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Remote Patient Monitoring Programs to Reduce Congestive Heart Failure Readmissions with a Cost-Benefit Analysis Tool to Model Expected Economic Impacts

By

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CERTIFICATE OF APPROVAL

This is to certify that the Master's Capstone Project of

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"**Remote Patient Monitoring Programs to Reduce Congestive Heart Failure Readmissions with a Cost-Benefit Analysis Tool to Model Expected Economic Impacts**"

Has been approved

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Abstract

Objective: This purpose of this Capstone project was to create a cost-benefit analysis (CBA) tool that healthcare organizations can use to evaluate the expected changes in revenue after introduction of a remote patient monitoring (RPM) program to prevent congestive heart failure (CHF) readmissions. This paper also examines technical considerations of an RPM program and applies a socio-technical framework and best practices from existing literature to inform the design and implementation of an RPM program.

Methods: A review of available literature guided development of a CBA model, and default parameters, for the economic evaluation of an RPM program to prevent CHF readmissions. Expected changes in revenues and return on investment (ROI) for RPM, compared to usual care, were calculated over a range of treatment periods from 30 days to one year after index hospitalization. Deterministic sensitivity analyses were conducted across the range of treatment periods to assess the relative impact of each variable on expected net changes in revenue with RPM as compared to usual care. Two-way sensitivity analyses across the range of RPM treatment periods were performed to assess the robustness of CBA model projections.

Results: Using default values, the highest expected ROI was 4.34 when using RPM to prevent 30-day readmissions among CHF patients. Deterministic sensitivity analysis demonstrated the most important variable impacting the anticipated change in revenue across all treatment periods was the expected reduction in hospital readmission with RPM. For treatment periods between 30 to 180 days, the second most important variable

was the average cost of a CHF readmission. For a 365-day program, monthly cost of the RPM program was the second most important variable affecting the anticipated net change in revenue.

Conclusions: Application of this CBA tool to the challenge of managing a CHF patient population demonstrates that an RPM program focused on prevention of hospital readmissions provides a positive return on investment across a wide range of treatment time horizons and input variable values. Healthcare organizations can input organization-specific costs and CHF prevalence data into the CBA tool developed for this project to assess the potential economic impact of an RPM program for their CHF patient population. If an organization determines that RPM is an economically viable option to prevent CHF readmissions, they should consider applying a socio-technical framework and best practices from existing literature when designing and implementing such a program.

Introduction

U.S. Healthcare Costs are Driven by Hospitalizations

Healthcare costs in the U.S. are increasing at an unsustainable rate. Total healthcare expenses have risen from $1.4 trillion in 1996 (13.3% of gross domestic product [GDP]) to $3.1 trillion in 2016 (17.9% of GDP).[1] This equates to an increase in estimated annual healthcare spend of $5,529 per person in 1996 to $9,655 in 2016.[1] Inpatient hospitalizations are the largest cost category and make up an estimated 33% of total U.S. healthcare expenses.[2]

Congestive heart failure (CHF) is a common chronic disease that exemplifies the disproportionate costs incurred by hospitalizations.[3] With an estimated prevalence of 6.9 million in the U.S. in 2020, CHF patients account for 34% of total Medicare spending and cost an average of three times more per member per month (PMPM) compared to a Medicare beneficiary without CHF.[4] The majority of CHF patient costs are related to hospitalizations.

One study of Medicare claims between 2011 through 2012 reported that hospital admissions accounted for 51.6% of all CHF-related costs and the percentage of CHF healthcare costs due to hospitalizations appears to be rising.[5] A systematic review of 87 studies published between January 2014 through March 2020 reported that the total annual medical cost for adults ≥ 18 years of age with CHF was an estimated $24,383 per patient.[3] Of that total, $15,879 (65%), were due to CHF-related hospitalizations.[3] The heavy financial burden of CHF hospitalizations is unsurprising given that CHF is the most common reason for admission and readmission within 60 days for U.S. patients

aged 65 or older.[4] Effective interventions are urgently needed to reduce excess CHF costs as the number of people with CHF in the U.S. is expected to reach 8.5 million in 2030.[3]

