Mobile Health Monitoring:
Development and Implementation of an app in a Diabetes and Hypertension Clinic

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Abstract

Significant effort is being spent on providing better control of health in patients suffering from chronic diseases such as diabetes and hypertension in United States. About 1 in 5 adults are suffering from diabetes or hypertension and more than $13,700 per year is spent on each patient diagnosed with diabetes [1]. The increasing cost of healthcare is a big concern not only to the nation but across the world. The total estimated cost in United States to treat diabetes alone was $245 Billion in 2012 [1]. This paper explains the development and implementation of a mobile ambulatory blood pressure monitoring technique in a Diabetes and Hypertension Clinic. Based on the patient data collected, we performed a cost benefit analysis of its use in the clinic as compared to using routine clinical cuff BP measurements. We found that the use of this app assists patients and providers to control chronic disease states through validated continuous monitoring and medication control. It also proved to be more effective and satisfying to the patients and providers.

1. Introduction

Chronic conditions such as diabetes and hypertension are the major cause of illness, disability, and death in the United States. According to World Health Organization (WHO) the number of patients suffering from diabetes could increase up to 300 million globally by 2025 [2]. Center of Disease Control predicts, if this trend continues, 1 out of 3 Americans will suffer from diabetes in 2050. The most challenging issue healthcare faces today is to control the ever-present condition of chronic diseases without spending billions of dollars to treat these patients. Extensive research has been performed to find robust and streamlined methods to gain control over these chronic conditions. Over the last few years, the number of patients with diabetes and hypertension has been increasing into the millions and the trend shows that it will almost double in the next 35 years. Mobile health monitoring systems have been explored extensively in the last few years to take control over these chronic conditions. The patients are now looking for solutions that could assist them to monitor their blood pressure and/or blood sugar and communicate the readings instantly to their care providers.

Despite the availability of evidence-based treatments, hypertension remains a leading cause of preventable deaths. The
amount of uncontrolled hypertensive patients is larger among ethnic minorities and low income population [3]. Even small reductions in high blood pressure have major impacts in clinical outcomes and health care spending. For example, a decrease of 2 mm Hg in systolic blood pressure (SBP) or diastolic blood pressure (DBP) significantly reduces risk of stroke, coronary heart disease, and mortality from vascular causes. Patients of all age groups suffering from chronic conditions, make about 4 primary care visits and 5 to 6 specialty care visits per year [4]. It has been known that regular home monitoring may improve blood pressure control as compared with infrequent office-based monitoring [5].

One of the authors, Dr. R. A. Ramanujan, is a physician practicing endocrinology and treating patients with chronic diseases for over 35 years. The clinic has more than 7000 patients. Wanting to improve patient care using the newest technology, he teamed up with Mr. Anu Banerjee to develop and use a smartphone app called CheckMyVitals® [6]. The app is being installed on more than 1500 patients currently. The office does intend to install the application on all patients gradually. The clinic employs a data validator who helps the patients to install the applications. In additions to patients in the local serving area, the app is also used remotely by patients living in rural areas in New York and far away states such as Florida, Massachusetts, and Pennsylvania to monitor their chronic problems. There has been quite an interest to acquire this app from large industrial companies, other physicians and private physician groups. In the remainder of this paper, we explain the current healthcare delivery method, the details of our app CheckMyVitals®, cost benefit analysis, and patient feedback of the application.

2. Current healthcare delivery method

In traditional healthcare delivery method, patients document vital signs only during normal office visit encounters every year or in several high-stress situations, which leads to skewed results over a period of time. Office visits usually consume time to capture demographics like height, weight, office vital signs and usually receive very less time with the physician. This is problematic for patients with chronic diseases like diabetes and hypertension because the provider cannot gain continuous and accurate readings. Hence, using mobile apps overcomes some of these difficulties. In addition, regular fee based office visits will soon be limited by the Accountable Care Act (ACA), because ACA regulations would enforce capitation based payments.

