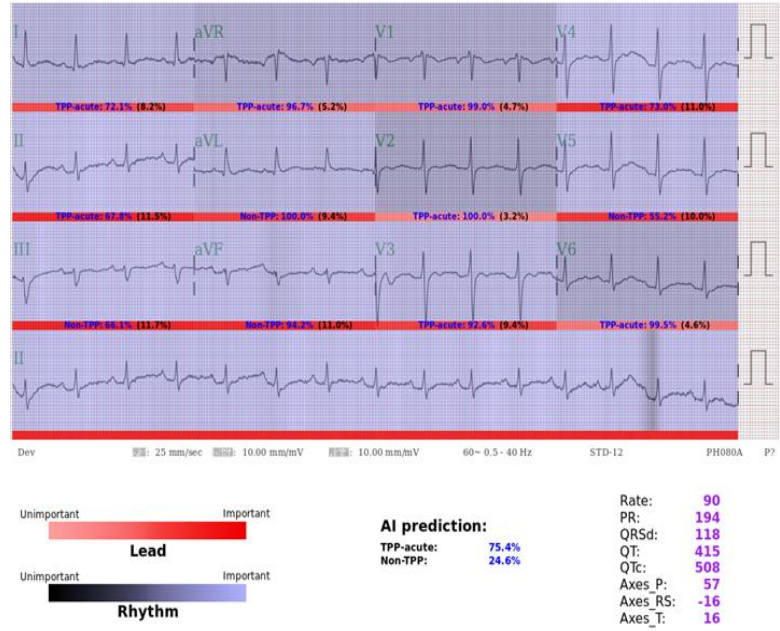
Chen CC, et al. CKJ, 2025

TPP: ECG
Hyperthyroidism on heart
Hypokalemia on heart
K Shift into cells

AI-ECG for Help Diagnose the causes of Hypokalemic Paralysis: TPP vs non-TPP







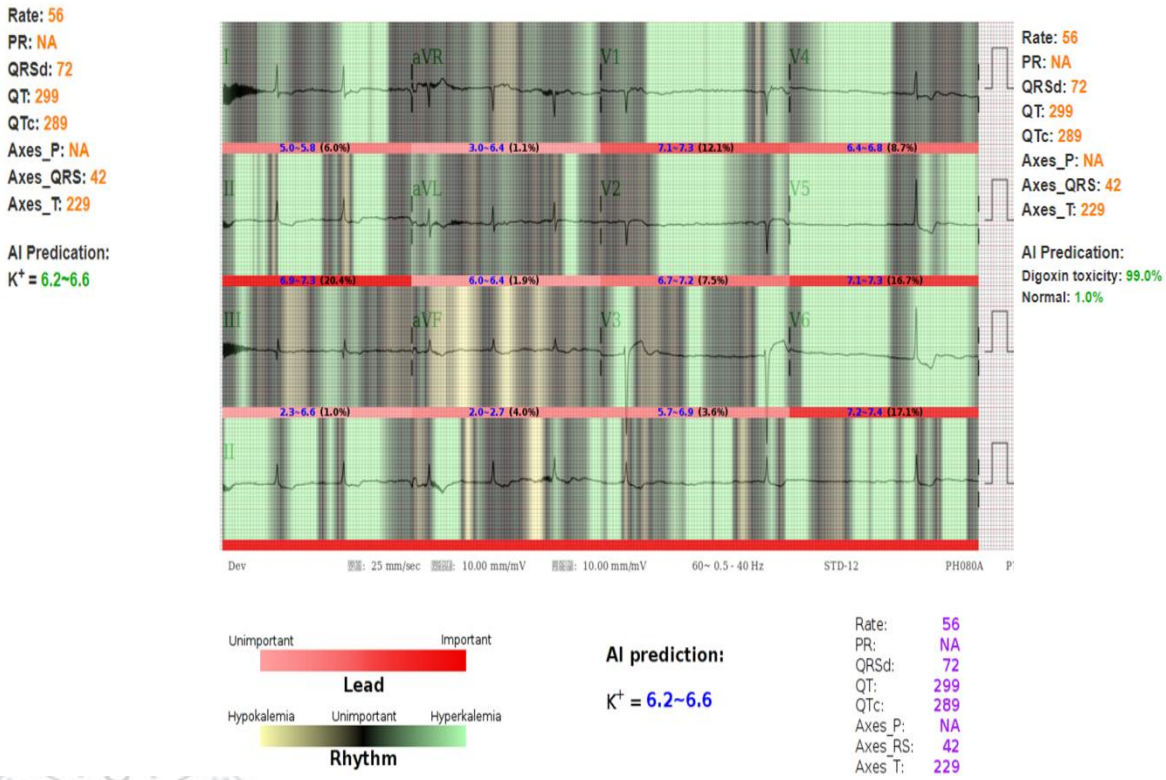
60 mmol K^+ supplement

The ECG-TPP score defined as the similarity of ECG of typical TPP by DLM had the value of probability >50.0% with a sensitivity of 87.5% and a specificity of 69.2%.

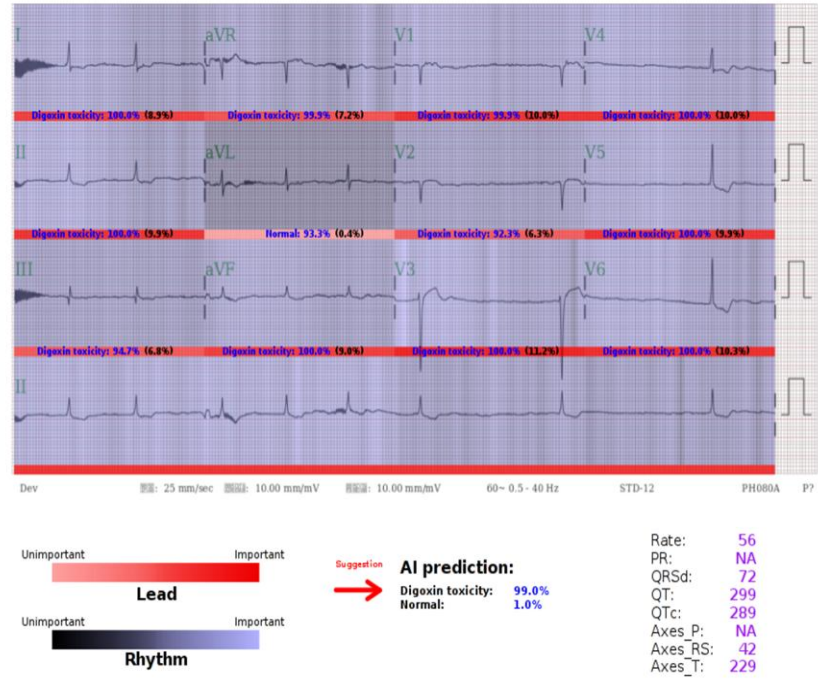
Lin C et al. J Endocrinol Soc 2021 Featured article and high-cited paper

- 86-year-old female with intermittent desaturation and bradycardia for about 2 days
- Past history:
  - VHD with moderate to severe MR (LVEF 53%)
  - **Persistent atrial fibrillation with rapid ventricular response, CHA2DS2VASc 5 on digoxin treatment, amidarone**
  - Type 2 Diabetes mellitus

