Remote Patient Monitoring

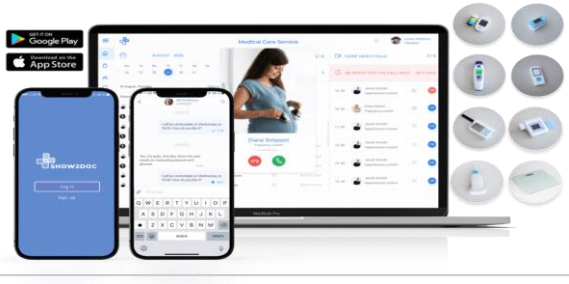
RPM

Definition of RPM

Remote patient monitoring (RPM) uses **digital technology** to collect medical and other health data from a patient in one location and electronically transmits that information securely to a health care provider in a different location.

Data is collected using devices, such as, **biosensors, wearables, smartphones, and implantable** and then transmitted to providers in primary care settings, hospitals, nursing homes, and other care management programs.

RPM provides a **more comprehensive view of a patient's health over time** , while also allowing providers to track treatment progress and initiate timely interventions when needed



This helps to keep patients healthy and ***reduce the number of hospitalizations*** ,which can improve quality of life and contain costs.

In addition, some RPM technologies allow for ***real time audio and video interactions*** between patients and providers

How RPM Works?

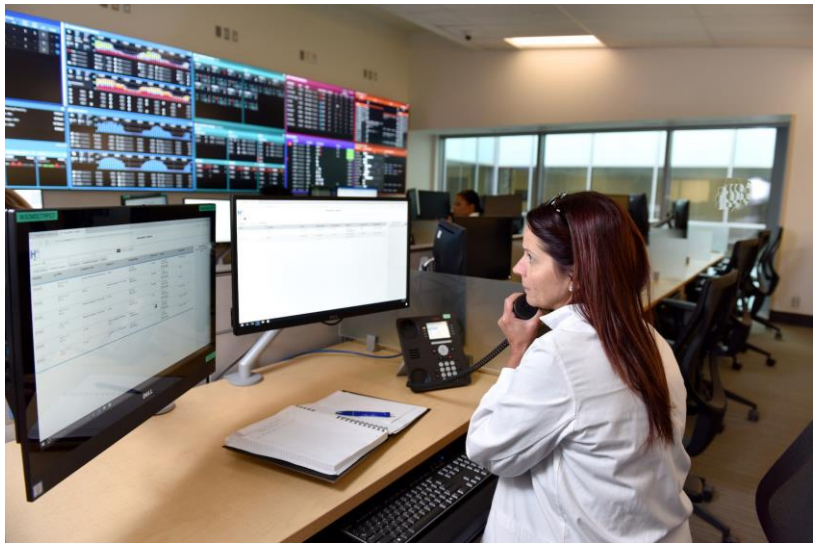
1 SCHEDULE
Clinic schedules dates for the patient to send information from their device to the clinic.

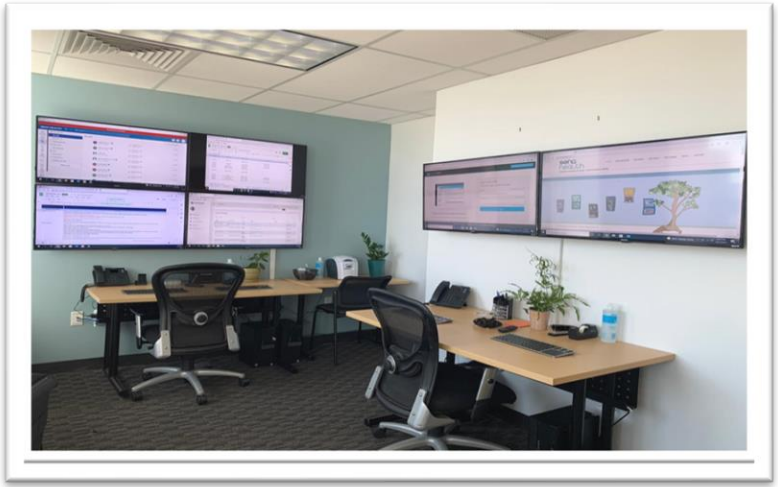
2 SEND
Device information is sent automatically (for wireless ICDs) or manually by the patient (for pacemakers).

