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RESEARCH LETTER

Mobile Phone Detection of Atrial Fibrillation With Mechanocardiography

The MODE-AF Study (Mobile Phone Detection of Atrial Fibrillation)

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Because of 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, mechanical cardiac activity is recorded with accelerometers and gyroscopes, standard components of modern smartphones.[2] In our previous proof-of-concept study, smartphone mechanocardiography demonstrated 94% sensitivity and 100% specificity for detecting AF among 39 subjects.[2] Here, we validate smartphone mechanocardiography detection of AF against visual interpretation of telemetry electrocardiographic recordings in hospitalized patients.

For the present 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 informed consent was obtained, a 3-minute mechanocardiography recording was acquired from each subject with a Sony Xperia smartphone placed on the sternum, and a simultaneously obtained 5-lead telemetry electrocardiography (Philips IntelliVue MX40) recording was used as the comparison method to assess rhythm and the number of supraventricular and ventricular extrasystoles. Electrocardiographic rhythm classifications were confirmed by 2 independent cardiologists, and a third cardiologist made the final decision if interpretations diverged. In addition, physical measurements were recorded, and electronic patient records were searched for the subjects' clinical history and investigations conducted during the index hospitalization. The institutional ethics review board approved the study protocol.

The mechanocardiography recordings were analyzed with 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 of the 6 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 mechanocardiography data is shown in the 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 mechanocardiography algorithm correctly classified AF in 143 of 150 cases and SR in 144 of 150 controls. Altogether, 4 of the 6 cases in SR misclassified as AF had marked sinus arrhythmia, whereas no

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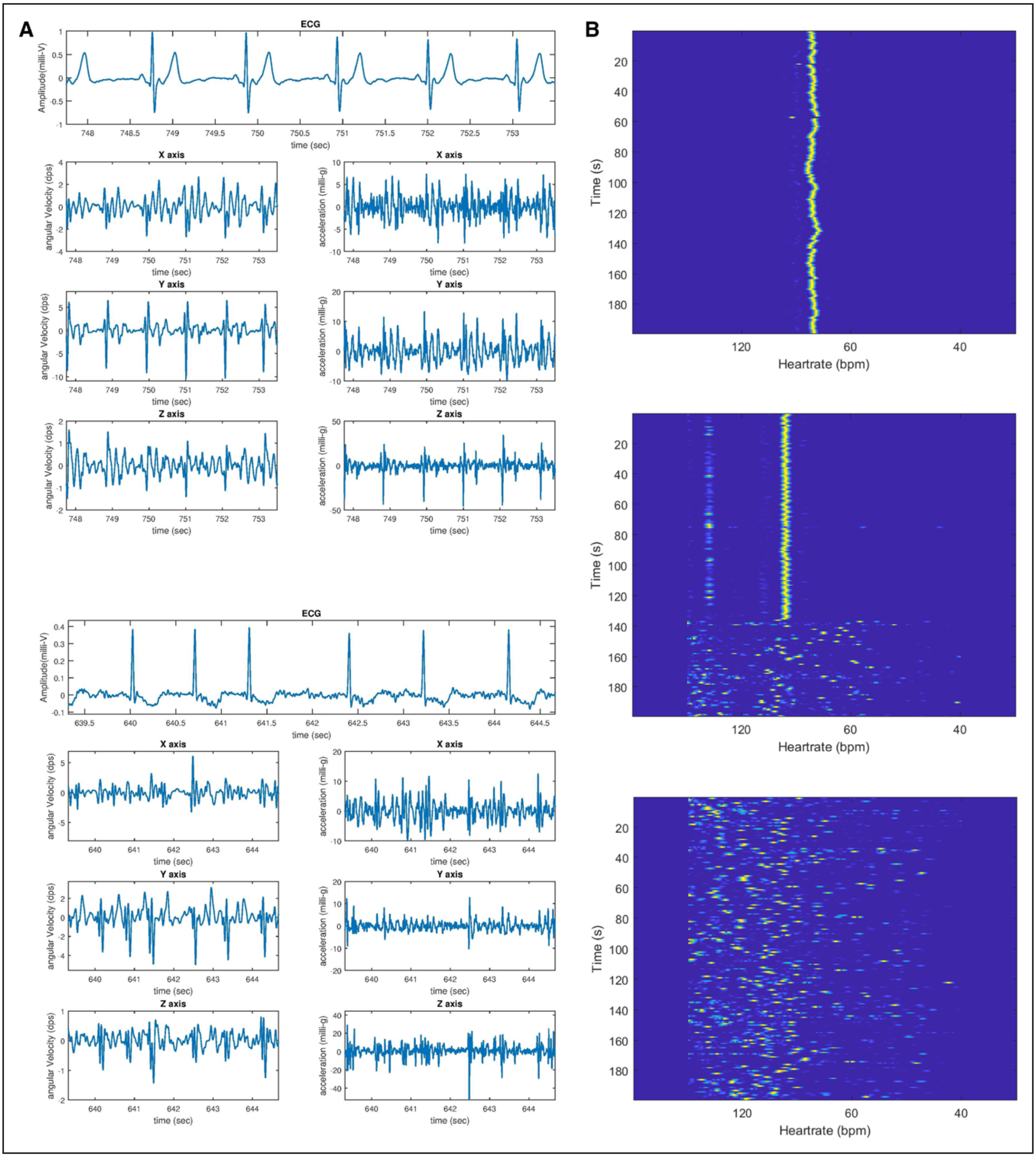