To MER: TPR : 36.8/45/17 BP : 140/64, Sat; 90% on O2 mask

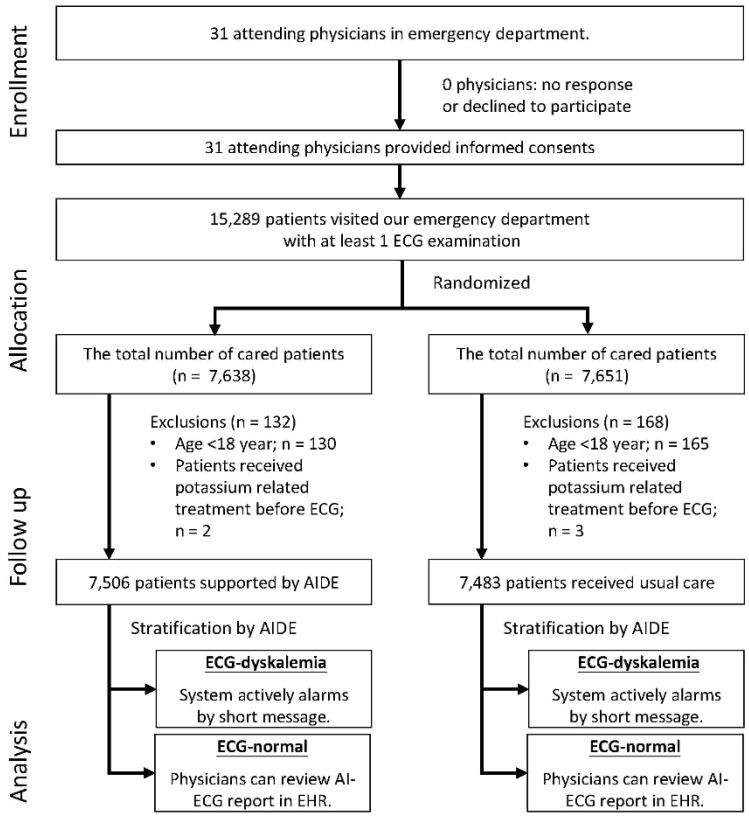


Lab K^+: 5.9 mmol/L



Serum digoxin level: 4.5 ng/ml

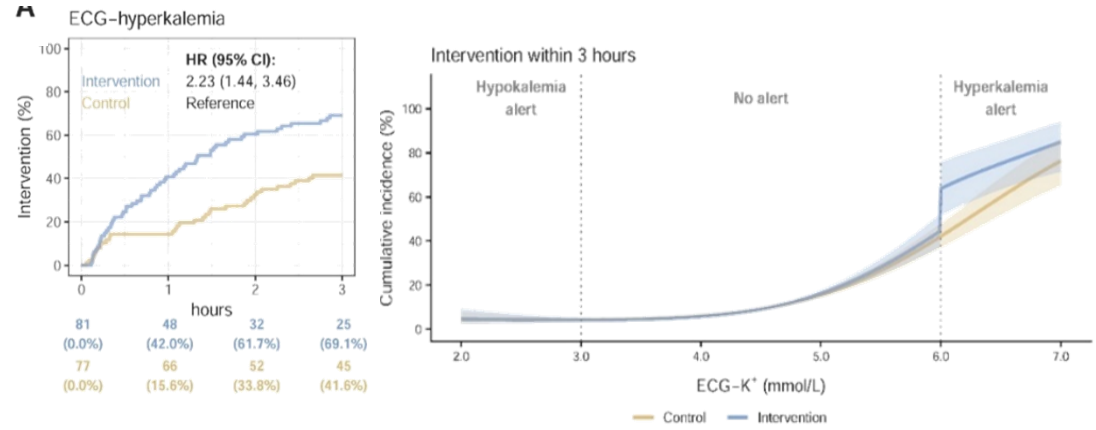
(V) Artificial Intelligence enabled Dyskalemia using Electrocardiogram (AIDE): a pragmatic randomized controlled trial



