Comparison of Electrocardiogram (ECG) Waveforms and Centralized ECG Measurements Between a Simple 6-Lead Mobile ECG Device and a Standard 12-Lead ECG

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Background

The 12-lead electrocardiogram (ECG) is a standard measurement used in clinical trials for the evaluation of cardiac rhythm, interval duration measurements (IDMs), and other cardiac findings

A major limitation of the standard 12-lead ECG is obtaining reliable measurements for interpretation and comparison between serial measurements because of the necessity for correct placement of the 4 limb and 6 precordial electrodes, and little tolerance for incorrect lead positioning

The technique required for a standard 12-lead ECG measurement (accurate placement and patient in a supine position) makes it difficult to perform outside of a medical facility or investigational site

Therefore, it would be advantageous to have a method for obtaining patient-recorded ECGs at home without the need for complex medical equipment and a trained healthcare professional

The current coronavirus disease 2019 pandemic during which many patients may be unable or unwilling to conduct a healthcare visit in person has underscored this need

KardiaMobile, a mobile, 6-lead ECG measuring device, allows a patient to self-administer and record a 6-lead ECG reading without the need for professional healthcare support and with minimal instruction

Objectives

The objectives of this study were to compare recordings from the AliveCor 6-lead device with ECGs collected with standard 12-lead devices in terms of: quality of recordings, ECG waveform morphology, IDMs, heart rate (HR), QTcF (HR-corrected QT value), PR interval, and QRS duration

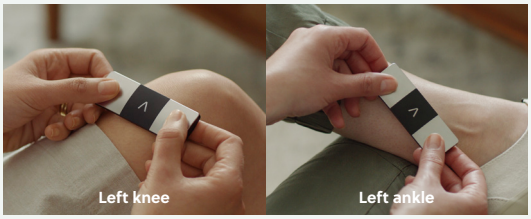
Methods

- This was a prospective study of patients referred to the Mayo Clinic Windland Smith Rice Genetic Heart Rhythm Clinic between April 2018 and February 2020
  - Standard 12-lead and mobile 6-lead ECGs were recorded sequentially at the same visit
    - 12-lead ECGs were recorded with the patient in the supine position, with readings filtered at 500 Hz
    - Patients then sat up and, after receiving instructions on its use, collected a 2-minute recording with the AliveCor KardiaMobile device using both hands and the left leg (**Figure 1**)
- ECGs from each reading were transferred digitally to a centralized core laboratory and analyzed by a cardiologist
  - ECG readers and cardiologists were not aware of subject identifiers, treatment, or study details
- For the statistical analysis, the Bland-Altman method was used for the primary comparison between 6- and 12-lead readings; bias analysis was used to assess the potential bias of measurements between recording devices; means and differences of the ECG intervals between the 2 methods were assessed using regression using an M estimator; and the fitted bias analysis slope and 95% CIs were derived to show linear trends between the 2 variables and indicate whether the observed difference between methods varied with the magnitude of the absolute value

FIGURE 1. (a) Bottom and top of the AliveCor KardiaMobile 6L device; (b) positioning of the device for a 6-lead ECG

(a)

(b)



Results

- Interpretable 6-lead and 12-lead recordings were available for 685 of 705 eligible patients (97%); the average patient was 28.7 years of age, and 43% of the patients were male
- The most common diagnosis was congenital long QT syndrome (50%)
- 11 of the 685 patients (1.6%) were not included in the data analysis because a >30-minute lapse occurred between the 6- and 12-lead recordings

OBJECTIVE 1: To evaluate and compare ECG recording quality in 6-lead and 12-lead ECG readings

- Recordings from both the 12-lead and the 6-lead devices were of good quality and all were sufficient for cardiologist interpretation, although the 12-lead readings had less artifact and did not require filtering whereas the 6-lead recordings had significantly more artifact and required filtering before interval durations could be measured

OBJECTIVE 2: To evaluate and compare ECG waveform morphology in 6-lead and 12-lead ECG readings

- Morphology was similar between the 6- and 12-lead recordings overall, although there were substantial differences between the 2 recordings in some participants; for example, some pairs showed ventricular pacing in 1 recording and a nonpaced rhythm in the other
  - Because the ECGs were recorded with patients in 2 different positions and 15 to 30 minutes between readings, it is likely that the changes reflected true ECG morphology changes rather than differences in recording methods

Results (cont'd)

OBJECTIVE 3: To evaluate and compare IDMs in 6-lead and 12-lead ECG readings

- 50 of the 6-lead measurements and 51 of the 12-lead recordings could not be measured in lead II and were measured in a secondary lead (usually lead I for the 6-lead measurements and lead V5 for the 12-lead measurements)

OBJECTIVE 4: To evaluate and compare HR measurements in 6-lead and 12-lead ECG readings

