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Validation of Apple Watch heart rate monitoring for patients under general anaesthesia

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Abstract

Background: The popularity and capabilities of wearable devices are increasing. We evaluated the accuracy of series III Apple Watch heart rate monitoring for patients under general anaesthesia.

Methods: Heart rate monitoring was performed on 5 patients (66.80 +/- 11.34 years) undergoing plastic/reconstructive surgery procedures. The Apple Watch heart rate records were compared with the heart provided by lead II electrocardiograph (1214 matched pairs) and differences assessed against the heart rate device accuracy criterion stipulated by the American National Standards Institute.

Results: The Apple Watch measurements were in close agreement with the electrocardiograph recordings with concordance correlation coefficient = 0.975). Only 3 of the 1214 Apple Watch records differed from the corresponding electrocardiograph heart rate by more than the American National Standards Institute criterion and the standard deviation of differences was 1.25bpm. The small average difference of 0.60 bpm is not clinically significant.

Conclusions: The results validate the series III Apple Watch as a reliable HR monitoring device for patients under general anaesthesia. This is supported by current literature. However, further investigation is required to determine the broader applications of the Apple Watch in anaesthesia.

Key words: Fitness Trackers, Photoplethysmography, General Anaesthesia, Heart Rate, Physiologic Monitoring and Telemetry

To the editor:

Accurate assessment of heart rate (HR) is imperative in anaesthetic monitoring. Both electrocardiography (ECG) and photoplethysmography (PPG) are useful technologies for monitoring HR and rhythm in anaesthesia. Wearable devices like the Apple Watch (AW) use PPG to monitor HR.

Wearable devices have the potential to be used as adjuncts to or replacement for traditional monitoring techniques and may become standard telemetry equipment, allowing long-term monitoring. Wearable devices also have the capacity to be used in resource poor settings.

They can be shipped without great difficulty and some can be provided at low cost. It is also possible for the wearable device to be used as a health system itself. This may be particularly applicable to refugees who experience significant physical displacement.

The accuracy of wearable device HR monitoring has been discussed extensively in the literature[1-6]. The accuracy of the AW HR monitoring system has not been reported on adult patients under general anaesthesia.

We evaluated the accuracy of HR measurement by a series III AW in patients undergoing general anaesthesia to assess its utility in anaesthesia monitoring. This was done by comparing AW HR values with those of the gold-standard monitoring system, ECG.

Materials and methods

Study design:

Patients wore a series III AW while under general anaesthesia. Lead II ECG was used as the HR control. Recordings at 5 second intervals, on average, were taken for about 25 minutes per patient. The data were examined to assess differences between the AW and lead II ECG recordings against the American National Standards Institute (ANSI) specified error criterion for cardiac monitors and HR meters, which holds that readout errors should be no greater than 5bpm or 10% of the HR, whichever is greater.

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Test subjects:

The five participants were patients undergoing elective surgical procedures requiring general anaesthesia. The study was explained verbally and in written format, and informed consent was obtained.

Data collection:

The AW was set to "workout" mode which prompts more frequent HR measurements (12 per minute). The AW measured HR 12 times per minute but not strictly every 5 seconds.

Recording intervals varied from 1 to 9 seconds with 80% being 4, 5 or 6 seconds. Each ECG HR record was matched with the nearest AW data point, provided the time difference was no more than 2 seconds. There were approximately 250 matched readings for each patient with a combined total of 1214 pairs.

Statistical analysis:

Any difference between the AW reading and the accompanying ECG reading was assumed to reflect AW error:

Error = AW reading – ECG reading

The ECG and AW traces, error scatterplots and AW vs. ECG scatter were examined to develop a qualitative understanding of the data. A matched pairs t-test was used to investigate any mean error (offset) in AW readings.

RESULTS

Five participants were enrolled. The mean (SD) age was 66.80 (11.34) years with a range of 47 to 75.

The ECG and AW traces for patients 2 and 4 are depicted in Figures 1 and 2 to give a visual comparison of heart rate readings. Figure 3 displays the errors (AW – ECG HR) and the ANSI error bounds plotted against ECG HR. For most data pairs the AW reading 3 was within 4 bpm of the ECG readings. Only 3 in a total of 1214 pairs had a difference outside the ANSI criterion.

ECG readings of HR varied from 45bpm to 72bpm. The mean difference between AW and ECG readings was 0.60bpm (95% CI: 0.53 to 0.67bpm) which is statistically significant (matched pairs t-test, p=0.000) but not clinically significant. The standard deviation in errors for the combined data for all five patients was 1.25 bpm. The smallest standard deviation was 0.68 for Patient 3 and the largest was 1.95 for patient 4.