RCT settings

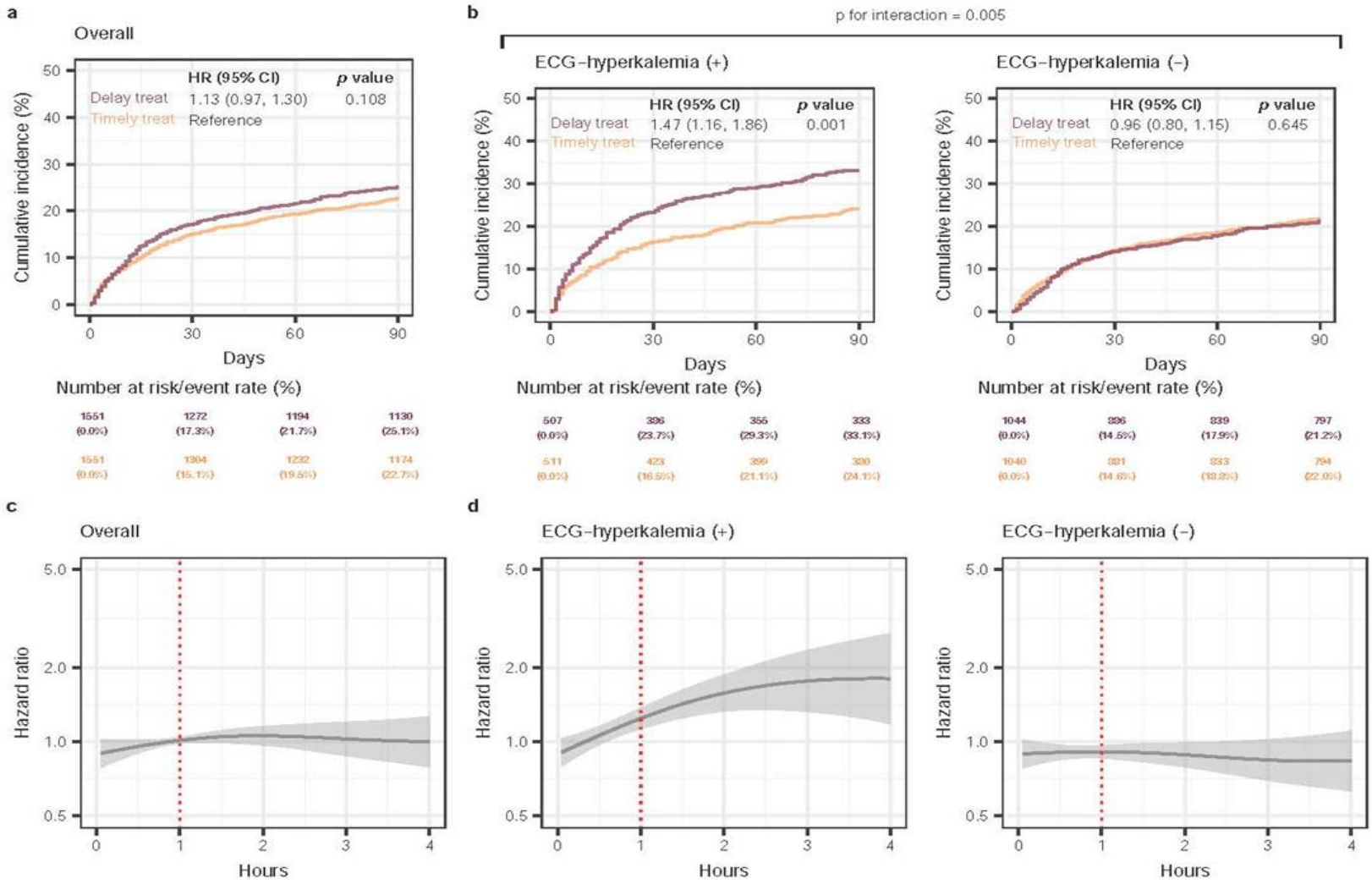
- **Emergency department in TSGH (~6 months)**
- **AI alert vs. usual care for physicians**
- **Primary endpoint: early treatment**

