

ORIGINAL ARTICLE

Prognostic performance of ECG abnormalities compared to vital signs in acutely ill patients in a resource-poor hospital in Uganda



Teopista Namujwiga^a, Immaculate Nakitende^a, John Kellett^{b,*}, Martin Opio^c, Alfred Lumala^a, on behalf of the Kitovu Hospital Study Group

^a Kitovu Hospital, Masaka, Uganda

^b Department of Emergency Medicine, Hospital of South West Jutland, Esbjerg, Denmark

^c Department of Medicine, Kitovu Hospital, Masaka, Uganda

ARTICLE INFO

Keywords:

Acute illness

Early warning scores

Risk stratification

ECG

Prolonged QTc

Left ventricular hypertrophy

ABSTRACT

Background: There are few reports of electrocardiogram (ECG) findings and their prognostic value in acutely ill patients admitted to low resource hospitals in sub-Saharan Africa.

Methods: We undertook an observational study of acutely ill medical patients admitted to a low-resource hospital in Uganda. Vital signs were used to calculate the National Early Warning Score (NEWS), and all ECGs were assessed using Tan et al.'s scoring system as described in Clin Cardiol 2009;32:82–86.

Results: There were 1361 ECGs performed, covering 68% of all acutely ill medical patients admitted to the hospital during the study. The most common ECG abnormality was a prolonged QTc interval (42% of all patients) and left ventricular hypertrophy (13.5%). Compared to the 519 patients (38%) with no Tan score abnormality, the 842 (62%) patients with one or more abnormalities were more likely to die in hospital (OR = 2.82; CI_{95%} = 1.50–5.36) and within 30 days of discharge (OR = 2.46; CI_{95%} = 1.50–4.08). There was no relationship between age and mortality; however, after adjustment by logistic regression, any NEWS ≥ 1 on admission, a Tan score of ≥ 1, and male sex all remained clinically significant predictors of both in-hospital and 30-day mortality.

Discussion: The majority of acutely ill medical patients admitted in a low-resource hospital in sub-Saharan Africa had ECG abnormalities, of which prolonged QTc and left ventricular hypertrophy were most common. Those with any Tan score abnormality were twice as likely to die as those without an abnormality.

African relevance

- Patients with ECG abnormalities are twice as likely to die as those without them.
- We found a high prevalence of QTc prolongation and left ventricular hypertrophy in this patient population.
- ECG changes, National Early Warning System, and male sex were independent predictors of mortality in this population; age was not.
- This is the first report of a novel re-usable belt ECG system as part of routine care in a low-resource African hospital.

Introduction

The 12-lead electrocardiogram (ECG) is a rapid, non-invasive test of value in the detection of cardiac and related non-communicable diseases (NCDs), both of which cause a large and growing disease burden

in sub-Saharan Africa [1–6]. Although numerous studies have demonstrated the prognostic value of ECGs for cardiac conditions [7–10], there are few reports of the ECG findings and their prognostic value in acutely ill medical patients, and only one study performed on acutely ill medical patients in a low resource hospital in sub-Saharan Africa. In a cohort of nearly 10,000 acutely ill medical patients with a mean age of 60 years (SD 20.0) admitted to an Irish hospital, an abnormal ECG was a predictor of in-hospital mortality: 4 of 4,177 (0.1%) acutely ill patients with an ECG interpreted as normal died within 24 h, and the odds ratio for 30-day mortality for those with an abnormal ECG was 5.2 (CI_{95%} = 3.7–7.4, $p < 0.0001$) [11,12]. In a separate study on younger acutely ill medical patients (mean age 39.5; SD = 15.9 years) performed in Malawi [13], the odds ratio of an abnormal ECG for in-hospital death was 2.08 (CI_{95%} = 1.12–3.88, $p = 0.02$). These comparisons should be interpreted with caution: there is no gold standard for ECG interpretation [14] and each study has determined its standards

Peer review under responsibility of African Federation for Emergency Medicine.

* Corresponding author.

E-mail address: jgkellett@eircom.net (J. Kellett).

<https://doi.org/10.1016/j.afjem.2018.12.005>

Received 3 April 2018; Received in revised form 2 September 2018; Accepted 19 December 2018

Available online 07 February 2019

2211-419X/ 2019 African Federation for Emergency Medicine. Publishing services provided by Elsevier. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

differently. In the Irish study, ECG normality was determined by Marquette proprietary software and, in the Malawi study, by absence of a list of criteria drawn up by the authors.

Tan et al. [15] reported a simple score that awarded one point to each of 12 ECG abnormalities: left and right bundle branch block, diagnostic Q waves, intra-ventricular conduction defect, atrial fibrillation, left atrial abnormality, left and right axis deviation, left and right ventricular hypertrophy, ST depression, and a QTc interval > 450 ms. This simple, non-proprietary score predicts mortality independently of standard risk factors. It outperforms other ECG scoring systems, such as the Selvester Score, CIIS and Minnesota Code [15], and its determination of ECG abnormality has been shown to be comparable to Marquette proprietary software [16]. On the other hand, vital signs, especially when combined into weighted scores, are well-established predictors of mortality [17,18]. This study reports the ECG abnormalities observed in acutely ill medical patients admitted to a resource-poor hospital in Uganda and compares their prognostic performance with vital signs.