3 TRANSMIT
Device information travels from the remote monitor to the clinic.

4 REVIEW
The clinic reviews the device information on a secure website.

Data is transmitted to the monitoring centers who communicate the results with physicians.





Benefits of RPM

76% decrease hospital readmissions

48% improved patient outcome

42% faster access to health care services

41% increased ownership of patient's own health

Evolution of RPM

An estimated 30 million U.S. patients – or 11.2% of the U.S. population – will use remote patient monitoring tools by 2024, according to a report by Insider Intelligence.

It has become increasingly popular to use apps, Bluetooth devices, and wearable monitors to connect patients to their doctors and help them stay on top of their health.

With mobile devices in everyone's hands, remote patient monitoring is convenient and effective, allowing people to be in control of their health.

WIDESPREAD ADOPTION

An Insider Intelligence survey showed that **23.4 million** U.S. patients used RPM in 2020.

The University of Pittsburgh used RPM to reduce hospital readmissions by **76%**.

McKinsey attributes the widespread adoption of RPM to three factors:

- Increased patient willingness to use telehealth
- Increased incorporation by providers
- Regulatory changes to access and reimbursement

Most Common Types of Traditional RPM Devices

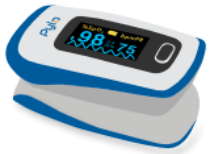
According to the CDC, almost **half of U.S. adults have hypertension, and nearly half a million U.S. deaths in 2017 included hypertension as a primary or contributing cause.** Practices are increasingly leveraging blood pressure monitors, typically cuffs worn on patients' wrists, to improve hypertension management.

CDC reports that in 1999-2000, the obesity rate was 31%. Fast forward to 2017-2018, and the data showed a rate of 42%.

Practices can use remote weight monitoring, typically performed via a scale, for **multiple purposes** including congestive heart failure patients, a sudden weight gain of even just a few pounds may be an indicator that the condition is worsening, prompting practitioners to take action.

Remote spirometry was on the uptick even before the COVID-19 health crisis. Remote spirometry allows practitioners to monitor a patient's lung condition virtually as well as assess whether treatments, including medications, are proving successful in helping patients better manage breathing issues.

Blood glucose monitoring can be performed using various types of RPM devices, some of which do not require patients to draw blood. Practitioners can use the data captured by a remote blood glucose monitoring device to detect potential alarming changes in glucose level and take immediate actions. Also, the data can provide insights that practitioners will use to guide recommendations concerning medications, diet, and exercise.



COPD is recognized as the third leading cause of death by disease in the United States.
The use of remote pulse oximeter monitoring delivers real-time pulse oximetry measurements to practitioners so they can review the readings and assess whether patients are potentially experiencing hypoxemia — the deficiency in oxygen reaching body tissues.

While the previous five devices are the most common for RPM,
there are many other types of devices

Thermometer

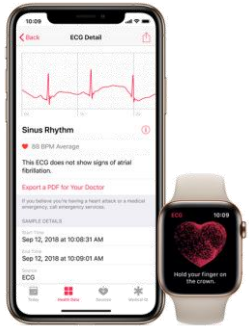
Anticoagulation testing

Electrocardiography (ECG)

Wearables

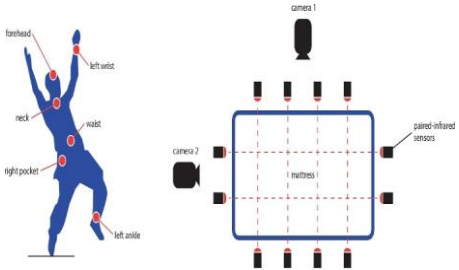
Some New Advances in RPM Technology

Apple Watch EKG



PERS Devices

Accelerometers Sensors



Combinatin Devices

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1.