The traditional method of operation is followed by accepting patients in provider offices multiple times a year, sending the patients through emergency department and increasing the number of inpatient visits in times when they need to be admitted in adverse circumstances. Frequent office visits, rapid medication changes, and multiple emergency visits to the hospital were a common method to control blood pressure and blood sugar. The reimbursement for each
office visit and hospital stays was paid to the provider based on the patient payer history and level of complexity of the patient encounter. The vicious circle of creating multiple office visits based on a certain fee was the common best practice for primary care and specialty care providers.

Figure 1: Fee for Service based traditional method of treating Diabetes and Hypertension.

The current clinic encounters each patient at least 3–4 times a year with the providers and completes at an average of level 3 or level 4 office visit based on the complexity of the system. The level of office visits allowed the provider to charge for their visit. The provider charged the office visit based on the level of complexity and used a charge code called CPT (Current Procedural Technology) billing code to the insurance company, in return getting reimbursed at a pre-set rate decided by the regulation and the insurance companies.

There are over 800,000 apps available for each of the dominant mobile platforms [7], but there are only a few apps that are impacting traditional method of delivery. The current state of mobile medical application market is dominated by Apple iOS and Google Play applications. There are more than 900,000 applications that are being developed and available for each of these vendors. Windows OS and Blackberry OS are not that prevalent in the application market [8]. The amount of applications being designed for Apple and Android operating systems are targeted towards a specific audience. It has been seen that these apps are being sold in the price ranging from $0.99 to more than $9.99 on the iTunes or the Google Play store. The window mobile operating system apps have not been common in the medical mobile application arena. It has been noticed that most of the iOS applications of medical mobile category are used by physicians, unsupervised providers such as nurse practitioners and physician assistants, patients with different kinds of healthcare issues, and the rest of the population who are not suffering from any healthcare issues [7].

Current methods of obtaining vital measurements using these apps do not provide direct communication between patients and physicians. There are many apps in market today that provide monitoring either through manual entry or through technology like wireless and bluetooth in selected blood pressure monitoring devices. These devices then transfer the information as-is to the providers. One of the drawbacks for the providers is that they cannot rely on these readings, as they do not communicate with their patients, unless
they see them at the clinic. At the same time the patients do not know whether or not their reading is outside the healthy range and should seek medical treatment. The provider treats the patient only after the patient takes their physical or electronic logs to the provider’s office. In emergency cases the patient usually visits the emergency department.

The method of operation of entering vital signs through paper, and other forms of manual entries has been very unreliable. The mobile apps would assist the patients and the providers to keep track of vital signs history and to integrate patient history into their intervention methods.

The manual process allowed the providers to look at the data at the time of patient encounter. The manual data is not reliable because it is not validated, and is error prone to manual entry. There have been many accuracy issues that patients and providers deal with while using this method. There are some bluetooth or wi-fi blood pressure measuring devices which allows patients to log readings automatically, but they are still prone to errors. These patient readings are entered manually through excel in offices but are not validated through any intervention by nurses or educators in the clinic. Because of these manual errors, the treatment intervention plans based on this data set are not accurate.

As mentioned before, the current method of capturing vital measurements and signs were proving to be very time consuming and stressful to patients. Despite the many antihypertensive medications available, it was seen two-thirds of patients with hypertension do not achieve blood pressure control. This is a result of combination of poor patient education, poor medication adherence, and clinical inertia. Studies show trials evaluating interventions for home BP monitoring and home medication monitoring and control to address issues related to diabetes and hypertension in patients with poor control towards these deadly diseases [3].

This created a dire need for a tool that allows patient and providers to communicate with each other without paying multiple copays and unnecessary repetitive office visits annually.

3. Literature Review

We reviewed the literature to find out similar medical applications that could be utilized. It was seen that mobile monitoring is extremely common in
healthcare today. For measuring blood pressure (BP) in clinical practice for the diagnosis and treatment of diabetes and hypertension, the universally recommended technique has been auscultation, the method of listening to heart and lung sounds using stethoscope. Over the past 30 years, however, the progressive growth in the use of automated devices, both for home and ambulatory blood-pressure monitoring over 24 hours has shown limitations of traditional clinic blood-pressure readings in assessing the severity of hypertension and prediction of risk [9].