Importance of Reducing CHF Hospitalizations

Despite the high costs of CHF hospitalizations, until recently there has been no clear financial incentive to reduce their incidence under the historically predominant fee-for-service (FFS) payment model. However, starting in 2012, the Hospital Readmissions Reduction Program allowed Medicare to levy 30-day readmission penalties to hospitals for a variety of conditions, including CHF.[6] Although penalties are capped at 3% of the total Medicare payments to the hospital, they still provide a financial motivation for FFS organizations to reduce CHF 30-day readmissions.[6]

While FFS organizations should focus on reducing 30-day readmissions to avoid penalties, healthcare organizations that engage in fully capitated value-based payment (VBP) contracts must strive to reduce any type of CHF hospitalization. VBP contracts are increasing in number. A report from the Health Care Payment Learning & Action Network showed that FFS payments have fallen from 62% in 2015 to 41% in 2017.[7] Correspondingly, alternative payment model FFS arrangements with shared savings along with population based PMPM capitated payment models have combined to increase from 23% in 2015 to 34% in 2017.[7]

Even though there are many types of VBP models, the financial implications of reducing CHF hospitalizations are most significant for Medicare Advantage (MA) fully capitated organizations. Fully capitated MA organizations receive lump sum payments based on the total population they are caring for. Payments are adjusted for each patient's

individual “risk adjustment factor” score, calculated using medical conditions coded during the previous year.[8] Because fully capitated VBP organizations are responsible for all healthcare costs incurred by their patient population, these organizations have a clear incentive to prevent avoidable expenses.

Given the prevalence of CHF and the resultant costs of CHF-related admissions, it is imperative for VBP healthcare organizations to identify treatment options that are financially viable and have the potential to reduce CHF-related admissions. FFS organizations also have an incentive to reduce 30-day CHF readmissions to avoid payment penalties.

Background

To conduct a CBA regarding the use of RPM in CHF, it is critical to identify expected readmission risk within the length of the RPM intervention, among many other cost and benefit-related factors. The following sections summarize findings from the literature regarding key factors to include in a CBA. Study findings provide a basis for default assumptions, estimates, and parameter values for the CBA tool described in subsequent sections of this paper.

RPM for Reducing CHF Admissions and ED Visits

Remote patient monitoring involves the use of technology to enable monitoring outside of clinical settings, including the locations where patients live and work. Multiple studies have demonstrated that RPM programs reduce CHF readmissions. A meta-analysis of 39 studies of tele-monitoring for CHF patients found that RPM programs reduced CHF

admission rates (pooled odds ratio [OR] = 0.63, 95% confidence interval [CI] 0.53 to 0.76, p<0.001).[9]

A study specific to the MA CHF population, utilized propensity matching to create two evenly sized groups of 8,907 – one that received usual care and one that received remote intensive disease management.[4] A subset of 4,352 patients in the intensive disease management group used a Bluetooth enabled digital scale that automatically transmitted daily weights into an electronic database which then alerted case management staff for any clinically concerning weight gain.[4]

This study illustrated that patient compliance in reporting daily weights is a concern, as only 1,173/4,352 (27%) of patients used the scale at least 25 times per month, however, patients who used a scale ≥ 25 days per month had a 31.9% chance of re-admission during the 12 months measurement period after an index admission, compared to a 43.1% chance of readmission in the control group ($p < 0.0001$).[4] This readmission reduction translated into a statistically significant reduction in PMPM spend, with patients using the scale ≥ 25 days/month having an average PMPM spend of $1,080 as compared to $2,134 PMPM for the usual care control group ($p = 0.0007$).[4]

Single organizations that have studied CHF hospitalization rates with RPM programs have shown similar reductions. A study including 60 patients at Mount Sinai in New York showed a 57% reduction in their 30-day rate of CHF readmission, from 23% with usual care to 10% with RPM.[10] Flagstaff Medical Center in Arizona experienced a 54% reduction in 30-day CHF readmission rates, from 24% with usual care to 11% with