Apple Watch EKG

In addition to functioning as a timekeeping device, the initial smart watches kept track of a person's movement, count of their daily steps and also detect a person's heart rate during rest and workout.

With the advances in technology, now these smart watches with special sensors can record tracing of a heart's electrical signature (electrocardiogram or ECG) and alert a patient if it detects an irregular rhythm.

Apple Inc. advanced into digital healthcare device space with the release of the Apple watch 4 series, which helps to detect heart arrhythmias such as atrial fibrillation.

Apple Watch looks for arrhythmias using a photoplethysmography-based algorithm, and the ECG app on Apple Watch Series 4, which is capable of generating an ECG similar to a lead I electrocardiogram.

2.

PERS Devices

- PERS stands for Personal Emergency Response System. The term is synonymous with medical emergency devices.

  This is a small device that is used to request help from a monitoring center in the event of an emergency.

  As people setup and wear their medical emergency devices, someone needs to be monitoring them in the event they have to use the device.

  When a fall is detected or an individual presses the pendant for help, the central monitoring station is alerted and responds to the call.

3. Accelerometers Sensors

An accelerometer is an **electronic sensor** that measures the **acceleration forces acting on an object**, in order to determine the object's **position in space and monitor the object's movement.**

Acceleration, which is a vector quantity, is the rate of change of an object's velocity (velocity being the displacement of the object divided by the change in time).

The most common method for wearable-device based fall detection involves the use of data acquired from a 3-axial accelerometer and a threshold-based algorithm for triggering an alarm.

RPM Connectivity Types

Direct Cellular

Direct cellular devices use wide-area 4G LTE technology to send all device readings directly to the receiving RPM platform.

These are the easiest to use of all device types as the patient just adds batteries and they are ready to go.

Cellular Gateways

Cellular gateways connect with Bluetooth RPM devices and then send the data along over the cellular network. Some gateways have a tablet-like interface and extra non-RPM features (e.g., video telehealth) while others are simple passive gateways.

Direct Wi-Fi

Direct Wi-Fi devices use a mobile phone app to connect the device to the patient's home Wi-Fi network.

Once that is complete, the devices send readings directly to the RPM platform as long as the devices are kept within Wi-Fi range.

Classic Bluetooth

Bluetooth RPM devices use short-range wireless connections to transmit data to an internet-connected device. Patients can transmit health data via the internet to their healthcare team without any concern of cellular network availability if they have internet access and a Bluetooth-capable device.

Bluetooth Low Energy (BLE)

BLE devices utilize a different protocol than traditional Bluetooth. As the name implies, it uses less energy, but it also allows for a much quicker and easier “pairing” process. The patient just opens an associated RPM application on their mobile phone and uses the device.

Cloud Connected (oAuth)

Some RPM platforms can pull health information from cloud and mobile health applications (e.g., FitBit, Google Fit). In these instances, the provider of the RPM platform will typically send patients an email with a link where they can use their third-party cloud app username and password to authorize the RPM vendor to collect their health data.

Securing RPM

Hackers and criminal groups are able to exploit vulnerabilities and easily infiltrate a network for financial gain or operational disruption.