ClinicalTrial.gov: NCT05118022



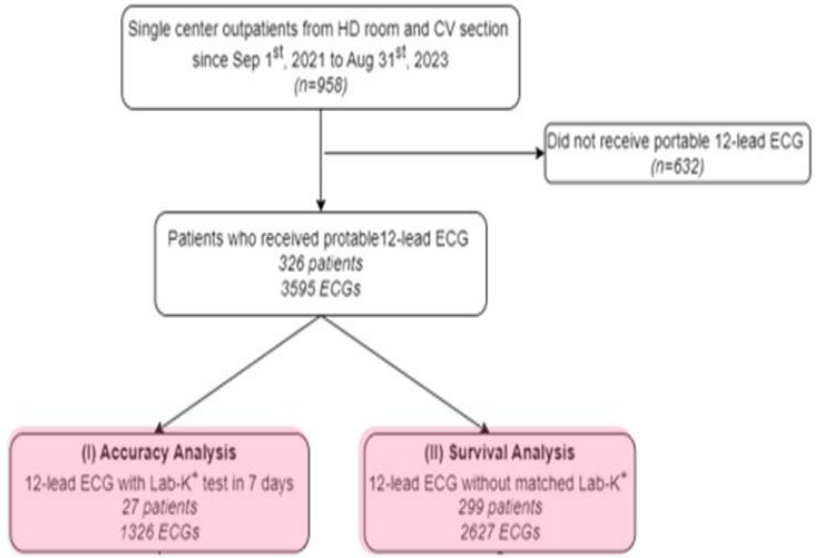
Nature Comm 2025 Lin C and Lin SH

Timely vs Delayed K^+-lowering therapy and 90-day mortality events, stratified by AI-ECG hyperkalemia: A Target Trial Emulation.



Artificial Intelligence-enabled Electrocardiography for Predicting Dyskalemia using Home-based ECG Devices