Methods

This was an observational study carried out as part of an audit in an ongoing quality improvement project. The cohort was a convenience sample of acutely ill medical patients admitted to our facility. It was performed on patients being admitted to the medical ward at St. Joseph's Kitovu Health Care Complex, a 220 bedded healthcare facility located near Masaka, Uganda and 140 km from the capital city of Kampala. Together with the 330 bed Masaka Regional Referral Government Hospital, it serves Masaka Municipality (population of 79,200) and Masaka District (rural population of 804,300). The hospital has no intensive care or renal dialysis unit but can provide artificial ventilation.

From 10 August 2016 to 15 January 2018, two nurses, employed 12 h per day for 7 days a week, entered each patient's clinical status and vital signs twice daily into a clinical data management and decision support system (Rapid Electronic Assessment Data System (READS), Tapa Healthcare DAC). In addition, an ECG was performed on as many patients as possible within 12 h of admission to hospital using a reusable ECG belt and a portable mobile ECG device (LevMed Mobile ECG Kit, LevMed Ltd). All ECGs were interpreted by JK without knowledge of the patient's identity, clinical condition, or outcome. Although ECG axis, PR, QRS, QT and QTc intervals were all provided automatically by the ECG device software, all values were checked manually by JK. The Tan ECG score abnormalities were determined according to published criteria [15 and supplemental material]: if no Tan score abnormalities were present, an ECG was judged to be normal. Other non-Tan score ECG abnormalities (i.e. poor R wave progression, T wave inversion, ST flattening, ST elevation, heart block and ectopic beats) were also recorded.

Vital signs were entered into READS at the bedside immediately after their measurement; all data entries were automatically time and date stamped. Patient disposition (i.e. discharge or death) was also subsequently recorded into READS. All the READS data sets were complete. The National Early Warning Score (NEWS) [19], a well validated predictor of imminent mortality [18], was calculated from the heart rate, respiratory rate, systolic blood pressure, level of consciousness, temperature, oxygen saturations, inspired oxygen entered into the READS database.

This study was confined to patients who were 20 or more years of age. The clinical status 30 days after discharge was collected directly from patients or their relatives who consented to provide a contact mobile phone number and answer a call after discharge.

Primary outcomes were ECG abnormalities, in-hospital, and 30-day mortality. Age, gender, length of stay, admission NEWS and components, and ECG specifics (axis, PR, QRS, QT and QTc intervals, all the Tan score ECG abnormalities, as well as T wave inversion, ST flattening, ectopic beats, and poor R wave progression) were examined in relation to the primary outcomes. The tympanic temperatures of all patients were measured using the iProven dual mode infrared thermometer.

Temperatures were considered either high or low if they did not score zero NEWS points (i.e. > 38 °C or < 36 °C) [19].

All calculations were performed using Epi-Info version 6.0 (Center for Disease Control and Prevention, USA) and logistic regression analysis using Logistic software [20]. The p-value for statistical significance was 0.05 and was tested using Student's t-test and Chi square analysis that applied Yates continuity correction.

Ethical approval of the study was obtained from the Ethics Committee of Kitovu Hospital, which conformed to the principles outlined in the Declaration of Helsinki [21]. Since no interventions were additional to the usual standard of care, the need for written consent was waived. The study is reported in accordance with the STROBE statement [22].

Results

During the study period 1361 eligible patients admitted to the hospital had an ECG recorded: 600 (44%) of them were male and 75 (5.5%) died in hospital. Thirty-day follow-up was achieved in 588 (43%) of the 1361 patients on whom and ECG was performed: 123 (20.9%) of them died. The 773 patients lost to follow-up had similar age (52.1 SD 20.1 vs. 53.3 SD 20.5 years, $p = 0.30$) and length of stay (77.5 SD 55 vs. 80.0 SD 58.4 h, $p = 0.41$) distributions, but a lower NEWS on admission (3.3 SD 2.7 vs. 3.9 SD 3.1, $p = 0.0005$).

During the study period 642 patients (32% of all those admitted to hospital) did not have an ECG recorded. These patients, who were not included in the study, were older (54.7 SD 21.7 vs. 52.6 SD 20.3 years, $p = 0.04$), had a higher NEWS on admission (4.4 SD 3.3 vs. 3.6 SD 2.9, $p < 0.0001$), a shorter length of stay (69.2 SD 61.9 vs. 78.6 SD 56.5 h, $p < 0.0001$), and a higher in-hospital mortality (i.e. 11.8% vs. 5.5%, $p < 0.0001$) than participants: 69 (92%) of the 75 non-participant patients who died without an ECG being performed did so within 5 h of admission.

Only three patients had pathological ST elevation: one aged 75 years died 23 days after admission from a presumed myocardial infarction; the other two (age 30 and 56 years) were still alive 30 days after discharge. We suspect the younger patient had pericarditis and the older one a myocardial infarction. Six patients had complete heart block: all survived to hospital discharge, two to 30 days after discharge, the other four were lost to follow-up. No Tan score abnormality was observed in 519 (38%) patients. One Tan score abnormality was observed in 441 (30%), two in 242 (18%), three in 122 (9%), four in 41 (3%), five in 19 (1.4%) and six in 7 (0.5%) patients: no patients had more than six ECG abnormalities. The 842 (61.9%) patients with one or more Tan score abnormality present were older (57.2 SD 19.8 versus 45.1 SD 18.8 years, $p < 0.0001$), had a longer length of stay (83.6 SD 57.3 versus 70.4 SD 54.2 h, $p < 0.0001$), and a higher NEWS on admission (4.0 SD 3.0 versus 3.0 SD 2.7, $p < 0.0001$) than those with a normal ECG. The commonest ECG abnormality was a prolong QTc interval (42% of all patients) and left ventricular hypertrophy (13.5% of all patients); left ventricular hypertrophy and left atrial abnormality were more as common in men, and prolonged QTc, ST depression and ST flattening were more common in women (Table 1).