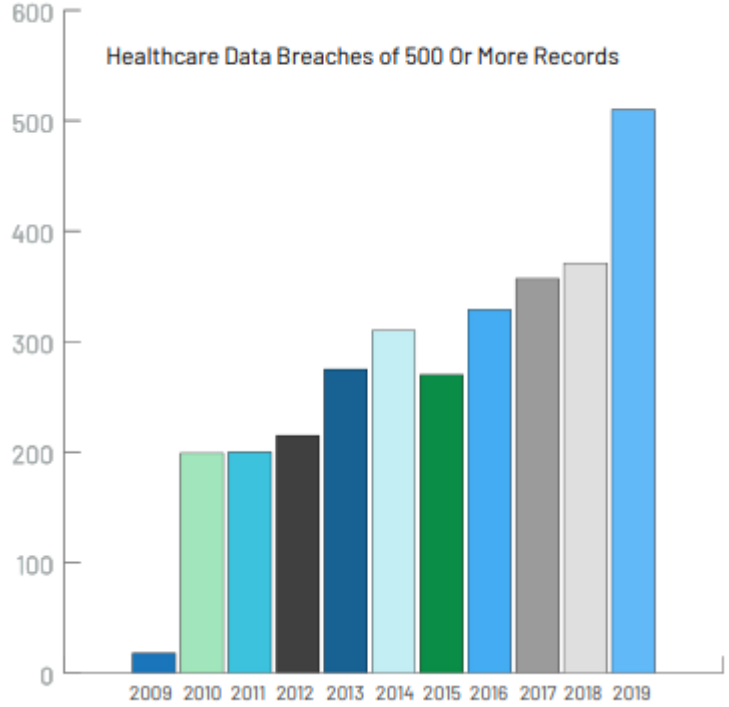
117% increase in website/IP malware security alerts

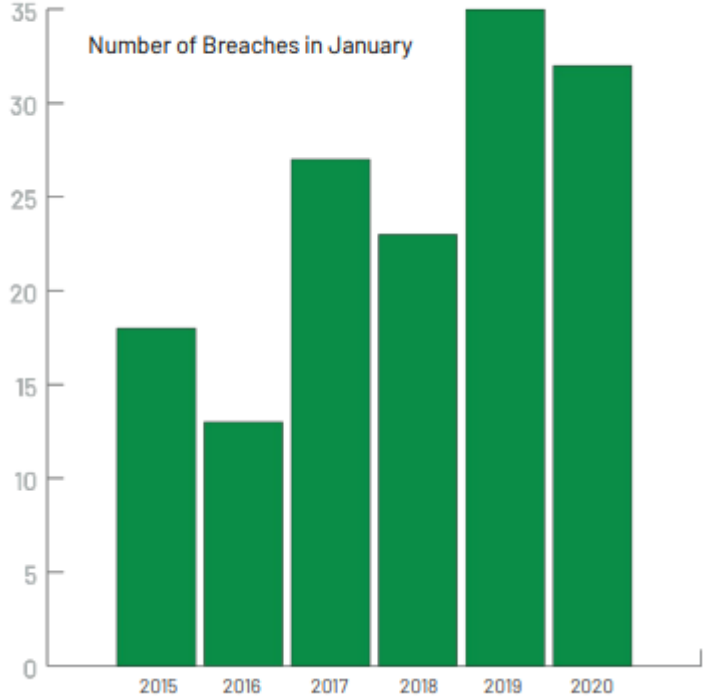
65% increase in security patching of known vulnerabilities

56% increase in endpoint vulnerabilities that enable data theft

42% increase in file transfer protocol vulnerabilities between a client and a server on a network

Healthcare has been decimated by cyber-attacks.





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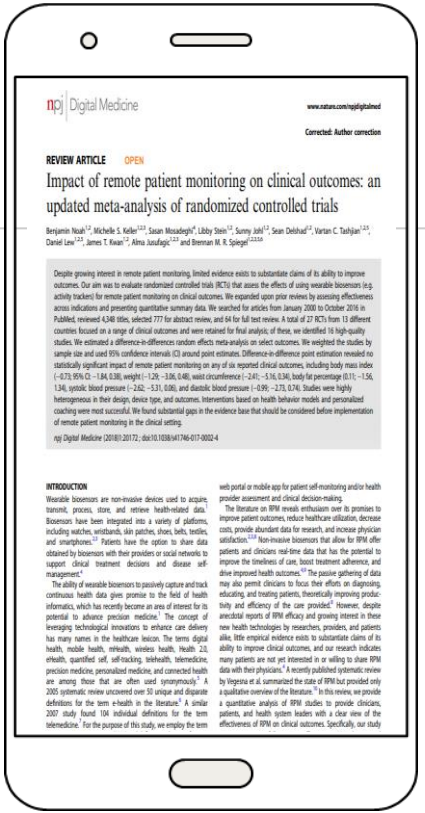
Implementing Cybersecurity on RPM services

- Identifying and implementing controls and policies which assist in the development of organizational awareness of risk.
- Implementing appropriate safeguards to provide for end-to-end data security between patients and organizations.
- Detecting anomalies and security events through appropriate security controls (i.e., a security incident event management tool) and performing security continuous monitoring.
- Responding to and mitigating security events and vulnerabilities to contain the impact of cybersecurity incidents.
- Recovering and resuming normal operations after a cybersecurity incident.