RPM.[11] Sharp Healthcare in San Diego, CA reported a 50% decline in 30-day readmissions and a 21% decline in 90-day readmissions compared to usual care.[11]

Although relatively rare in published literature, some organizations have described the economic benefits of CHF RPM programs. The Geisinger healthcare system, based in Pennsylvania, reported a 44% reduction in 30-day CHF readmissions with an RPM program.[11] This reduction resulted in a return of investment of 3.3 with an 11% cost savings from the program.[11] Banner Healthcare, located in Arizona, had a 30% reduction in total cost PMPM for RPM patients during a year of monitoring compared to the same cohort's costs 12 months prior to entering the monitoring program.[11]

To date, studies of the effectiveness of RPM solutions have primarily utilized hospital readmission as a study outcome. However, CHF patients may return to an emergency department (ED) after a hospitalization and be discharged back home from the ED rather than being admitted. Although ED visits do not trigger cost penalties in an FFS model, organizations that operate under a VBP payment model have a financial incentive to manage ED costs. There is currently a dearth of published information regarding the effectiveness of RPM to prevent CHF-related ED visits in the U.S. A Canadian study using RPM for 95 total patients with a variety of chronic conditions, including CHF, reported a non-statistically significant 34% reduction in ED utilization ($p = 0.08$) over the five month study period.[12]

CHF Hospitalization and Emergency Room Costs

Medicare beneficiaries with at least one CHF admission between July 1, 2005 through December 31, 2011, had an average CHF admission cost of $14,631 when adjusted to

2015 dollars.[13] More recent evidence demonstrates that CHF admissions remain costly. A systematic review of CHF costs between 2014 through 2020 for all adults aged 18 or greater, estimated that the median cost for a CHF-specific hospitalization is $13,418 (interquartile range [IQR]: $11,125 - $15,667).[3] Hospitalization costs were slightly higher for CHF patients with another comorbid condition such as diabetes or coronary artery disease, with a median cost of $14,015 (IQR: $11,769 - $20,373).[3] The mean cost of a 30-day readmission back to the initial index hospital was $15,732, but increased to a mean of $25,879 per admission if the patient was readmitted to a different hospital.[3]

ED visits are an additional cost category for potential inclusion in a CBA model. One study looking at CHF ED visits from 2006 through 2010, for all adults aged 18 or older, found median ED charges for a CHF exacerbation visit were $1,558 (IQR: $1,018 - $2,335).[14] A meta-analysis of studies from between 2014 through March 2020 determined that the median cost for a CHF ED visit is $1,441 (IQR: $829 - $1,933).[3]

CHF Readmission Rates by Time Frame

For the purposes of CBA, FFS healthcare organizations are primarily concerned with preventing 30-day readmissions, while fully capitated VBP organizations are concerned about all costs related to CHF. Whichever strategy a healthcare organization chooses it is important to understand that the readmission risk for CHF patients remains elevated, compared to non-admitted CHF patients, for one year after an index admission.[6] However, the most substantial risk period is shortly after being discharged. For the Medicare patient population, the highest daily risk of CHF readmission is three days after

discharge, and the risk for readmission does not decrease by 50% until 38 days after discharge.[6]

To conduct a CBA, it is critical to have data on the expected readmission risk during the expected length of the RMP intervention. One retrospective study of a sample of Medicare patients, reviewing admissions between 2005 through 2011, reported that after an index admission 22.3% of CHF patients had a 30-day readmission, 33.3% had a 60-day readmission, and 40.2% had a 90-day readmission.[13] As a point of comparison, the 30-day readmission rates for other conditions that are subject to readmission penalties were reported as 20.2% for COPD, 17% for acute myocardial infarction, 16.9% for pneumonia, 14.9% after a coronary artery bypass surgery, and 4.8% after a knee or hip replacement.[13]

A 2019 study, specifically analyzing the Medicare Advantage population, reported a patient with a CHF index admission had a 25% chance of a 30-day readmission and a 50% chance of readmission within 6 months.[4] A study of just over 50,000 adults with hypertension who had their first CHF-related hospital admission between 2000 and 2014 found that 61.3% would be readmitted within 1 year.[15]