- The mean difference in HR as measured with the 6-lead (sitting position) and 12-lead (supine position) ECGs was 5.5 beats per minute (bpm) (95% CI, 4.9–6.0 bpm); patient positioning is likely the reason for the differences in HR
  - The bias analysis for HR demonstrated a mean difference of 0.3 bpm between methods over an HR range of 10 bpm

OBJECTIVE 5: To evaluate and compare the QTcF value in 6-lead and 12-lead ECG readings

- The mean difference in the QTcF measured on the 6- and 12-lead devices was −2.6 ms (95% CI, −4.1 to −1.1 ms), although there were some patients for whom a large difference (>50 ms) was measured
  - The bias analysis for QTcF measurement demonstrated a mean difference between methods of 1 ms over a QTcF range of 100 ms

OBJECTIVE 6: To evaluate and compare the PR interval in 6-lead and 12-lead ECG readings

- The mean difference between the PR interval measured on the 6- and 12-lead ECGs was −0.97 ms (95% CI, −2.086 to 0.155 ms)
  - The bias analysis of PR demonstrated a mean difference between methods of 2.1 ms over a PR range of 100 ms

OBJECTIVE 7: To evaluate and compare QRS duration in 6-lead and 12-lead ECG readings

- The mean difference between the QRS duration measured on the 6- and 12-lead ECGs was 1.17 ms (95% CI, 0.48–1.86 ms)
  - The bias analysis of QRS duration demonstrated a mean difference between methods of 0.4 ms over a QRS range of 10 ms

Table 1 shows a summary of the agreement for the IDMs of the bias assessment, and a categorical analysis of differences in ECG interval measurements from the 6- and 12-lead recordings are shown in **Table 2**.

TABLE 1. Summary of Differences Between IDMs From 6- and 12-Lead ECGs With Upper and Lower Limits of Agreement and Bias Sensitivity Results

Parameter	Difference: 6-Lead Minus 12-Lead (95% CI)	Lower Limit of Agreement	Upper Limit of Agreement	BA Slope	Standard Error	95% CI
QTcF (ms)	−2.6 (−4.1 to −1.1)	−41.39	36.26	−0.01	0.018	−0.05 to 0.03
HR (bpm)	5.5 (4.9 to 6.0)	−9.28	20.17	0.03	0.02	−0.01 to 0.07
PR (ms)	−1.0 (−2.1 to 0.2)	−29.76	27.83	0.02	0.02	−0.02 to 0.06
QRS (ms)	1.2 (0.5 to 1.9)	−16.67	19.02	−0.04	0.03	−0.10 to 0.02

BA, Bland–Altman; bpm, beats per minute; ECG, electrocardiogram; HR, heart rate; IDM, interval duration measurement; QTcF, QT interval corrected for heart rate.

TABLE 2. Categorical Analysis of Differences in ECG Intervals Between 6- and 12-Lead Recordings

Parameter	Absolute Difference	Frequency
QTcF ms (n=671)	<10	297 (44.3%)
	10 to <20	221 (32.9%)
	20 to <30	69 (10.3%)
	30 to <40	50 (7.5%)
	40 to <50	19 (2.8%)
	≥50	15 (2.2%)
HR bpm (n=674)	<10	478 (70.9%)
	10 to <20	168 (24.9%)
	20 to <30	26 (3.9%)
	30 to <40	2 (0.3%)
	40 to <50	0
	≥50	0
PR ms (n=663)	<10	383 (57.8%)
	10 to <20	184 (27.8%)
	20 to <30	58 (8.7%)
	30 to <40	25 (3.8%)
	40 to <50	6 (0.9%)
	≥50	7 (1.1%)
QRS ms (n=673)	<10	492 (73.1%)
	10 to <20	158 (23.5%)
	20 to <30	18 (2.7%)
	30 to <40	3 (0.4%)
	40 to <50	2 (0.3%)
	≥50	0

HR, heart rate; QTcF, QT interval corrected for heart rate.

Conclusions

Comparison of readings from a standard 12-lead ECG recording device versus the 6-lead KardiaMobile device demonstrated:

Consistency in IDMs with no indication of systematic measurement bias at high or low measurement values

The usefulness of smartphone-enabled mobile technology to provide rapid, high-quality ECG recordings remotely for use in many applications in clinical medicine and clinical trial settings, including assessment of cardiac rate and rhythm, atrioventricular conduction, and standard IDMs (PR, QRS, QT/QTc)

The lack of precordial leads on the KardiaMobile would limit the detection of other conditions like unstable angina, anterior wall ischemia or infarction, or repolarization syndromes that manifest mainly in the chest leads

Importance to AliveCor

This study demonstrated that the KardiaMobile device can be a useful tool in both the office and clinical trial settings to assess patient safety between visits, enabling quick assessment of new symptoms or detection of large changes in QTC, PR, or QRS intervals

The KardiaMobile device offers a simple-to-use alternative for patients who are unable or unwilling, for any reason, to attend an in-person physician visit