RPM Use Cases



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Corrected: Author correction

REVIEW ARTICLE OPEN

Impact of remote patient monitoring on clinical outcomes: an updated meta-analysis of randomized controlled trials

Benjamin Noah[1,2], Michelle S. Keller[2,3], Sasan Mosadeghi[4], Libby Stein[1,2], Sunny Johl[1,2], Sean Delshad[1,2], Vartan C. Tashjian[1,2,5], Daniel Lew[1,2,5], James T. Kwan[1,2], Alma Jusufagic[1,2,5] and Brennan M. R. Spiegel[1,2,5,6]

Despite growing interest in remote patient monitoring, limited evidence exists to substantiate claims of its ability to improve outcomes. Our aim was to evaluate randomized controlled trials (RCTs) that assess the effects of using wearable biosensors (e.g. activity trackers) for remote patient monitoring on clinical outcomes. We expanded upon prior reviews by assessing effectiveness across indications and presenting quantitative summary data. We searched for articles from January 2000 to October 2016 in PubMed, reviewed 4,348 titles, selected 777 for abstract review, and 64 for full text review. A total of 27 RCTs from 13 different countries focused on a range of clinical outcomes and were retained for final analysis; of these, we identified 16 high-quality studies. We estimated a difference-in-differences random effects meta-analysis on select outcomes. We weighted the studies by sample size and used 95% confidence intervals (CI) around point estimates. Difference-in-difference point estimation revealed no statistically significant impact of remote patient monitoring on any of six reported clinical outcomes, including body mass index (−0.73, 95% CI: −1.84, 0.38), weight (−1.29, −3.06, 0.48), waist circumference (−2.47, −5.16, 0.34), body-fat percentage (0.17, −1.56, 1.34), systolic blood pressure (−2.62, −5.31, 0.06), and diastolic blood pressure (−0.99, −2.73, 0.74). Studies were highly heterogeneous in their design, device type, and outcomes. Interventions based on health behavior models and personalized coaching were most successful. We found substantial gaps in the evidence base that should be considered before implementation of remote patient monitoring in the clinical setting.

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INTRODUCTION

Wearable biosensors are non-invasive devices used to acquire, transmit, process, store, and retrieve health-related data.[1] Biosensors have been integrated into a variety of platforms, including watches, wristbands, skin patches, shoes, belts, textiles, and smartphones.[2,3] Patients have the option to share data obtained by biosensors with their providers or social networks to support clinical treatment decisions and disease self-management.[4]

The ability of wearable biosensors to passively capture and track continuous health data gives promise to the field of health informatics, which has recently become an area of interest for its potential to advance precision medicine.[5] The concept of leveraging technological innovations to enhance care delivery has many names in the healthcare lexicon. The terms digital health, mobile health, mHealth, wireless health, Health 2.0, eHealth, quantified self, self-tracking, telehealth, telemedicine, precision medicine, personalized medicine, and connected health are among those that are often used synonymously.[6] A 2005 systematic review uncovered over 50 unique and disparate definitions for the term e-health in the literature.[7] A similar 2007 study found 104 individual definitions for the term telemedicine.[8] For the purpose of this study, we employ the term web portal or mobile app for patient self-monitoring and/or health provider assessment and clinical decision-making.