Estimation of CHF ED Visits

Due to the lack of information on the expected reduction in ED visits with RPM, the estimate for this variable was derived from two studies that looked at CHF-related costs for all adults aged 18 or older. One study, conducted from 2006 through 2014, determined that a CHF-related ED visit led to a hospitalization 82% of the time.[16] A systematic review, analyzing data from 2014 through 2018, concluded that 83.7% of

CHF-related ER visits led to a hospitalization.[3] Based on this data, the CBA tool contains an input variable for anticipated "ED to hospitalization rate" with the expected rate set at 80%. This variable was then incorporated into calculations to estimate the percentage of CHF patients that would have an ED visit, with the assumption that all CHF readmissions would first present to the ED.

Remote Patient Monitoring Costs

Costs of implementing RPM are reported in the literature, although often at a lower level of granularity than is optimal for development of a CBA. The previously mentioned CHF RPM study conducted at Mount Sinai reported an implementation cost of $110 per patient.[10] This implementation cost included a Bluetooth enabled blood pressure monitor and weight scale for each patient.[10] Devices were configured to automatically send blood pressure and weight readings to an application that could be accessed by the patient's care team through a web-based portal.[10] This study, however, did not report the application cost or cost of personnel time required for ongoing monitoring of incoming data streams from RPM devices.[10]

An economic modeling study for CHF RPM employed expert opinion to create a base case monthly monitoring estimate of $80 per month, with a range of $50 to $450 per month.[17] A commercial company, mTeleHealth, has published a cost of $1,200 for one monitoring kit per year, but states this kit can be subsequently deployed to multiple patients throughout the year.[18] Their solution includes a digital scale and BP cuff, an app, and an administrator that receives and monitors all the data, along with activation and

communication fees.[18] This same company alternatively, will charge $70 per kit per month, including installation, with a 24 month contract.[18]

A 2013 Canadian study on remote monitoring for patients with CHF, hypertension, COPD, or diabetes reports installation costs of CAD$476 per patient (approximately US$362 per patient).[12] This installation cost included the purchase and installation of hardware in the patient's home, maintaining a regional server, preparing clinical protocols, and staff training.[12] The monthly monitoring costs were CAN$99 per member over the course of five months (approximately US$75 per month).[12] Monitoring costs in this study included the cost of a nurse to oversee the program and hourly nursing costs to monitor incoming data and place calls to patients as needed during 10 hours per weekday and one hour per weekend.[12] The authors of this study reported the total cost five month cost averaged CAD$1,803 per patient (approximately US$1,375 total or US$275 per month).[12] Costs were not reported at a disease-specific level.[12] Across all four conditions, this study reported a 41% savings over baseline spending, equivalent to CAD$1,557 per patient (approximately US$1,187) in the RPM group compared to usual care.[12] A 66% decrease in hospitalizations ($p < 0.001$) was aggregately reported over the same time period for CHF and COPD patients.[12]

Remote Patient Monitoring Reimbursement

It is notable that Medicare will reimburse for various components of an RPM program. However, if an organization bills for RPM this will generate a 20% co-payment for a patient with a Medicare Part B plan and has the potential for co-payment for Medicare Advantage patients.[19] Furthermore, if a provider would like to bill for RPM services there

are numerous rules and regulations that apply.[20] Also, with regards to RPM reimbursement codes, the Centers for Medicare & Medicaid Services (CMS) is still "seeking comment from the medical community" which means that RPM reimbursement may change in the near future.[20] Because of this uncertainty it would be inadvisable to base a decision on RPM on anticipated reimbursement from the program. It is also assumed that most FFS organizations will not elect to bill for this service to avoid pricing patients out of the program, and that VBP organizations would also not submit bills as this would have the adverse effect of increasing their own attributed healthcare spend.