Clinically, 22% of deaths were likely caused by pneumonia or sepsis, 19% by heart failure, 18% by HIV or its complications, 13% by suspected tuberculosis, and the remainder by miscellaneous causes. Men had a higher in-hospital and 30 days after discharge mortality than women. Those with an abnormal ECG were more likely to die in hospital and within 30 days of discharge. Although more Tan score abnormalities were observed in older patients (Table 2), there was no relationship between age and mortality. In contrast to ECG abnormality, neither in-hospital nor 30-day mortality rates were significantly different in any age group (Fig. 1). Although patients who died had a higher NEWS on admission than survivors, there was no difference in the ages or the length of hospital stay between those who died and survivors: the individual components of NEWS (i.e. heart rate, respiratory rate, blood pressure, high and low temperature, alertness, oxygen saturation, and the use of supplemental oxygen) were all

Table 1

ECG abnormalities observed and their association odds with male sex.

ECG abnormality	Patient number (%)	OR male sex	Chi-square	p
Tan score abnormalities				
Any abnormality	842 (61.9%)	1.04 (0.82–1.30)	0.07	0.8
QTc > 450 ms	570 (41.9%)	0.78 (0.62–0.98)	4.78	0.03
Left ventricular hypertrophy	183 (13.4%)	2.06 (1.48–2.88)	19.86	< 0.001
ST depression	152 (11.2%)	0.69 (0.48–1.00)	3.97	0.046
Left atrial abnormality	137 (10.1%)	1.51 (1.04–2.19)	4.83	0.03
Q wave	120 (8.8%)	1.21 (0.81–1.79)	0.08	0.37
Inter ventricular conduction defect	114 (8.4%)	1.07 (0.71–1.61)	0.06	0.8
Left axis deviation	93 (6.8%)	0.83 (0.52–1.30)	0.58	0.45
Right ventricular hypertrophy	65 (4.8%)	1.61 (0.95–2.75)	3.08	0.08
Right axis deviation	47 (3.5%)	1.02 (0.55–1.92)	0.00	0.94
Right bundle branch block	32 (2.4%)	0.76 (0.34–1.65)	0.33	0.56
Left bundle branch block	29 (2.1%)	0.56 (0.23–1.33)	1.54	0.21
Atrial fibrillation	21 (1.5%)	0.63 (0.23–1.69)	0.61	0.44
Other non-Tan score abnormalities				
ST flattening	298 (21.9%)	0.67 (0.51–0.89)	8.32	0.004
T wave inversion	250 (18.4%)	1.04 (0.78–1.38)	0.03	0.85
Ectopic beats	72 (5.3%)	0.62 (0.36–1.06)	3.10	0.08
Poor R wave progression	29 (2.1%)	0.77 (0.34–1.75)	0.24	0.63

associated with mortality (Table 3). Any NEWS value ≥ 1 was associated with a significantly increased risk of mortality: the value with the highest Chi-square for in-hospital mortality was a NEWS ≥ 7 (OR 9.81, CI_{95%} 5.82–16.58, $X^2 = 112.05$, $p < 0.0001$).

The only ECG abnormalities associated with in-hospital mortality were a prolonged QTc and left atrial abnormality. The only abnormalities associated with 30-day mortality were a long QTc, left atrial abnormality and Q waves (Table 3). After adjustment by logistic regression NEWS eliminated all its component parameters as predictors of mortality. However, any increase in NEWS on admission, a Tan score of 1 or greater, and male sex all remained clinically significant predictors of both in-hospital and 30-day mortality (Table 4).

Discussion

This study showed that acutely ill patients treated in a resource-limited hospital in sub-Saharan Africa with an abnormal ECG are more than twice as likely to die as those with a normal ECG on presentation. After adjustment by logistic regression, any increase in NEWS on admission, a Tan score of 1 or greater, and male sex all remained clinically significant comparable predictors of both in-hospital and 30-day mortality.

In the developed world, older acutely ill patients are more likely to die than younger ones. However, in this patient population there was no association between mortality and age, yet a clear increase in ECG abnormalities with age. The only other report from sub-Saharan Africa on the association between ECG changes and mortality was on just 89 patients and found the ECG to only be a univariate predictor of death [13]. This study shows that ECG abnormality is a significant predictor of mortality even when adjusted for vital sign changes, albeit with a

lower odds ratio for death up to 30 days after discharge than that previously reported for acutely ill Irish patients [11,12].

A prolonged QTc interval > 450 ms and left atrial abnormality were the only Tan score abnormalities associated with in-hospital death. Only prolonged QTc interval, left atrial abnormality and Q waves were associated with death within 30 days of discharge. Failure to show an association of the other nine Tan score abnormalities with mortality is probably explained by the short follow-up period: the 12 Tan score ECG abnormalities were those found to be associated with increased mortality in 29,320 outpatient male veterans over an average follow-up period of 7.5 years [15].