The literature on RPM reveals enthusiasm over its promises to improve patient outcomes, reduce healthcare utilization, decrease costs, provide abundant data for research, and increase physician satisfaction.[3,9,10] Non-invasive biosensors that allow for RPM offer patients and clinicians real-time data that has the potential to improve the timeliness of care, boost treatment adherence, and drive improved health outcomes.[4,5] The passive gathering of data may also permit clinicians to focus their efforts on diagnosing, educating, and treating patients, theoretically improving productivity and efficiency of the care provided.[4] However, despite anecdotal reports of RPM efficacy and growing interest in these new health technologies by researchers, providers, and patients alike, little empirical evidence exists to substantiate claims of its ability to improve clinical outcomes, and our research indicates many patients are not yet interested in or willing to share RPM data with their physicians.[11] A recently published systematic review by Vegesna et al. summarized the state of RPM but provided only a qualitative overview of the literature.[12] In this review, we provide a quantitative analysis of RPM studies to provide clinicians, patients, and health system leaders with a clear view of the effectiveness of RPM on clinical outcomes. Specifically, our study

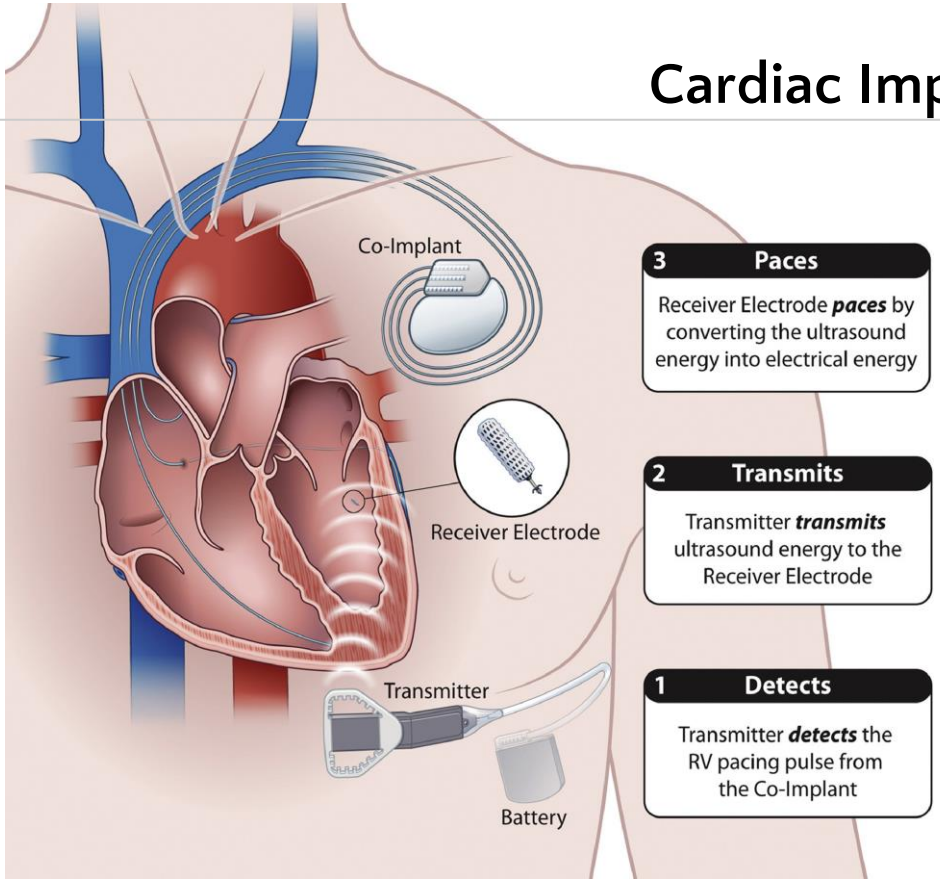
Remote Monitoring in Cardiac Electrophysiology

- Frequent RPM has improved the quality of patient's life with multiple positive outcomes, including early detection of atrial fibrillation (AF) and reduction in inappropriate shocks from ICD which further lead to a decrease in mortality.

- The advent of cardiac implantable electronic devices (CIEDs) have opened the possibility for early detection of arrhythmias and estimate cardiac function in terms of cardiac indices such as stroke volume, ejection fraction, etc.