Based on findings from published literature, the default RPM billable revenue is set to $0 within the CBA tool. However, the model does allow for an organization to change this default setting and run an analysis with remote monitoring revenues included if so desired. The current rates for RPM reimbursement range from $18.77 for the initial set-up of applicable devices, and monthly reimbursement rates that range from $32.84 to $62.44 per month depending on the specific code and facility type.[21]

Methods

Methodology for Creation of the Cost-Benefit Analysis Tool

A baseline value for estimated costs, readmission rates, and RPM treatment effects and a reasonable estimate of a 10^{th} and 90^{th} percentile value, for sensitivity analysis, was determined by integrating the previously reviewed evidence. Because FFS and VBP providers may have different strategies for the optimal length for monitoring individual patients, the literature data was synthesized to estimate the expected readmission risk and expected reduction in readmission risk with RPM over five different timeframes. Five

post-hospitalization time periods were used as scenarios in this CBA model: 30-day, 60-day, 90-day, 180-day, and 365-day intervals. The baseline, 10th percentile, and 90th percentile variable values for CHF readmission cost, readmission rate, estimated ED cost, ED to admission rate, RPM installation costs, RPM monthly costs, and RPM readmission reduction rate used as model inputs for the CBA tool are presented below in Table 1.

Variable	Baseline Value	10th Percentile	90th Percentile	Reference(s)
CHF readmission cost	$15,000	$8,000	$24,000	3,14
30-day readmission rate	22.5%	20%	25%	4,14
60-day readmission rate	33%	30%	36%	14
90-day readmission rate	40%	35%	45%	14
180-day readmission rate	50%	45%	55%	4
365-day readmission rate	60%	50%	70%	16
Estimated ED Visit Cost	$1,500	$1,000	$2,000	3,15
ED to admission rate	80%	70%	90%	3,13
RPM Installation Costs	$150	$75	$350	10,12
RPM Monthly Costs	$170	$70	$270	12,17,18
RPM 30-day admit reduction	45%	25%	60%	10,11
RPM 60-day admit reduction	42.5%	20%	50%	extrapolated
RPM 90-day admit reduction	37.5%	15%	50%	11
RPM 180-day admit reduction	30%	10%	40%	extrapolated
RPM 365-day admit reduction	25%	5%	35%	4
RPM Monthly Reimbursement	$0	$0	$60	21

Table 1 – Variables for the CBA tool along with the default baseline values and 10th and 90th percentile values. Reference numbers correspond to the references section.

The CBA tool was built in Excel. Instructions for use of this tool and a downloadable version of this tool are available at: https://scholararchive.ohsu.edu/concern/etds/h702q7299?locale=en.[22]

CBA Tool Formulas

To calculate the expected changes in revenue and return on investment (ROI), the first step was to calculate expected costs of usual care for each scenario. For the purposes of this paper, total expected usual care cost is defined as the sum of expected readmission costs plus the expected ED visit costs during the timeframe of interest for each scenario. In all following equations, (n) represents the number of patients in the equation.

> Expected usual care readmission cost = (n * cost per readmission * usual care readmission rate)

> Expected usual care ED cost = (n * estimated cost per ED visit) * (estimated usual care readmission rate / estimated ED to readmission rate)

> Total expected usual care cost = Expected usual care readmission cost + Expected usual care ED cost.

The next step was to calculate the expected cost of care for each RPM scenario. This value was obtained by summing the expected RPM readmission costs, expected RPM ED costs, expected RPM setup costs, and expected RPM monthly monitoring costs.

Expected RPM readmission cost = (n * estimated cost per readmission * estimated usual care readmission rate) * (1-estimated RPM readmission reduction rate)

Expected RPM ED cost = (n * estimated cost per ED visit * estimated usual care readmission rate / estimated ED to readmission rate) *(1-estimated RPM readmission reduction rate)

Expected RPM setup cost = (n * estimated RPM installation costs per patient)

Expected RPM monthly monitoring cost = (n * estimated monthly PRM costs per patient * number of months)

Total expected RPM cost = Expected RPM readmission cost + Expected RPM ED cost + Expected RPM setup cost + Expected RPM monthly monitoring cost

The net change in revenue under each scenario was then calculated as:

Net change in revenue = Total expected usual care cost – Total expected RPM care cost

