Temperature monitoring with an implantable loop recorder in a patient with presumed COVID-19

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Introduction
The pandemic caused by novel coronavirus (SARS-CoV-2) has had an enormous impact on the health and economy of the entire world.1 The total numbers of cases and fatalities continue to rise and the mortality rate is currently estimated to be 1%–5%.2 Of the multiple symptoms and clinical findings that have been attributed to COVID-19 infection, fever and cough are the most common,3 and significance in terms of widespread screening has been defined as temperatures ≥100.5°F/38°C.4 Cardiac injury and cardiac mortality have also become part of the emerging clinical picture of COVID-19,4–6 and this raises the prospect of how to use implantable devices such as implantable cardiac monitors (ICMs) to aid in the screening or triage of suspected patients. With daily remote monitoring capabilities, screening from such a device could occur without reliance on patient compliance or recognized symptoms, even among a nonambulatory, mobility-limited, or quarantined/self-isolated population.

We describe here the application of temperature measurement within an ICM (BIOTRONIK BIOMONITOR III; BIOTRONIK, Inc, Lake Oswego, OR) to screen for systemic infection based on measurements of fever and concomitant cardiac resting rate changes. The BIOMONITOR III ICM contains an internal, integrated solid-state temperature sensor that has been enabled for research and data collection purposes but has not, until now, been evaluated in vivo for approval in the product. Additionally, statistics like percent activity per day, resting heart rate, and mean rate per day are currently available in the ICM, and there is a known relationship between fever and heart rate parameters.7 The on-board temperature sensor was evaluated here for possible use as a screening tool for patients with implants. Although this was a retrospective study and clinical confirmations of fever were not performed across the entire population, we describe here the details of 1 patient for which clinical confirmation with device data was possible.

Case report
An elderly woman residing in the New York City metropolitan region was implanted with a BIOMONITOR III in November 2019 following a cerebrovascular accident. Trend data of daily measurements of temperature, activity, mean heart rate (daily), and mean heart rate at rest (during the night) from the time of implant through the first 90 days is shown in Figure 1. The figure shows the stable temperature trend and other metrics during this time period post implant. The standard deviation of day-to-day measurements was 0.35°C from...
implant through the first 90 days, confirming a stable measurement by the device from within the subcutaneous pocket.

On February 23, 2020, the patient was admitted to the Emergency Department for a workup that was negative for fever. The sensor confirmed there were no observations related to temperature in this timeframe. However, in late March the patient reported fever again, coincident with the onset of rapid disease spread in the city. By that time, her spouse, with whom she resided, had been diagnosed COVID-19 positive and she was advised to remain at home by Emergency Medical Services and considered COVID-19 presumptive positive.

The trend data from the period are shown in Figure 2. Note the sharp increase in temperature on March 23, which was coincident with the patient contacting Emergency Services. Temperature as measured by the device trended upwards from an average of 36.8°C in the 5 days preceding the episode to 38.4°C average following the onset of fever. Activity as measured by the device trended downwards from an average of 4.6% preceding the fever to an average of 2% afterwards. The heart rate at rest was 70 beats per minute (bpm) before and 85.6 bpm after the temperature increase, while the daily mean heart rate (entire day average) during these times increased from 87.6 to 93 bpm. The patient remained at home and the fever episode resolved within approximately 7 days.

Utilizing a criterion of 2 consecutive days with a 1°C temperature elevation identified multiple additional patients with clinically realistic episode trend data. An additional example is shown in Figure 3; a device implanted in mid-July 2019 is shown with a full trend of daily data transmitted. In this case, the temperature trend was relatively unremarkable except for a short episode in early November showing brief decrease in activity and increases in heart rate metrics. In mid-March 2020, however, a significant clinical episode was detected
with pre- and postdetection 5-day averages of 37.4°C to 38.5°C, 10.3% to 8.3% activity, 85.2 bpm to 113.8 bpm mean rate, and 77 bpm to 103.2 bpm mean rate at rest. Further information beyond the trend data is not available for this patient.

Discussion
This report demonstrates the utility of performing temperature monitoring with an implantable device, specifically the BIOMONITOR III ICM. The Home Monitoring Service of BIOTRONIK provides daily messages without patient interaction when the patient unit is within range of the device and allows tracking of heart rate, arrhythmia data, and electrocardiogram snapshots, among other statistics. Although there are numerous existing temperature measurement methods with traditional contact, noncontact, and wearable varieties, all mainstream solutions require the subject to play a role: to remember to take their reading and to properly acquire it. Varying accuracy and coverage over time is achieved in reality. This new temperature monitoring functionality was evaluated in the context of screening and triage related to COVID-19 or other highly contagious infectious diseases. The hands-free radiofrequency transmission capabilities of this device make it highly suitable as a means for remote monitoring in this scenario, as quarantined populations can be monitored easily and clinics can remotely screen patients for further follow-up.