- The new generation CIEDs can measure, store, and transmit data like thoracic impedance, heart rate, and patient activity. They are capable of predicting HF-related hospitalization days to weeks ahead

Cardiac Implantable Electronic Devices (CIEDs)



They are capable of predicting HF-related hospitalization days to weeks ahead.

CIEDs can give valuable information on the progression of the disease by monitoring patient's physical activity.

RPM for rehabilitation: Parkinson's disease

- 40 participants with Parkinson's disease undergoing gait training were randomized to home visits from the researcher who provided training on using a smartphone application and ankle-based wireless devices that offered positive and corrective feedback on gait, or an active control, in which they received personalized gait feedback from the same researcher during home visits

- Both groups improved on the primary outcomes (single- and dual-task gait speed), **but patients using the app and wireless devices improved significantly more on balance and experienced less deterioration over the six-week period.**

MEASUREMENT OF PHYSIOLOGICAL METRICS FROM WEARABLE SENSORS FOR COVID-19 MONITORING

Respiration Monitoring

In a person who has a high likelihood of COVID19 exposure, a device that is able to detect subtle changes in respiratory function prior to the onset of clinical symptoms, such as shallow respirations, wheezing, and shortness of breath, has the potential to be an effective tool

Cardiovascular Strain, Sleep, and Activity Levels

The use of wearable sensors toward monitoring activity levels could provide an objective means of staying physically active and healthy during the COVID-19 pandemic.

Recovery assessments are based on sleep, sleep quality, and HRV. There is a growing amount of evidence showing a clear downward trend in recovery scores in the days leading up to the onset of COVID-19 symptoms

Hospital at Home

C.D (Sena Health Hospital at Home Patient)

Congestive Heart Failure

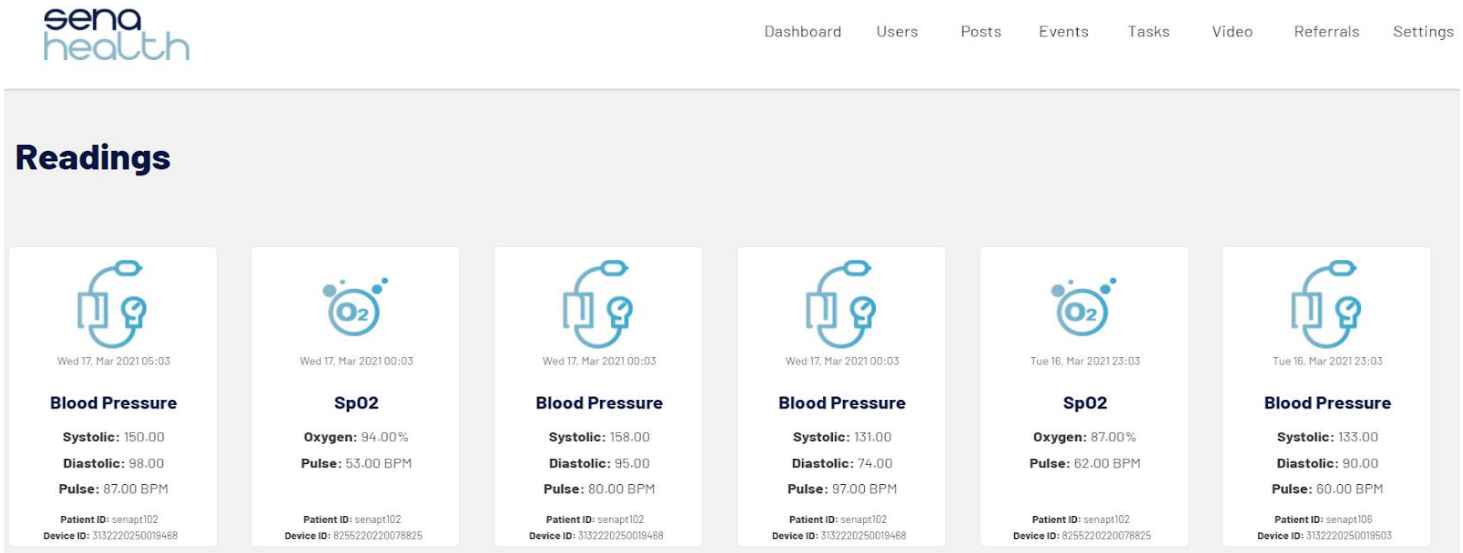
Left leg ulcer with bl chronic lymphedema

