Mobile Phone Detection of Atrial Fibrillation Using Mechanocardiography – the MODE-AF Study

Jaakkola et al - Mobile Phone Detection of Atrial Fibrillation

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Due to the frequent asymptomatic presentation of atrial fibrillation (AF), stroke is too often its first manifestation[1]. For effective stroke prevention, timely diagnosis of AF is crucial. Mobile devices are becoming ubiquitous providing significant possibilities for screening applications. In mechanocardiography (MCG), mechanical cardiac activity is recorded with accelerometers and gyroscopes – standard components of modern smartphones[2]. In our previous proof-of-concept study, smartphone MCG demonstrated 94% sensitivity and 100% specificity to detect AF among 39 subjects[2]. In this paper, we validate smartphone MCG detection of AF against visual interpretation of telemetry electrocardiography (ECG) recordings in hospitalized patients.

For the current case-control study, 150 consecutive patients in AF and 150 age- and sex-matched patients in sinus rhythm (SR) were enrolled from the cardiology and internal medicine wards of Turku University Hospital, Finland between April and September 2017. After acquiring informed consent, a three-minute MCG recording was acquired from each subject with a Sony Xperia smartphone placed on their sternum, while a simultaneously obtained 5-lead telemetry ECG (Philips IntelliVue MX40) recording was used as the comparison method to assess rhythm and the number of supraventricular (SVES) and ventricular extrasystoles (VES). ECG rhythm classifications were confirmed by two independent cardiologists, and a third cardiologist made the final decision if interpretations diverged. Additionally, physical measurements were recorded and electronic patient records searched for the subjects' clinical history and investigations conducted during the index hospitalization. The institutional ethical review board approved the study protocol.

The MCG recordings were analyzed utilizing an algorithm developed beforehand by investigators blinded to the underlying rhythm. The data were first preprocessed by applying a band-pass filter to remove signal noise and bias. The algorithm then examined each six data axes of the signal with 5-second autocorrelation windows to find evidence of constant beat-to-beat intervals. Finally, for classification as AF or SR, the share of signal segments with regularity was determined. A visual presentation of MCG data is presented in Figure.

The mean age of all subjects was 74.8 years (95%-confidence interval [CI] 73.7-75.9) and 132 (44.0%) were female. The MCG algorithm correctly classified AF in 143/150 cases and SR in

144/150 controls. Altogether, 4 of the 6 cases in SR misclassified as AF had marked sinus arrhythmia, while no potential reasons for the other misclassifications could be identified. The resulting sensitivity was 95.3% (95%-CI 90.6-98.1) and the specificity 96.0% (95%-CI 91.5-98.5). The respective positive and negative predictive values were 96.0% (95% CI 91.6-98.1) and 95.4% (95%-CI 90.9-97.7), while the positive and the negative likelihood ratios were 23.8 (95% CI 10.9-55.8) and 0.05 (95%-CI 0.02-0.10), respectively. Reducing the duration of analyzed section of recording to 60 seconds did not affect sensitivity or specificity. An unweighted kappa coefficient of 0.913 (95%-CI 0.866-0.960) indicated near–perfect agreement in rhythm classification between the MCG algorithm and visual interpretation of telemetry ECG recordings.

Body mass index, respiratory rate, heart rate or SVES count were not associated with false positive rhythm classification. Compared to subjects with a true negative result, those with a false positive result had a higher median VES count (1 [interquartile range 0-1] (maximum count 7) vs 0 [interquartile range 0-1] (maximum count 16), p=0.011), more frequently a history of heart failure (4 (66.7%) vs 20 (13.9%), p=0.006) and more often pulmonary edema in chest X-ray (5 (100%) vs 33 (34.4%), p=0.006). However, only one subject with false positive classification had a left ventricular ejection fraction <40% (data missing on one subject). False negative rhythm classification was not significantly associated with any recorded clinical characteristic.

In the current study, smartphone MCG accurately discriminated AF from SR among a large clinically relevant cohort. There is demand for self-operated rhythm screening tools, as intermittent screening is required for effective detection of AF. Smartphones are becoming ubiquitous, even among the elderly and in third world countries, thus presenting a unique opportunity for cost-effective screening of AF. AliveCor is a smartphone-mounted single-lead ECG-recorder that recently demonstrated 67% sensitivity and 99% specificity to detect AF with algorithm-interpretation of rhythm in a large primary healthcare cohort[3]. An irrefutable advantage of handheld ECG-recorders is the option for physician-interpretation of tracings[4], but additional hardware is required for recording and single-lead ECG quality is not always sufficient for reliable AF diagnosis. Similarly to MCG, AF detection with smartphone photoplethysmography requires no additional hardware. Recently, 95% sensitivity and 95% specificity were reported for AF detection with the method[5]. Despite comparable accuracy, photoplethysmography has notable drawbacks not affecting MCG: Positioning a finger statically against a smartphone camera is difficult and unfeasible for elderly people, while extended recording periods of up to five minutes are required for reliable recordings[5]. In the future, the precision of MCG should be further evaluated in a large-scale screening study.

In conclusion, smartphone mechanocardiography reliably detects AF without any additional hardware and provides a new easy-to-use and accessible concept for AF screening.