QTc prolongation was the commonest Tan score ECG abnormality: it was observed in more than 40% of our patients compared with 5% of the ECGs of performed on 387 urban South Africans who were not acutely ill [23]. Numerous factors associated with acute illness can influence the QTc interval (e.g. drugs, electrolyte disturbances, diabetes, liver and renal disease, etc). Indeed, both HIV infection and antiretroviral drugs can prolong the QTc interval [24]. Continuous monitoring has demonstrated that variation of the QTc interval is common during acute illness and that its prolongation is associated with mortality [25]. Recently institution wide systems have been introduced to detect it [26].

This study has some potential weaknesses. Only one ECG was performed shortly after admission, so it is probable that evolving changes were missed, especially in patients who died. Only one researcher read all the ECGs, and it is well known that both intra- and inter-observer errors occur in ECG interpretation [14]. Moreover, there was a low follow-up of patients, which makes it difficult to know if our results can be generalised. The exact timing between the vital sign recordings and the ECG being performed was not recorded. The nurses' work pattern was to first perform vital signs on all patients, and then perform an ECG

Table 2

Proportion of each Tan score ECGs abnormality observed in each age group.

Age (years)	Abnormal ECG	Prolonged QTc	LVH	ST depression	LAA	Q wave	IVCD	LAD	RVH	RAD	RBBB	LBbB	AF
20–19	39.0%	21.2%	10.6%	8.5%	3.8%	3.8%	4.7%	0.8%	4.2%	4.2%	0.0%	0.0%	0.4%
30–39	57.3%	38.9%	13.0%	10.8%	8.1%	4.9%	10.3%	3.2%	3.2%	3.2%	2.2%	1.1%	0.0%
40–49	48.7%	33.9%	8.6%	8.6%	4.3%	4.3%	2.7%	2.2%	4.8%	2.7%	1.6%	0.0%	0.5%
50–59	62.5%	42.9%	15.8%	11.4%	9.2%	9.2%	8.7%	4.3%	3.3%	0.5%	1.6%	0.5%	0.5%
60–69	73.5%	52.5%	11.0%	14.0%	14.5%	10.0%	11.5%	10.0%	6.0%	4.0%	2.5%	5.5%	1.5%
70–79	77.0%	53.1%	18.8%	12.7%	16.9%	12.7%	7.5%	13.6%	8.0%	4.2%	5.6%	4.2%	3.3%
80–89	79.9%	54.9%	18.8%	11.3%	15.0%	18.0%	15.0%	15.0%	2.3%	3.8%	3.8%	3.8%	3.8%
≥ 90	90.9%	68.2%	9.1%	22.7%	13.6%	27.3%	18.2%	18.2%	9.1%	13.6%	0.0%	4.5%	13.6%

LVH, left ventricular hypertrophy; LAA, left atrial abnormality; IVCD, inter ventricular conduction defect; LAD, left axis deviation; RVH, right ventricular hypertrophy; RAD, right axis deviation; RBBB, right bundle branch block; LBbB, left bundle branch block; AF, atrial fibrillation.

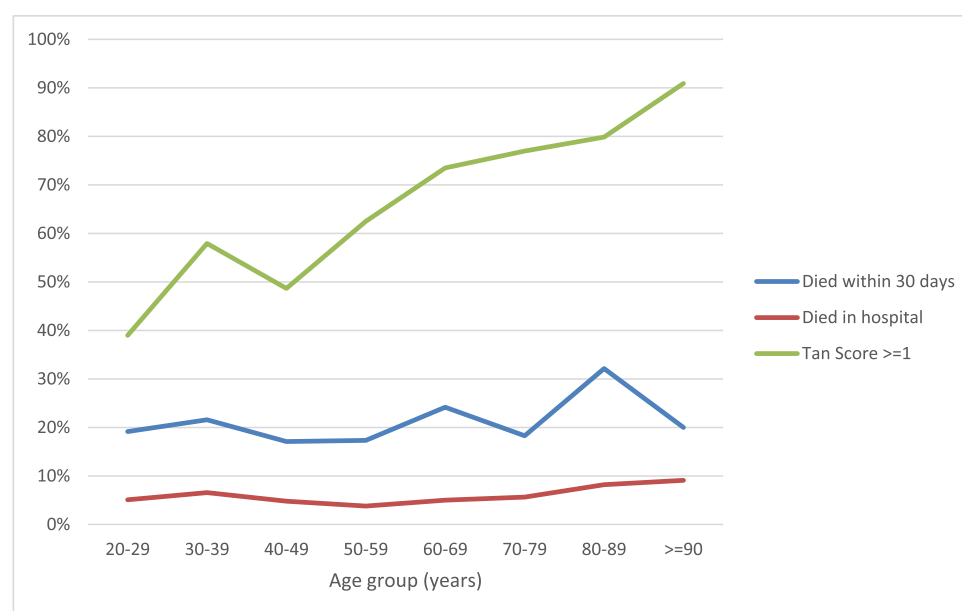


Fig. 1. Percentage of patients by age group who died in hospital and within 30 days of discharge, and who had a Tan score ≥ 1 .

on all new admissions. On average it took approximately 2 h to measure all the patients' vital signs, so there was usually a 3-or-more hour delay before an ECG could be performed. Since patients were only assessed twice a day, in early morning and late evening, it is possible that there may have been a delay of up to 12 h between admission to hospital and data entry. Similarly, many patients may have been discharged from hospital or died before there was an opportunity to perform an ECG.