In other industrialized countries, the management of hypertension is primarily controlled using prescription drugs. It still creates confusion and difficulties for providers to decide whether patients are normotensive or hypertensive. BP levels tend to be elevated in the clinical setting, leading to more inaccuracies. It was noted in a study that ambulatory blood pressure monitoring is more accurate than routine clinical cuff BP measurements [10]. Studies have shown to assess whether home blood pressure monitoring, and home medication titration can successfully improve blood pressure, and the impact of interventions is more persistent over a period of time. It was seen that ambulatory BP shows better prediction than clinic BP readings [3].

Many research methods discussed the methodology for measuring BP at home and provided its comparison to other measurement techniques. Some studies have conducted cost benefits over clinical management of hypertension [5]. Some of the clinical significance seen through literature in performing home blood pressure monitoring is considered as an integrated scheme for hypertensive patients. It was also noted that patient might have to consider taking readings under standardized conditions. It can improve patient compliance resulting in better BP control. Studies show improvement in management and predicting risk in patients show limitations of measurement of home BP that could interfere with patient daily activities and possibilities of their home devices being inaccurate [5].

Several studies have tried to assess the need to obtain a reliable estimate of patient BP to determine the adequate number of measurements required to make an accurate intervention [11]. It was attempted to determine resources and cost required to intervene patients for intensive clinical treatment than usual treatment care plans, and the combined intervention was seen more statistically significant in terms of improvement of BP controls relative to the traditional methods of care [4].

Patients who monitor themselves for SBP and DBP have impacted significantly positive than ordinary treatment plans. It has been believed that this was due to improved patient compliance in treatment plans along with active treatment care interventions provided by the physicians. In general, patient take an active part and are motivated to take a major role in their treatment plans [12].

Ambulatory blood-pressure monitoring has limited clinical importance, and home blood pressure
monitoring has increased usage without these limitations. Organizations like American Heart Association and European Society of Hypertension has been aiming to increase the use of applying the technique of using home blood pressure monitoring [9]. Large number of readings compared to a variable elevation of white coat office blood pressure readings impacts better prediction of clinical outcomes. Some discrepancies are seen in measurement of blood pressure while being measured in two different settings, whether the measurement was made in the clinic or at home [9]. Self-monitoring BP or home BP has advantages in evaluating patient with diabetes and hypertension. Even though these monitoring techniques are mandatory for routine diagnosis of these chronic diseases, these are proved to enhance the ability for identification of white coat diagnosed hypertension and far extend the control of BP in patients suffering from diabetes and hypertension [13].

4. Adopted method of operation using CheckMyVitals®

The patients seem more health conscious than before, are now expect a better treatment plan or method of operation to control their disease states. The first two authors took the initiative in designing and developing the patent pending proprietary application CheckMyVitals®. This application so far has been implemented on 1500 active patients out of a total of about 7000 patients in a diabetes and hypertension clinic. The method of operation adopted here through CheckMyVitals® is implemented at a clinic through a Hypertension Educator also knows as validator (whose role is explained later) in the Endocrinology office. Currently, the healthcare providers are not reimbursed for the service provided through this application. However, in the near future, healthcare providers will not be paid for fee based service for every office visit, and will be required to take care of their patients at home and outside the acute care setting.

As pointed out in the literature review, the benefits and effect of home BP measurement has been proven to achieve BP control targets for patients when they use home BP methods than the standard BP monitoring techniques in hypertensive patients. The studies concluded that the SBP and DBP decreased significantly in the self-monitoring groups than the groups who utilized the old traditional methods [12]. Hence, we saw an immediate need for a mobile solution that can improve the treatment plans as well as reduce cost for better delivery of care. We developed CheckMyVitals® that (i) can be implemented on a large population of patients, (ii) is independent of operating systems, location, and access to internet, (iii) communicates instantly with the provider to make immediate treatment modifications if needed, (iv) keeps complete track of patient history, and (v) allows multiple provider groups to communicate instantaneously through one portal to create a continuum of care model for the patients.