Figure. Visual presentation of mechanocardiography data.
A, Electrocardiographic, accelerometer, and gyroscope signals are presented in sinus rhythm (**top**) and atrial fibrillation (**bottom**). The corresponding heartbeats can be located in both the mechanical and the electrocardiographic signals during sinus rhythm and atrial fibrillation. Because 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**), whereas a scattered pattern is observed during an irregular rhythm such as atrial fibrillation (**bottom**). **Middle**, Sinus rhythm abruptly converts to atrial fibrillation at ≈140 seconds.

potential reasons for the other misclassifications could be identified. The resulting sensitivity was 95.3% (95% CI, 90.6–98.1) and the specificity was 96.0% (95% CI, 91.5–98.5). The positive and negative predictive values were 96.0% (95% CI, 91.6–98.1) and 95.4% (95% CI, 90.9–97.7), and 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 κ coefficient of 0.913 (95% CI, 0.866–0.960) indicated near-perfect agreement in rhythm classification between the mechanocardiography algorithm and visual interpretation of telemetry ECG recordings.

Body mass index, respiratory rate, heart rate, and supraventricular extrasystole count were not associated with false-positive rhythm classification. Compared with subjects with a true-negative result, those with a false-positive result had a higher median ventricular extrasystole count (1 [interquartile range, 0–1; maximum count 7] versus 0 [interquartile range, 0–6; maximum count 16]; P=0.011), more frequently had a history of heart failure (4 [66.7%] versus 20 [13.9%]; P=0.006), and more often had pulmonary edema in a chest x-ray (5 [100%] versus 33 [34.4%]; P=0.006). However, only 1 subject with false-positive classification had a left ventricular ejection fraction <40% (data missing on 1 subject). False-negative rhythm classification was not significantly associated with any recorded clinical characteristic.

In the present study, smartphone mechanocardiography accurately discriminated AF from SR among a large, clinically relevant cohort. There is demand for self-operated rhythm screening tools because 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 electrocardiographic recorder that recently demonstrated 67% sensitivity and 99% specificity for detecting AF with algorithm interpretation of rhythm in a large primary healthcare cohort.[3] An irrefutable advantage of handheld electrocardiographic 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. Similar to mechanocardiography, 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 mechanocardiography: Positioning a finger statically against a smartphone camera is difficult and unfeasible for elderly people, and extended recording periods of up to 5 minutes are required for reliable recordings.[5] In the future, the precision of mechanocardiography 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.

ARTICLE INFORMATION

Data sharing: Access to study data is regulated by Finnish law. Data are available from the Turku University Hospital Institutional Data Access and Ethics Committee for researchers who meet the criteria as required by Finnish law for access to confidential data.

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