Nevertheless, as far as we know, this is the first time ECGs have been introduced as part of routine care in a low-resource hospital in sub-Saharan Africa. Although ECG is a rapid, valuable, and non-invasive test, traditional machines are delicate, expensive, and require servicing and the use of consumables such as paper and electrodes. The secure storage of ECG tracings also incurs additional costs. All these factors limit ECG use and availability in the developing world [27]. The re-usable belt and ECG systems used in this study were simple, rapid, robust, and prevented wrong lead placement [28]. All ECGs were generated electronically on a tablet computer, could be stored on a server and, if required, transmitted by email for interpretation. Therefore, after the initial investment, the costs of maintaining the system and performing an ECG are negligible.

In the past, communicable diseases were considered to be sub-Saharan Africa's major health burden. However, cardiac-related and other NCDs are now major sources of morbidity and mortality and are projected to overtake infectious diseases by 2030 [29,30]. There were several differences in the prevalence of the ECG abnormalities observed in this study and those in the original Tan score derivation cohort of US veterans ([15] and supplemental data). The second commonest ECG abnormalities we observed was left ventricular hypertrophy (13.5% of patients) compared with 5.2% of the Tan score derivation cohort, but similar to the frequency seen in South African patients without known cardiac disease [23]. Although QRS voltage may be higher in those of African descent compared to Caucasians [31–33], pre-existing hypertension is the most likely explanation of left ventricular hypertrophy in our patients as all their ECGs fulfilled the Romhilt–Estes criteria and their blood pressures, even when acutely ill, were higher than patients without left ventricular hypertrophy (i.e. 129 SD 32 versus 112 SD 23 mmHg, $p < 0.0001$).

It is difficult to know what the advantages of ECG availability to low-resource hospitals in sub-Saharan Africa will prove to be. In the developed world, early warning scores based on vital signs are

frequently used for early risk stratification, which ensures that care is quickly concentrated on those who need it most [19]. The prompt and efficient use of care is even more important in resource-poor settings. This study shows that the ECG, unlike age, can help identify patients at imminent risk of death, even when their vital signs are not grossly deranged. Many of the ECG changes we found may be normal variants as several studies have described ECG characteristics in Africans such as inverted and flattened T waves, high R wave amplitude (especially in young males), ST elevation and axis deviation [23]. However, the ECGs in this study showed evidence of ischemic heart disease (i.e. 11% had ST depression, 8.8% Q waves and 6.8% left axis deviation) that are unlikely to be normal variants. The Heart of Soweto Study [34] also found frequent ECG abnormalities and advocated the potential value in resource-poor environments of the 12-lead ECG in detecting previously undiagnosed heart disease, particularly hypertensive heart disease [35] and valve disease [36]. Although only two patients with probable acute myocardial infarctions were identified by this study, the incidence of ischaemic heart disease in sub-Saharan Africa is increasing, and hypertension is its commonest risk factor [37].

This study found that the majority of acutely ill medical patients admitted to a resource-poor hospital in sub-Saharan Africa had ECG abnormalities, which included those associated with ischemic heart disease. There was a high prevalence of prolonged QTc interval and left ventricular hypertrophy, and ECG abnormalities were more frequently observed on older patients. A Tan score of 1 or greater ECG abnormalities, NEWS and male gender – but not age – were all clinically significant predictors of mortality in-hospital and for up to 30 days after hospital discharge.

Acknowledgements

The authors wish to acknowledge and thank LevMed Ltd. (www.levmed.net) who provided the LevMed Reusable ECG Belt and LevMed Mobile ECG Kit at no charge, and Tapa Healthcare DAC (Dundalk, Ireland) for the complimentary use of their Rapid Electronic Assessment Data System (READS). None of these sponsors played any part in the design or execution of the study, and all other costs were borne by the authors.

Table 3
Variables tested for prediction of in-hospital and 30 day mortality.