CheckMyVitals® is a mobile healthcare application that assists
patients and providers to control chronic disease states through validated continuous monitoring and medication control. The treatment plans are designed on the basis of parameters and clinical guidelines. It was designed to reduce unnecessary office visits which were scheduled to capture the prior blood pressure readings along with their office based cuff blood pressure readings. In order for the patients to receive the quality care they deserve, they must take regular measurements of their vital signs, as recommended by their physicians. Patients enter their at-home, office and other location and time of the day vital measurements into the user-friendly mobile software, where the measurements are instantly shared with their physicians. This mobile application allows patients and doctors to monitor patients’ blood pressure, blood sugar, Pulse, BMI, Height, Weight, Smoking and other vital signs. In order to keep track of patients’ abnormal readings, we employed a “validation coordinator” who is dedicated to ensure that patients are being called for any continuous abnormal readings being posted in the notification section of the application. The validator usually responded to 100 messages a day from the possible 1500 patients who use this application. The app does not eliminate all errors completely, but the data validation by the validation coordinator allows capturing data more accurately than manually collected data through paper logs. Currently there are no ambulatory blood pressure devices that send data automatically to CheckMyVitals®, but there are plans to coordinate with device manufacturers to collaborate with the application and send data automatically through bluetooth technology.

Figure 3: Mobile application log process CheckMyVitals® app

Figure 3 shows the electronic logging process followed by CheckMyVitals® which could be installed and implemented on any mobile operating system or desktop operating system. The CheckMyVitals® application allows the patients to enter data from any location offline or online, from any mobile or desktop application device. The mobile application stores data on mobile devices for a limited amount of memory assigned by the app depending on the memory capacity of the device. The server allows the application to draw the last 30 readings or the last 30 days recordings to keep the application effective to fit the display and speed configuration settings.

In this clinic, the CheckMyVitals® data gets saved on the device, as well as on the server. The providers and the validation coordinator receive the
readings instantly, validates the data. In case of any changes to the treatment plans or medication dosage changes, the coordinator communicates with the patient either via a phone call or through the chat function. The prescribed medication changes are then faxed to the preferred pharmacy. The patient request refills through the app before their medication 30 day refill runs out. The active medication list is shown on the app to share with other primary care physicians and specialty care physicians. Since last 2 years post implementation of CheckMyVitals®, the patients have documented more than 225,000 readings.

4.1 Functions

Most apps in the medical arena have a functionality of recording vital signs and sending it to physicians using a PDF or email format. Our app has a few more key functions that makes this app more users friendly and provides more information to the patients and providers.

(i) Offline Storage. The app allows the patients to save readings on their device when there is no internet connection or cell signal. The readings then transfer through an update algorithm programmable code to the server as soon as the device gets connected to cellular or Wi-Fi network. Patients can enter data from any places like farmer’s markets, walking in a park, home, etc. The patients can also enter data from any desktop device, and are allowed to enter data through multiple devices.

(ii) Thresholds based on Guidelines. These readings show on the provider side with different color codes based on guidelines and thresholds for BP and BS readings, it also sets a hypertension stage for the patients to determine a proper diagnosis. The patient logs into the app to see their current stage of hypertension as well as a green, yellow or red color assigned by the provider.

(iii) Encrypted Database and Chat Room. The app has an encrypted chat room that allows providers and patients to chat securely with each other. The provider and the validation coordinator have the capability to broadcast messages to all patients. The data is secured through secured socket layers (SSLs) and encrypted through algorithms to convert data into binary format if downloaded from the database without authorization. The device saves only limited readings on their device without any patient identification information saved on the device. It is also equipped with security features such as a locked login with a limited number of attempts. The data is saved in a secured database and is encrypted with a multi-level data encryption and firewall to
secure the highest level of security. The application saves all historical data for years in a secured encrypted database. It does not delete any information from these databases for future research purposes.