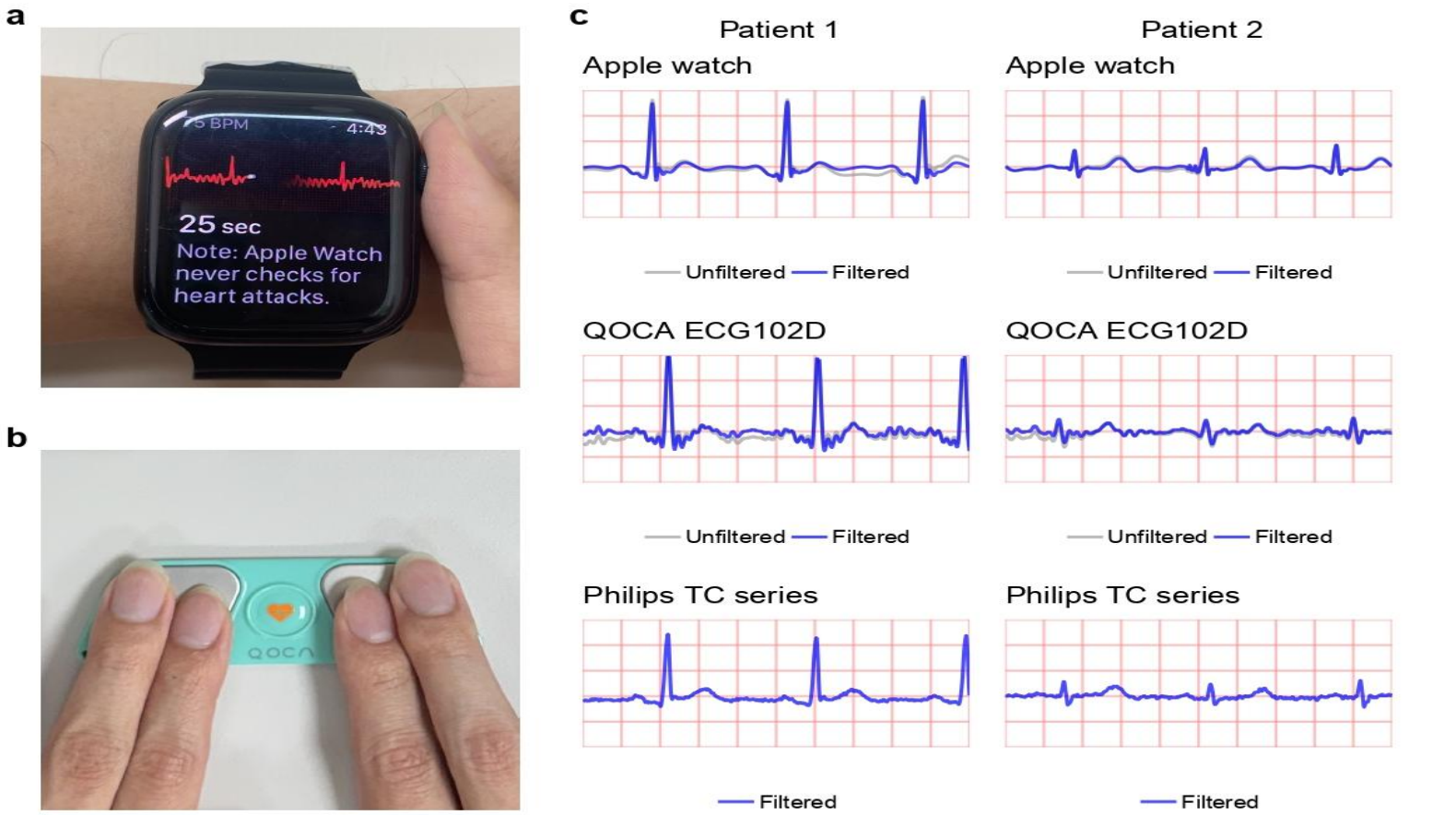
Methods



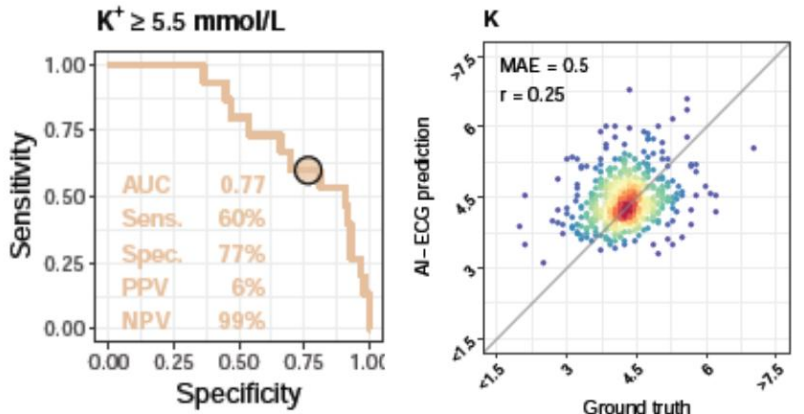
KIDNEY WEEK

JMIR Med Inform. 2020 Mar; 8(3): e15931
JAMA Cardiol. 2019 May; 4(5): 428–436

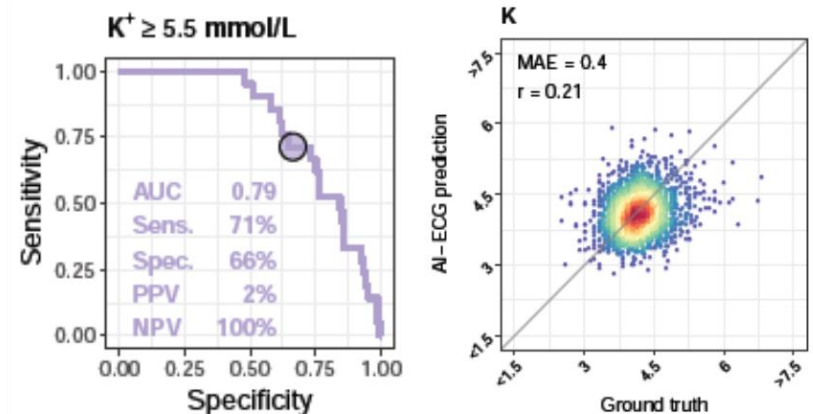
KIDNEY WEEK 2024



Apple Watch



QOCA ECG102D



應用心電圖快速偵測鉀離子異常

Q1

與廣達完成技轉(穿戴式裝置)

與廣達完成技轉(穿戴式裝置)

與QT medical/廣達合作，
採用Philips 12-Lead ECG (PH080A)
可推廣至各醫學中心

AL

美國專利申請

獲得美國專利

No. 16/910,035；2020.6.23

所屬專利家族	
獲得	77746427

國家/地區	申請案號
TW	TW.109108808.A
US	US.20201691003

全台第一

全台第一

We, 國家新創獎 New Ideas · New Solutions · New Generations Innovators

PAT TW 中華民國專利


中華民國專利證書

發明第 I732489 號

發明名稱：應用心電圖快速偵測鉀離子異常之方法及其系統

專利權人：國防醫學院

發明人：林石化；林錦宏；林嶔

專利期間：自2021年7月1日至2040年3月16日止

上開發明業經專利權人依專利法之規定取得專利權

經濟部智慧財產局 局長 洪淑敏

中華民國 110 年 7 月 1 日

TSGH NEP