DISCUSSION

The main finding is that the series III AW is sufficiently accurate in determining HR in patients under general anaesthesia to be viable as an adjunct to current monitoring systems. A total of 3 in 1214 (0.25%) of AW readings had error magnitude outside the ANSI criterion. The conclusion that the AW measures HR accurately agrees with previous studies conducted regarding the accuracy of wrist-worn fitness trackers.

There were several cases where the AW did not match the ECG result and was likely ECG artefact rather than AW error. ECG is subject to artefacts due to motion, improper lead connection, electrode distortion and diathermy use.

The evidence that the AW records HR accurately compared to ECG is important for a range of groups. It is important for both consumers and clinicians to understand wearable device accuracy. Additionally, it suggests that the AW can reliably monitor HR in anaesthetized patients. This may also be applicable to constant inpatient monitoring to detect clinical deterioration. A device which is comfortable, wearable, accessible and accurate may improve patient monitoring.

This study has several limitations. The number of patients was small (intended as a pilot study) and only a single AW was used. HRs were in a relatively narrow range from 45 to 73bpm. Lastly, all patients were in sinus rhythm and results cannot be extrapolated to patients not in sinus rhythm.

Figure 1: ECG (filled line) and Apple Watch (dashed line) traces for patient 2

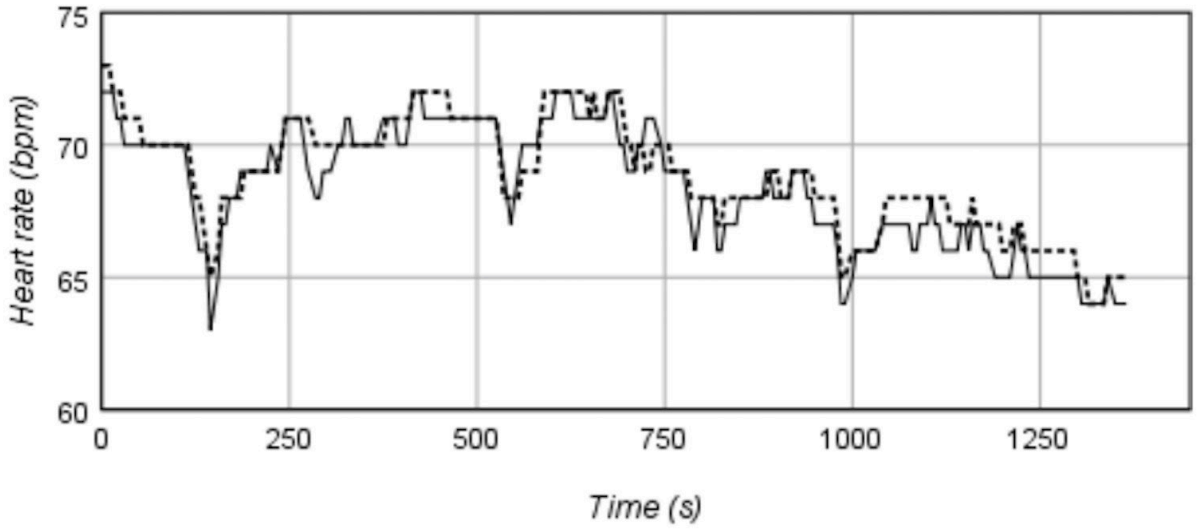


Figure 2: ECG (filled line) and Apple Watch (dashed line) traces for patient 4

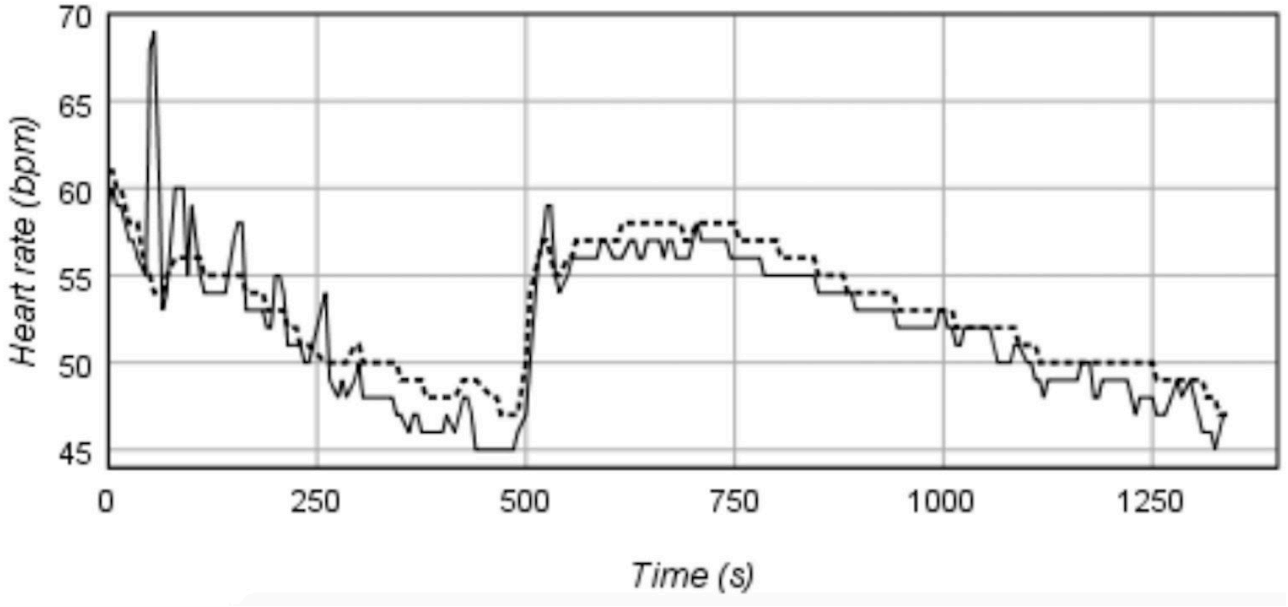
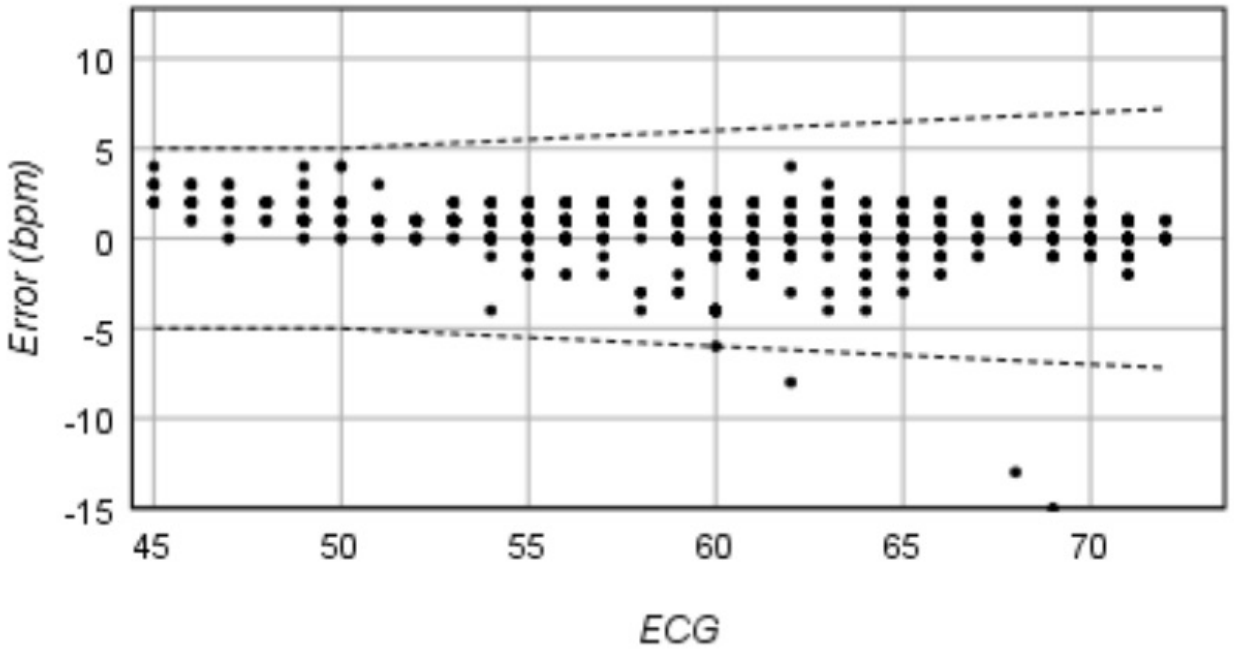


Figure 3: AW errors plotted against ECG HR and ANSI error bounds (---)



CONCLUSION

This study assessed HR measurement in five patients undergoing elective surgery using a series III AW compared with ECG readings. The AW error was found to be within the bounds specified by the American National Standards Institute for almost all readings (1211 of 1214 or 99.8%) and the concordance correlation, 0.975, is very close to unity. The AW may be a useful monitoring tool for HR in patients undergoing general anaesthesia.

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