(v) **Personalized Thresholds for patients.** The app also allows validation coordinator and providers to add personalized thresholds for patients. This allows creating a normalized set threshold for each patient based on their family history, their comorbid conditions, age, race, ethnicity, and their diet habits. This helps patients to stay calm and not panic in ranges which are not normal than the guidelines that applies to most of the patient population.

(vi) **Relaxation for patients.** The patients get to choose their music of their liking and add it to the app. The music allows patients to relax and provides better control of their health state.

(vii) **Reminders for patients.** The busy patient life can sometimes hinder them from entering their BP and BS readings on time. The reminder function allows patients to set reminders to enter data. Pop up reminders are displayed on the screen based on the date and time of their medication intake, and help request refills.
4.2 Patient Survey Results

Post-implementation on 385 patients, we had conducted a telephone survey on all patients to get their feedback on usage. A summary of the results of the survey showed, that the app was most used by:

- Patients with age group of 60 – 69, followed by 70 -79 and then 50 – 59 years.
- Patient with race as Caucasian.
- Females tend to use it more than males.
- Patients BMI > 30
- Patient who are non-smokers

We also asked the patients to identify the friendliness and ease of use. The survey showed that more than 65% agreed that the app was easy to use. After installing the application on 385 patients we conducted a telephone survey on all these patients. We received almost 100% success for patients responding to the survey. The survey consisted of multiple questions like the ease of use of application, and it was primarily conducted to get some feedback on the interface and as well as user friendliness of the application.

Figure 5: Survey showing patients for ease of use of CheckMyVitals® App

The clinic denied sharing some of the detailed results and hence we were not able to include the detailed data graphs for the survey analysis. We plan to modify the survey questions to capture more data. The current survey was not collected anonymously, but the modified survey is intended to collect data anonymously in future.

4.3 Cost Benefit Analysis

Some of the data captured helped us determine the cost of office visits paid by the insurance companies and the co-pays paid by patients. We performed a random selection of 56 patients from the total patients to perform our preliminary cost benefit analysis on these patients. We picked these patients based on the high frequency of their usage on the application.
Figure 6: Snapshot of a graph showing Cost benefit for patients and insurance companies by savings on reducing office visits CheckMyVitals® App

In figure 6 shows the cost benefit analysis without and with using this app based on the reduced number of office visits. Although the office did not elect to share the cost data, there was a reduction in the amount of co-pay and office visit charges. The providers could see that the new patient volume is growing as the method of operation for treating patients have been advantageous to patients and families.

5. Summary

As time evolves, CheckMyVitals® and similar mobile applications developed will provide more functionality to improve patient care. It will also create a new way to make the patient-provider experience better. The authors look into adding more functionality like audio and video chat availability between patients and providers. The “big” data collected through these encrypted methods will then be useful to judge population based management and allow counties and states to determine better use of healthcare dollars. This data can then be used to identify better use of drugs and formularies in the area. The insurance companies can utilize this data to determine a compromised reimbursement model for providers through tele-health or mobile-monitoring billing codes.

The future of maintaining chronic conditions like diabetes and hypertension could be a much involved process with technology, physicians, patients and other stakeholders like specialists and dieticians who would be actively involved in improving the quality of care. The blood pressure and blood sugar monitoring devices could then be integrated with the app to ensure smooth transition of data from monitoring device to a patient electronic medical record. We could then expand the use of these apps to other chronic diseases which can assist the nation and the world to improve care. The authors intend to conduct further data analysis to learn from the data collected.

6. Acknowledgment

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7. References


[6] Mr. Anu Banerjee and Dr. R. A. Ramanujan. “CheckMyVitals®”, a copyrighted patented application with all rights reserved by authors


Abbreviations and Acronyms
App – Application
ABPM - ambulatory blood pressure measurement
BP - blood pressure
BS – blood sugar
DBP - diastolic blood pressure
HBP (M) - home blood pressure (measurement)
OBPM - office blood pressure measurement
SBP - systolic blood pressure