The Clinical Value of Heart Rate Monitoring Using an Apple Watch

Carol L. Karmen, MD, Michael A. Reisfeld, MD,† Matthew K. McIntyre, BA,‡ Robert Timmermans, MD,* William Frishman, MD**

Abstract: Public interest in health monitoring devices has increased with the availability of wearable technologies or wearables such as the Apple Watch. These devices are collecting health data that may be useful to health professionals. Most studies to date have been conducted with a limited sample size and with healthy subjects. Recent studies have suggested the usefulness of long-term cardiac monitoring to reveal atrial fibrillation and prevent cryptogenic stroke. Wearable devices may become useful in cardiac monitoring, and further studies are needed.

Key Words: wearable technologies, wearables, heart rate monitoring, Apple Watch

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Within the past decade, there has been a dramatic increase in the public interest of health monitoring devices (ie, wearables), particularly for exercise tracking. These wearable devices, including the Apple Watch, Fitbit, Samsung Gear, and others, track health endpoints such as heart rate (HR), caloric expenditure, and exercise duration/intensity. Although the public health implications of these devices are potentially large, some have questioned the ability of wearable devices to impact actual changes in health behavior.[1] Despite this, individuals who wear these devices are collecting health data that may be useful to health professionals.

THE APPLE WATCH

The Apple Watch was first released in April 2015. The HR is monitored using photoplethysmography recordings based on green light absorption on the posterior side of the wrist (back of the watch face), and accuracy is based on temperature and the fit of the device, as well as skin photosensitivity and pigment.[2,3] Since its first release, the watch has evolved. The series 4 Apple Watch, recently redesigned, will not only monitor HR but also generate an electrocardiographic (ECG) waveform to identify irregular rhythms, including atrial fibrillation. Recent reports of this technology are promising and show that these newer devices can accurately discriminate atrial fibrillation from sinus rhythm with more than 93% sensitivity and 84% specificity compared with the ECG.[4,5]

Despite the widespread use of wearable devices, there remains a paucity of studies investigating their clinical accuracy, implications, and use. This lack of evidence is likely a result of the evolving nature of the devices, the variety of devices, price barriers, and the relative novelty of their widespread use. Notwithstanding, recent studies have shown encouraging results regarding the accuracy of these devices. Specifically, the Apple watch's HR measurements have shown correlation coefficients between 0.91 and 0.98 compared with gold standard 12-lead ECG.[2,6] According to 1 study, this corresponds to differences of 1.3 ± –4.4 beats per minute on average compared with the ECG reading.[2] In comparison, these same studies found that the Fitbit Charge HR had lower correlation coefficients ranging between 0.78 and 0.84.[2,6] Although these studies were performed during exercise, other studies suggest a decrease in accuracy compared with readings at rest. For example, 1 study found that the Fitbit Charge HR had a dramatic (0.83 to 0.58) decrease in correlation values at rest compared with exercise.[7]

Most studies concerning the accuracy of these devices are conducted with limited sample size and with healthy subjects. Variations in blood pressure (BP) as a result of cardiac episodes may limit the device's ability to accurately determine HR. These devices do not monitor BP. To date, there remains limited evidence evaluating the accuracy of wearables in ill patients, and we know of no studies examining the Apple Watch in this environment. However, 1 study conducted on a stable in-patient population found that the Fitibit Charge HR was significantly less accurate in patients in nonsinus rhythm compared with those in sinus rhythm.[8] Koshy et al[9] found similar results by showing the HR accuracy of the Apple Watch is lower in atrial fibrillation. Therefore, the clinical interpretation of historical HR data gathered from a wearable device must be used in concert with other tests, such as an ECG or echocardiogram. In particular, given the findings of Gladstone et al[10] in the 30-Day Cardiac Event Monitor Belt for Recording Atrial Fibrillation after a Cerebral Ischemic Event (EMBRACE) trial showing the usefulness of long-term atrial fibrillation monitoring,[10] there may be the potential for wearable devices in the prevention of cryptogenic stroke. As reported on some websites,[11] we cannot discount the value of potentially alerting the patient and his or her physician to a cardiac malady as a result of continuous monitoring with wearable devices.

OUR EXPERIENCE

A middle-aged female runner presented to her internist after 3 episodes of syncope and near-syncope. She had been in excellent health except that 1½ years earlier, during a physical examination, her internist noted a murmur consistent with aortic stenosis and referred her for an echocardiogram, but the patient did not follow through on this recommendation. She continued running several miles 5–6 times per week as part of an exercise routine that also included weight training and yoga. She purchased an Apple Watch and used it to monitor her exercise routine, logging her distances, and her HR.

The patient began to experience "tightness" in her chest while running. The feeling was relieved when she slowed her pace to a walk but after walking for several minutes, she began to run again. She repeated this cycle 3 times. The third time she started running she experienced dizziness, difficulty walking due to chest tightness, vomiting, and then losing consciousness. Cardiopulmonary resuscitation (CPR)

From the *Department of Medicine, New York Medical College, Valhalla, NY; †Department of Pediatrics, Northwestern University, Chicago, IL; and ‡Medical Student, New York Medical College, Valhalla, NY.

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Correspondence: Carol L. Karmen MD, Department of Medicine, New York Medical College, 20 Sunshine Cottage Road, Valhalla, New York 10595. E-mail: carol_karmen@nymc.edu.