Continuous variables	Died in hospital (n 75) versus Survivors (n 1286)			Died within 30 days(n 123) versus survivors (n 465)		
	Mean $\pm$ SD	Mean $\pm$ SD	p	Mean $\pm$ SD	Mean $\pm$ SD	p
Age (years)	54.2 $\pm$ 21.4	52.5 $\pm$ 20.2	0.50	55.0 $\pm$ 20.8	52.8 $\pm$ 20.4	0.30
Length of stay (hours)	89.6 $\pm$ 77.8	77.9 $\pm$ 55.0	0.08	86.9 $\pm$ 69.3	78.2 $\pm$ 55.0	0.14
NEWS on admission	7.3 $\pm$ 3.3	3.4 $\pm$ 2.7	<0.001	6.2 $\pm$ 3.3	3.3 $\pm$ 2.7	<0.001
Heart rate (bpm)	97 $\pm$ 25	86 $\pm$ 17	<0.001	94 $\pm$ 24	85 $\pm$ 17	<0.001
Temperature (°C)	36.9 $\pm$ 1.1	36.7 $\pm$ 0.8	0.12	36.8 $\pm$ 1	36.7 $\pm$ 0.7	0.36
Respiratory rate (bpm)	27 $\pm$ 9	21 $\pm$ 5		25 $\pm$ 8	21 $\pm$ 5	<0.001
SBP (bpm)	109 $\pm$ 31	115 $\pm$ 24	0.03	108 $\pm$ 30	115 $\pm$ 23	0.01
O2 saturation (%)	90 $\pm$ 12	95 $\pm$ 5	<0.001	92 $\pm$ 10	96 $\pm$ 6	<0.001
PR interval (ms)	159 $\pm$ 33	161 $\pm$ 33	0.69	155 $\pm$ 35	161 $\pm$ 34	0.09
QRS interval (ms)	94 $\pm$ 21	95 $\pm$ 18	0.78	93 $\pm$ 19	95 $\pm$ 19	0.32
QT interval (ms)	372 $\pm$ 71	382 $\pm$ 51	0.14	373 $\pm$ 66	381 $\pm$ 47	0.13
QTc interval (ms)	465 $\pm$ 56	448 $\pm$ 46	0.002	460 $\pm$ 53	447 $\pm$ 45	0.004
Axis (°)	35 $\pm$ 39	35 $\pm$ 38	0.98	39 $\pm$ 39	36 $\pm$ 38	0.41
Tan score	1.5 $\pm$ 1.3	1.1 $\pm$ 1.3	0.004	1.5 $\pm$ 1.3	1.1 $\pm$ 1.3	0.01

Categorical variables	n (%)	Odds ratio	95% Confidence intervals	Chi-square, p	n (%)	Odds ratio	95% Confidence intervals	Chi-square, p
Alert on admission	1291 (95%)	0.13	0.07 – 0.26	53.83, <0.001	551 (94%)	0.20	0.09 – 0.41	24.11, <0.001
Male gender	600 (44%)	2.36	1.41 – 3.97	11.93, <0.001	270 (46%)	2.16	1.41 – 3.33	13.44, <0.001
Use of supplemental oxygen	56 (4%)	7.8	3.77 – 15.07	46.50, <0.001	35 (6%)	3.97	1.88 – 8.40	15.41, <0.001
Temperature >38°C	51 (4%)	2.91	1.14 – 7.09	5.33, 0.02	25 (4%)	2.22	0.87 – 5.53	2.70, 0.10
Temperature <36°C	156 (11%)	2.85	1.57 – 5.11	13.64, 0.002	73 (12%)	2.22	1.25 – 3.91	8.05, 0.005
Tan score $\geq$ 1	842 (62%)	2.82	1.50 – 5.36	11.89, <0.001	377 (64%)	2.46	1.50 – 4.08	13.9, <0.001
Prolonged QTc	570 (42%)	2.44	1.47 – 4.08	13.11, <0.001	359 (61%)	1.77	1.16 – 2.70	7.3, 0.007
Left ventricular hypertrophy	183 (13%)	0.76	0.33 – 1.68	0.31, 0.58	73 (12%)	0.97	0.50 – 1.86	0.0, 0.95
ST depression	152 (11%)	0.95	0.41 – 2.10	0.00, 0.97	60 (10%)	1.29	0.66 – 2.51	0.42, 0.52
Left atrial abnormality	137 (10%)	2.17	1.12 – 4.15	5.49, 0.02	72 (12%)	1.95	1.09 – 3.47	5.25, 0.02
Q wave	120 (9%)	1.85	0.89 – 3.78	2.64, 0.10	53 (9%)	2.1	1.09 – 4.03	5.12, 0.02
IVCD	114 (8%)	1.75	0.81 – 3.66	1.89, 0.17	51 (9%)	1.48	0.73 – 2.98	1.03, 0.31
Left axis deviation	93 (7%)	0.76	0.23 – 2.23	0.09, 0.76	36 (6%)	0.74	0.27 – 1.94	0.19, 0.66
Right ventricular hypertrophy	65 (5%)	0.82	0.20 – 2.83	0.00, 0.96	34 (6%)	0.64	0.21 – 1.79	0.5, 0.48
Right axis deviation	47 (3%)	2.63	0.96 – 6.81	3.56, 0.06	26 (4%)	1.72	0.66 – 4.36	1.02, 0.31
Right bundle branch block	32 (2%)	1.15	0.00 – 5.11	0.04, 0.83	17 (3%)	0.80	0.18 – 3.08	0.00, 0.97
Left bundle branch block	29 (2%)	0.00	0.00 – 2.95	0.82, 0.37	14 (2%)	0.00	0.00 – 1.38	2.62, 0.11
Atrial fibrillation	21 (2%)	2.93	0.66 – 10.97	1.67, 0.20	15 (3%)	2.59	0.79 – 8.23	2.29, 0.13
T wave inversion	250 (18%)	0.75	0.37 – 1.51	0.50, 0.48	108 (18%)	1.03	0.59 – 1.77	0.00, 0.97
ST flattening	298 (22%)	0.73	0.38 – 1.41	0.72, 0.40	120 (20%)	0.99	0.58 – 1.67	0.01, 0.93
Ectopic beats	72 (5%)	0.73	0.18 – 2.51	0.07, 0.80	31 (5%)	1.0	0.43 – 2.79	0.00, 0.99
Poor R wave progression	29 (2%)	2.02	0.47 – 7.28	0.55, 0.46	12 (2%)	2.77	0.74 – 10.02	2.02, 0.15

SD, standard deviation; IVCD, intraventricular conduction defect

All values in italics are statistically significant.