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Figure

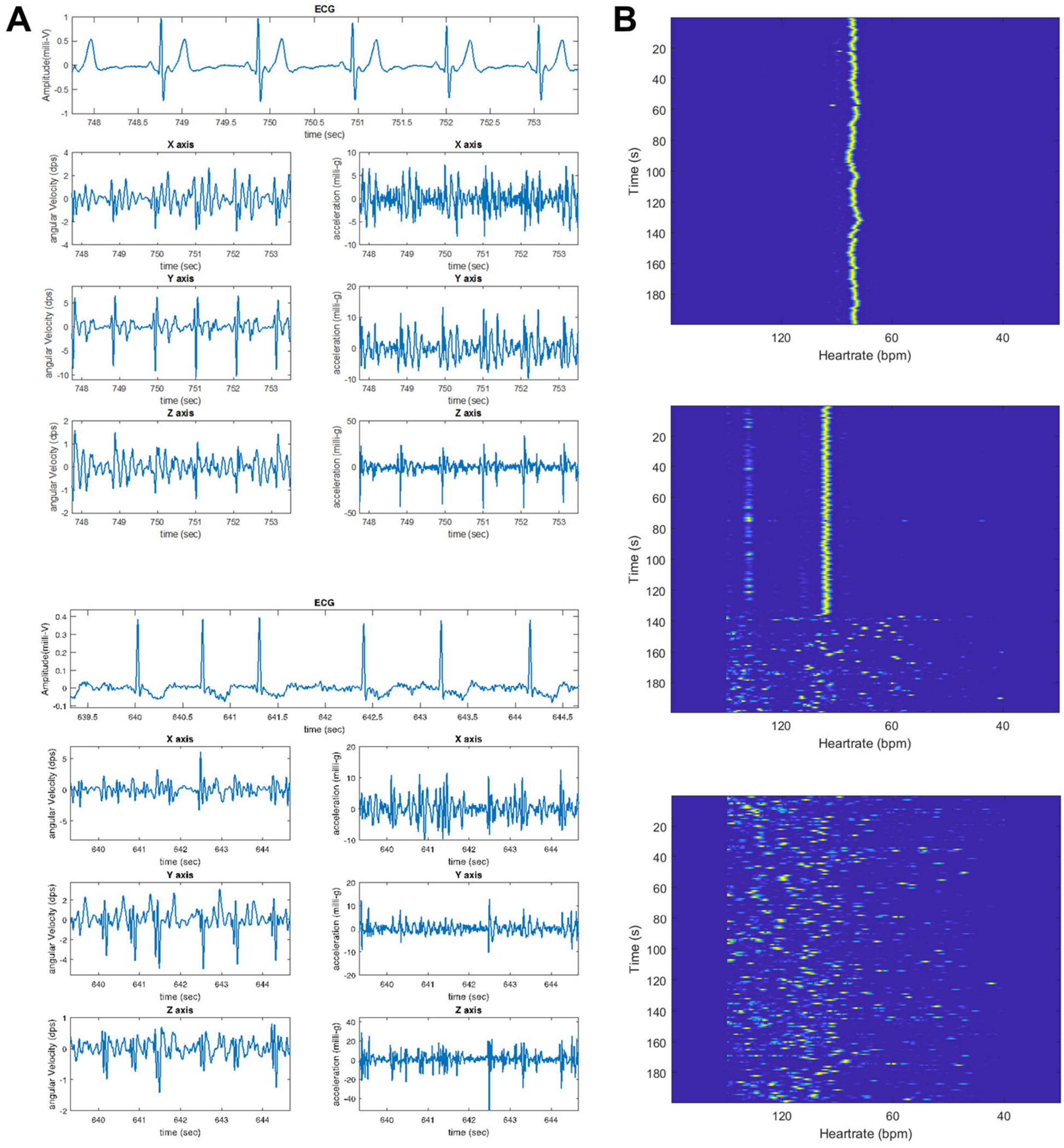
A
ECG
Amplitude(milli-V)
time (sec)
X axis
Y axis
Z axis
angular Velocity (dps)
acceleration (milli-g)
B
Time (s)
Heartrate (bpm)

Figure legend

Figure. Visual presentation of mechanocardiography data.

A, ECG-, accelerometer- and gyroscope signals are presented in sinus rhythm (top) and atrial fibrillation (bottom). The corresponding heart beats can be located in both the mechanical and the ECG signals during sinus rhythm and atrial fibrillation. As the different axes of the accelerometer and gyroscope signals appear to vary in quality, our algorithm takes advantage of combining the information from various axes to provide a reliable estimate of the heart rhythm. **B**, mechanocardiography signal periodicity is represented visually in sinus rhythm (top), sinus rhythm converting to atrial fibrillation (middle) and atrial fibrillation (bottom). The vertical axis represents time in seconds, and the horizontal axis represents the instant period of the signal converted into beats-per-minute to denote heart rate. A continuous signal shape is observed during a regular heart rhythm, such as sinus rhythm (top), while a scattered pattern is observed during an irregular rhythm, such as atrial fibrillation (bottom). In the middle image, sinus rhythm abruptly converts to atrial fibrillation at around 140 seconds.