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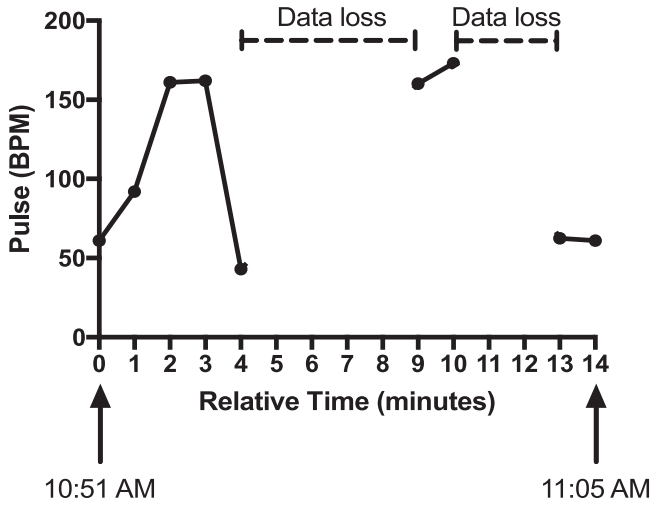

FIGURE 1. Apple Watch recording of pulse rate over time during first cardiac event. During this 14-minute interval, the patient had a dramatic fluctuation in heart rate. During this time, the device had 2 lapses in recording represented by the dashed lines. Multiple recorded data points at 11:00 AM and 11:04 AM are averaged.

helped her regain consciousness. An emergency medical technician noticed that she was wearing an Apple Watch and asked if he could see the recordings of her pulse rate but nothing was done with the data at the time. She was evaluated in a local emergency room where she received intravenous fluids. Her ECG was reported as normal. She was diagnosed with "heat exhaustion" and discharged home the same day.

The patient continued her exercise routine, and soon after, she began to feel the same symptoms that had led to her emergency room visit. She noted dizziness, chest tightness, palpitations, and an inability to stand. She sat down on a curb and eventually laid down on the ground for several minutes before she felt better. After this event, she continued to run but at a slower pace. She did not have any other symptoms until 1.5 months after the initial episode. She was able to run for less than half a mile before she began to feel ill. She stopped running but continued to walk. She then felt the need to sit down. She reported seeing black spots in her field of vision and vomited before resting on the ground.

The patient returned to her internist who confirmed a murmur consistent with aortic stenosis. An ECG showed sinus bradycardia with a HR of 46 beats per minute and voltage criteria for left ventricular hypertrophy (LVH). An urgent cardiology consult was called. An echocardiogram revealed a severely calcified bicuspid aortic valve (BAV) with severe stenosis (valve area = 0.7 cm^2), increased left ventricular wall thickness consistent with mild LVH, and an ejection fracture of 65%. An magnetic resonance angiogram of the aorta and magnetic resonance imaging of the heart showed a borderline enlarged ascending aorta with the largest diameter 3.7 cm and a thickened BAV suggestive of valvular calcifications and a turbulent jet with mild LVH. A cardiac catheterization showed normal coronary arteries. The patient then underwent aortic valve replacement with a bioprosthetic valve without complications. The patient shared the data she had recorded from her Apple Watch with her physician and medical students. The recordings from the first episode are depicted graphically in Figure 1.

DISCUSSION

A BAV is the most common congenital aortic valve abnormality, with an estimated prevalence of 13.7 cases per 1,000 individuals.[12] BAV is associated with the development of aortic stenosis on average 20 years earlier than normal valves.[13] There is a highly hereditary component to BAV, with some studies suggesting heritability as high as 89%, and 75% when considering other cardiovascular malformations that frequently accompany BAV.[14] The classic triad of symptoms in aortic stenosis are angina, syncope or presyncope, and dyspnea.[13] The presence of these symptoms suggests advanced disease, as earlier stages of aortic stenosis can be present without any evidence of physical symptoms or hemodynamic changes. According to the American Heart Association/American College of Cardiologist Task Force on Practice Guidelines, there are 4 stages of aortic stenosis, with only the last stage presenting with the classic triad of symptoms. At that point, there is a Class I recommendation for patients to undergo valve replacement surgery.[15]

A heart murmur was appreciated by the primary care physician more than 1 year before the patient became symptomatic, but the patient disregarded her physician's advice for further evaluation. Perhaps the patient's excellent physical conditioning led her to believe that there was no reason for concern and, unfortunately, the physician was unaware that the advice had not been followed. Our patient experienced chest pressure before she had her first syncopal episode. It is unclear whether she suffered a cardiac arrest, but a trained CPR provider did initiate CPR. Evaluation in an emergency room did not raise any alarms.

The retrospective analysis of our patient's Apple Watch data shows that she began her run at 10:51 AM. She reported that she began to feel tightness in her chest only a few minutes after beginning, likely corresponding to the physiologic increase in her HR seen in the recordings from 10:52 to 10:54 AM. The gap in readings from 10:55 to 11:00 AM and 11:01 to 11:04 AM suggest that the watch did not collect data for 5 minutes and then 3 minutes during this episode. This was likely due to a drop in BP significant enough to interfere with the watch's ability to continue to sense the patient's pulse. Although studies using the Apple Watch have noted HRs as low as 43 beats per minute,[16] we know of no reports that explicitly verify the minimum value that the device can accurately read.

CONCLUSIONS

Since wearables are quite popular, we expect the data they store to become useful in cardiac assessment. At the very least, the data these devices record should be reviewed and not ignored.[17]

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