Table 4
Logistic regression of ECG abnormality against age and NEWS on admission.

	Coefficient	(SE)	Odds ratio	(95% CI)	p
In-hospital mortality					
Constant	−5.8551	(0.5224)			0.00
Tan score ≥ 1	0.6837	(0.3280)	1.98	(1.04–3.77)	0.04
NEWS on admission	0.3739	(0.0402)	1.45	(1.34–1.57)	< 0.001
Male gender	0.9014	(0.2650)	2.46	(1.47–4.14)	0.001
Age	0.0019	(0.0064)	1.00	(0.99–1.01)	0.77
30 day mortality					
Constant	−3.6529	(0.4105)			0.00
Tan score ≥ 1	0.6855	(0.2719)	1.98	(1.16–3.42)	0.01
NEWS on admission	0.2937	(0.0363)	1.34	(1.25–1.44)	< 0.001
Male gender	0.7732	(0.2274)	2.17	(1.39–3.38)	0.001
Age	0.0016	(0.0056)	1.00	(0.99–1.01)	0.78

SE, standard error; 95% CI, 95% confidence interval.

Conflict of interest

John Kellett is a major shareholder, director and chief medical officer of Tapa Healthcare DAC. The other authors have no potential conflicts of interest.

Dissemination of results

This observational study was carried out as part of an audit in an ongoing quality improvement project on behalf of the Kitovu Hospital Study group. This project also includes regular staff education and training on the collection, interpretation and response to abnormal vital signs and symptoms, and the results of its ongoing studies. It also includes ongoing audit and discussion of patient outcomes, and how protocols can be devised to improve them.

Authors' contributions

Authors contributed as follows to the conception or design of the work; the acquisition, analysis, or interpretation of data for the work; and drafting the work or revising it critically for important intellectual content: TN, IN, and JK contributed 25% each, MO contributed 20% and AL contributed 5%. All authors agreed to be accountable for all aspects of the work related to accuracy or integrity.