Essential hypertension

Class 3 severe obesity with serious comorbidity and body mass index of 50.0 to 59.9 in adult

C.D Episode of Care

Vital signs (blood pressure, heart rate, pulse ox, temperature, weight) taken twice daily during video calls.



How AI-Powered Remote Patient Monitoring Can Improve Healthcare

Artificial intelligence (AI) offers healthcare organizations an ideal opportunity to utilize their existing data infrastructure to modify the traditional care delivery model in a meaningful way for their patients.

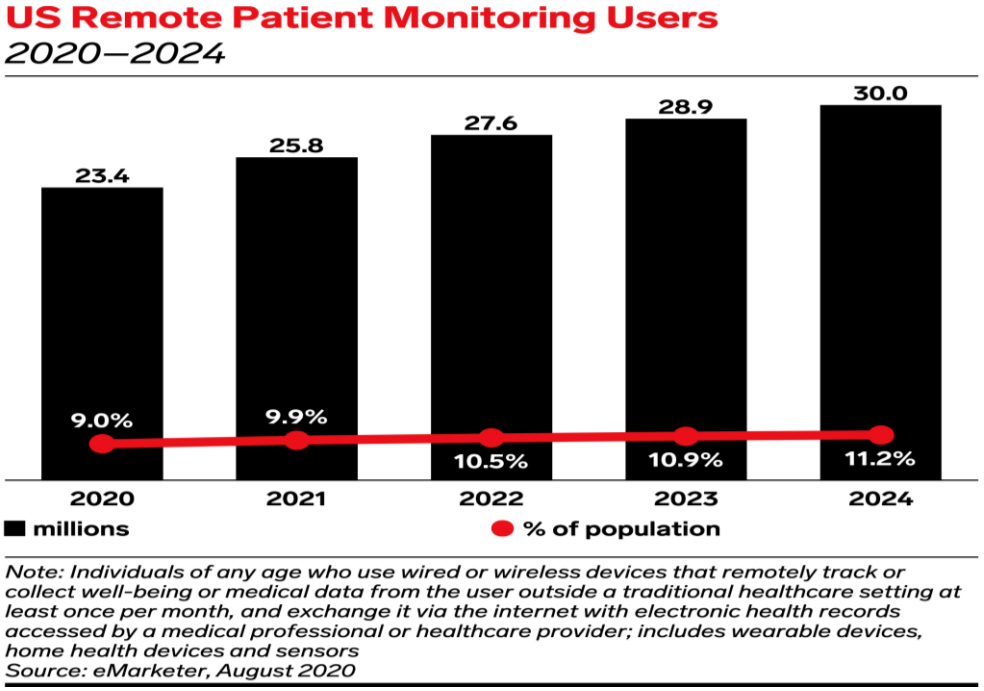
AI's ability to use algorithms that recognize patterns in large clinical datasets and classify patients based on these patterns.

An added benefit of AI-powered RPM solutions is the downstream effects of more proactive treatment for patients. This technology improves the timeliness of care and supports earlier detection of clinical deterioration, which enables earlier intervention to avoid unnecessary emergency room (ER) visits and inpatient utilization.

Natural language processing (NLP) can also be utilized to draft and sometimes fully automate personalized patient-facing communications. This materially scales clinicians' bandwidth for empathetic and informative patient communications.

Future of RPM

Trends of RPM usage in the U.S



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Summary of RPM

- Increased utilization/ use cases
- Increased acceptance
- Data Utilization
- Artificial Intelligence
- Cyber security
- People/Process/Technology

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