The temperature sensor data provided by the device confirmed a fever-negative episode, which was validated in the Emergency Department, and subsequently detected a fever-positive episode during a strongly presumptive COVID-positive episode. A second example with anonymous data demonstrated a dramatic fever and heart rate response via...
the trend data that would also warrant further investigation in the context of either general care or specifically cardiac care of the patient, given the impact of COVID-19 on cardiac health.

A retrospective analysis of available temperature and heart rate data from 4688 patients was performed to provide further perspective on the sensor data at a population level. The goal was to determine if these data could be used as a screening tool without undue false alerts. This exploratory analysis was conducted utilizing Real World Evidence methodology, which has been approved by an institutional review board granting waiver of informed consent and a full waiver of HIPAA authorization. Temperatures rises exceeding 1°C, compared to the 30-day mean temperature for 2 consecutive days, were considered clinically significant for this analysis. A total of 497,615 daily measurements of temperature (average of 106.1 days of monitoring per patient) were analyzed, and 103 patients within this population were identified using these criteria. The relatively small number of findings with a device-level prevalence of 2.2% over the observation period aligns well with an actionable alert paradigm that would not overwhelm Holter triage units while identifying patients of possible clinical interest according to guidelines.

This case report was somewhat limited owing to the extenuating circumstances of the COVID-19 pandemic and the public health policy to keep the infected but noncritical victims away from hospitals, which prevented the patient from obtaining COVID-19 testing at the time of their symptoms. Although an anonymized non–clinically validated assessment was possible across a broad number of devices, confirmation was performed in the presented case study only.

It is possible that sources of temperature elevation other than fever could also be detected by the sensor and present as false-positives for fever or infection. Notably, heat stroke

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**Figure 3**

A: The daily trends of a second exemplar patient with BIOMONITOR III (BIOTRONIK, Inc, Lake Oswego, OR) display a dramatic increase in daily temperature of the BIOMONITOR III subject in March. B: The activity data from the same subject are shown; note the drop in activity during the same period of temperature increase. C, D: Plots show, respectively, the daily mean heart rate (HR) and daily mean resting HR; note the remarkably concordant and dramatic increase in the HR and temperature. bpm = beats per minute.
and malignant hyperthermic reactions to anesthesia or certain drugs, heat application over the implant site, or even intense muscular activity could in theory generate temperature deviations in the subcutaneous implant. However, the time scales of these processes are typically quite short (minutes to hours) in comparison to the 24-hour average used here and thus should not represent a significant confounder for this sensor.

The temperature monitoring capability of the ICM is not specific to COVID-19 and cannot confirm a fever is related to COVID-19, but instead represents a tool for screening and triage of any device-implanted patient for significant fever. Temperature monitoring or the need for remote monitoring alone would not warrant the implantation of an ICM. However, owing to the severity of the COVID-19 pandemic and the implications for cardiac complications related to the disease, screening for fever in the existing cardiac monitor population makes intuitive sense for early detection and additional follow-up. With a low overall detection rate and multiple variables (heart rate, activity) it is possible to remotely construct a broader picture of patient health based on this vital data.

Vital data such as this can be easily incorporated into the current remote monitoring infrastructure. Trend data would be available on the internet (BIOTRONIK Home Monitoring) through the cardiac monitoring unit’s traditional credentials, and alerts could be programmed to directly push messages out to specified contacts upon meeting preselected criteria, such as a 1°C increase. In the future, expansion of those specified contacts could permit new distribution channels to general practitioners, general triage teams, or even patients themselves, within an appropriate framework. This is especially important in case of health data, such as temperature, with wider than traditional cardiac implications. As identical remote monitoring capabilities are available in BIOTRONIK pacemakers and implantable cardioverter-defibrillators as well, development of temperature sensors and extension of these capabilities into those devices would confer similar benefits, although a wider patient population could be addressed.

Conclusions

Based on current capabilities of the BIOMONITOR III ICM and the additional possibility of making temperature data available, we believe the device offers a unique opportunity to facilitate screening and triage in the context of the current coronavirus pandemic. The potential benefits are numerous: (1) earlier detection could reduce mortality—especially among at-risk patient groups who may not be subjectively aware of relatively minor temperature elevation; (2) early suspicion of possibly contagious patients could protect caregivers, family, and others; (3) fever, specifically, could be monitored remotely and hands-free to manage at-home care; and (4) additionally, normal ICM surveillance remains in place for screening and diagnosis of cardiac injury or complications during recovery. Temperature monitoring functionality as demonstrated here could be a very important addition to implantable monitors to move these devices towards vital sign monitors with high compliance and significant clinical impact.

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