References

- [1] Holmes MD, Dalal S, Volmink J, Adebamowo CA, Njelekela M, et al. Non-communicable diseases in Sub-Saharan Africa: The case for Cohort studies. *PLoS Med* 2010;7(5):e1000244 <https://doi.org/10.1371/journal.pmed.1000244>.
- [2] Unwin N, Setel P, Rashid S, Mugusi F, Mbanya JC, et al. Noncommunicable diseases in sub-Saharan Africa: where do they feature in the health research agenda? *Bull World Health Organ* 2001;79:947–53.
- [3] Abegunde DO, Mathers CD, Adam T, Ortegon M, Strong K. The burden and costs of chronic diseases in low-income and middle-income countries. *Lancet* 2007;370:1929–38.
- [4] Mensah GA. Ischaemic heart disease in Africa. *Heart* 2008;94:836–43.
- [5] Connor MD, Walker R, Modi G, Warlow CP. Burden of stroke in black populations in sub-Saharan Africa. *Lancet Neurol* 2007;6:269–78.
- [6] Parkin DM, Sitas F, Chirenje M, Stein L, Abratt R, et al. Part I: cancer in indigenous Africans—burden, distribution, and trends. *Lancet Oncol* 2008;9:683–92.
- [7] De Bacquer D, De Backer G, Kornitzer M, Blackburn H. Prognostic value of ECG findings for total, cardiovascular disease, and coronary heart disease death in men and women. *Heart* 1998;80:570–7.
- [8] Greenland P, Xie X, Liu K, Colangelo L, Liao Y, Daviglius ML, et al. Impact of minor electrocardiographic ST segment and/or T-wave abnormalities on cardiovascular mortality during long-term follow-up. *Am J Cardiol* 2003;91:1068–74.
- [9] Auer R, Bauer DC, Marques-Vidal P, Butler J, Min LJ, Cornuz J, et al. Association of major and minor ECG abnormalities with coronary heart disease events. *JAMA* 2012;307:1497–505.
- [10] Groot A, Bots ML, Rutten FH, den Ruijter HM, Numans ME, Vaartjes I. Measurement of ECG abnormalities and cardiovascular risk classification: a cohort study of primary care patients in the Netherlands. *Br J Gen Pract* 2015;65:e1–8.
- [11] Kellett J, Deane B. The Simple Clinical Score predicts mortality for days after admission to an acute medical unit. *Q J Med* 2006;99:771–81.
- [12] Kellett J, Deane B, Gleeson M. Derivation and validation of a score based on hypotension, oxygen saturation, low temperature, ECG changes and loss of independence (HOTEL) that predicts early mortality between 15 minutes and 24 hours after admission to an acute medical unit. *Resuscitation* 2008;78:52–8.
- [13] Wheeler I, Price C, Sitch A, Banda P, Kellett J, Nyirenda M, et al. Early warning scores generated in developed healthcare settings are not sufficient at predicting early mortality in Blantyre, Malawi: a prospective cohort study. *PLoS One* 2013;8(3):e59830 <https://doi.org/10.1371/journal.pone.0059830>.
- [14] Salerno SM, Alguire PC, Waxman HS. Competency in interpretation of 12-lead electrocardiograms: a summary and appraisal of published evidence. *Ann Intern Med* 2003;138:751–60.
- [15] Tan SY, Sungar GW, Myers J, Sandri M, Froelicher V. A simplified clinical electrocardiogram score for the prediction of cardiovascular mortality. *Clin Cardiol* 2009;32:82–6.
- [16] Kellett J, Clifford M. The prediction of death up to 100 days after admission to hospital for acute medical illness – the comparison of two ECG interpretation methods with ECG-dispersion mapping. *Acute Med* 2015;14(4):151–8.
- [17] Bleyer AJ, Vidya S, Russell GB, Jones CM, Sujata L, Daeiagh P, et al. Longitudinal analysis of one million vital signs in patients in an academic medical center. *Resuscitation* 2011;82:1387–92.
- [18] Smith GB, Prytherch DR, Meredith P, Schmidt PE, Featherstone PI. The ability of the National Early Warning Score (NEWS) to discriminate patients at risk of early cardiac arrest, unanticipated intensive care unit admission, and death. *Resuscitation* 2013;84:465–70.
- [19] Royal College of Physicians. National Early Warning Score (NEWS): standardising the assessment of acute illness severity in the NHS. Report of a Working Party. London: RCP; 2012. www.rcplondon.ac.uk/resources/nationalearlywarningscore-news.
- [20] Dallal GE. LOGISTIC: a logistic regression program for the IBM PC. *Am Stat* 1988;42:272.
- [21] World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA* 2013;310:2191–4.
- [22] Vandenbroucke JP, von Elm E, Altman DG, Gøtzsche PC, Mulrow CD, et al. Strengthening of Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *PLoS Med* 2007;4(10):e297 <https://doi.org/10.1371/journal.pmed.0040297>.
- [23] Sliwa K, Lee GA, Carrington MJ, Obel P, Okreglicki A, Stewart S. Redefining the ECG in urban South Africans: electrocardiographic findings in heart disease-free Africans. *Int J Cardiol* 2013;167:2204–9.
- [24] Chinello P, Petrosillo N. QT interval prolongation and antiretroviral treatment: another point of interest. *Clin Infect Dis* 2007;44:1388–9.
- [25] Pickham D, Helfenbein E, Shinn JA, Chan G, Funk M, Weinacker A, et al. High prevalence of corrected QT interval prolongation in acutely ill patients is associated with mortality: results of the QT in practice (QTIP) study. *Crit Care Med* 2012;40:394–9.
- [26] Haugaa KH, Bos JM, Tarrell RF, Morlan BW, Caraballo PJ, Ackerman MJ. Institution-wide QT alert system identifies patients with a high risk of mortality. *Mayo Clin Proc* 2013;88(4):315–25.
- [27] Varma J. Role of the surface electrocardiogram in developing countries. *J Electrocardiol* 2010;43:612–4.
- [28] Opio MO, Kellett J. Kitovu Hospital Study Group. An observational study of the quality of ECGs recorded by inexperienced staff in a resource-poor African hospital using a reusable ECG belt linked to an internet ECG device. *Eur J Intern Med* 2017;42:e17–8.
- [29] Yach D, Hawkes C, Gould CL, Hofman KJ. The global burden of chronic diseases: overcoming impediments to prevention and control. *JAMA* 2004;291:2616–22.
- [30] Mathers CD, Loncar D. Projections of global mortality and burden of disease from 2002 to 2030. *PLoS Med* 2006;3:e442 <https://doi.org/10.1371/journal.pmed.0030442>.
- [31] Hancock EW, Deal BJ, Mirvis DM, et al. AHA/ACCF/HRS recommendations for the standardization and interpretation of the electrocardiogram: Part V: Electrocardiogram changes associated with cardiac chamber hypertrophy: a scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society. Endorsed by the International Society for Computerized Electrocardiology. *J Am Coll Cardiol* 2009;53:992–1002.
- [32] Okin PM, Wright JT, Nieminen MS, et al. Ethnic differences in electrocardiographic criteria for left ventricular hypertrophy: the LIFE study. Losartan intervention for endpoint. *Am J Hypertens* 2002;15:663–71.
- [33] Hinderliter AL, Blumenthal JA, Waugh R, Chilukuri M, Sherwood A. Ethnic differences in left ventricular structure: relations to hemodynamics and diurnal blood pressure variation. *Am J Hypertens* 2004;17:43–9.
- [34] Sliwa K, Wilkinson D, Hansen C, et al. Spectrum of heart disease and risk factors in a black urban population in South Africa (the Heart of Soweto Study): a cohort study. *Lancet* 2008;371:915–22.
- [35] Stewart S, Libhaber E, Carrington M, et al. The clinical consequences and challenges of hypertension in urban-dwelling black Africans: insights from the Heart of Soweto Study. *Int J Cardiol* 2011;146:22–7.
- [36] Sliwa K, Carrington M, Mayosi BM, Zigiriadis E, Mvungi R, Stewart S. Incidence and characteristics of newly diagnosed rheumatic heart disease in urban African adults: insights from the Heart of Soweto study. *Eur Heart J* 2010;31:719–27.
- [37] Tibazarwa K, Ntyintyane L, Sliwa K, et al. A time bomb of cardiovascular risk factors in South Africa: results from the Heart of Soweto Study “Heart Awareness Days”. *Int J Cardiol* 2009;132:233–9.