ROI was calculated for each scenario as:

$$ROI = \frac{Net\ change\ in\ revenue}{Expected\ RPM\ setup\ cost + Expected\ RPM\ monthly\ monitoring\ cost}$$

To conduct a deterministic sensitivity analysis and a two-way sensitivity analysis a freely available sensitivity analysis package for Excel was downloaded from Dartmouth's Tuck School of Business at: http://mba.tuck.dartmouth.edu/toolkit/ [23]

Results

The resulting model was applied to five scenarios using baseline values synthesized from published literature, with a hypothetical population of 100 CHF patients. In all scenarios, the CBA model determined that an RPM program to prevent CHF readmissions was profitable. The highest ROI (4.34) was found for the 30-day RPM scenario and ROI steadily declined as the RPM treatment period increased, with a low of 0.16 for the 365-day scenario (see Table 2).

30-day Readmission Strategy			
	Usual Care Expected Costs:	RPM Care Expected Costs	Net Change in Revenue
Readmission Costs:	$337,500	$185,625	
ED Visit Costs:	$42,188	$23,203	
RPM Setup Costs:	0	$15,000	
RPM Total Monthly MonitoringCosts:	0	$17,000	
RPM Monthly Billable Revenues	0	$0	
Total Costs:	**$379,688**	**$240,828**	**$138,859**
ROI:			**4.34**
60-day Readmission Strategy			
	Usual Care Expected Costs:	RPM Care Expected Costs	Net Change in Revenue
Readmission Costs:	$495,000	$284,625	
ED Visit Costs:	$61,875	$35,578	
RPM Setup Costs:	0	$15,000	
RPM Total Monthly MonitoringCosts:	0	$34,000	
RPM Monthly Billable Revenues	0	$0	
Total Costs:	**$556,875**	**$369,203**	**$187,672**
ROI:			**3.83**
90-day Readmission Strategy			
	Usual Care Expected Costs:	RPM Care Expected Costs	Net Change in Revenue
Readmission Costs:	$600,000	$375,000	
ER Visit Costs:	$75,000	$46,875	
RPM Setup Costs:	0	$15,000	
RPM Total Monthly MonitoringCosts:	0	$51,000	
RPM Monthly Billable Revenues	0	$0	
Total Costs:	**$675,000**	**$487,875**	**$187,125**
ROI:			**2.84**
180-day Readmission Strategy			
	Usual Care Expected Costs:	RPM Care Expected Costs	Net Change in Revenue
Readmission Costs:	$750,000	$525,000	
ER Visit Costs:	$93,750	$65,625	
RPM Setup Costs:	0	$15,000	
RPM Total Monthly MonitoringCosts:	0	$102,000	
RPM Monthly Billable Revenues	0	$0	
Total Costs:	**$843,750**	**$707,625**	**$136,125**
ROI:			**1.16**
365-day Readmission Strategy			
	Usual Care Expected Costs:	RPM Care Expected Costs	Net Change in Revenue
Readmission Costs:	$900,000	$675,000	
ER Visit Costs:	$112,500	$84,375	
RPM Setup Costs:	0	$15,000	
RPM Total Monthly MonitoringCosts:	0	$204,000	
RPM Monthly Billable Revenues	0	$0	
Total Costs:	**$1,012,500**	**$978,375**	**$34,125**
ROI:			**0.16**

Table 2 – CBA Tool Output with Baseline Assumptions. Usual care as compared to RPM care expected costs across the five treatment scenarios. Net change in revenue and ROI are calculated and displayed for each scenario.

A deterministic sensitivity analysis was conducted for each scenario using estimated 10th and 90th percentile values for each variable. This type of sensitivity analysis changes one variable in the model to the 10th or 90th percentile value while holding all other variables constant at their baseline value. This process is used to determine which variables contribute most to the outcome of interest. For this CBA model, the outcome of interest is the net change in revenue when using RPM as compared to usual care.

The deterministic sensitivity analysis for this model found that the most important variable that impacted expected revenue across all five scenarios (30, 60, 90, 180, and 365-day RPM treatment period) was the percent reduction in readmissions achieved with the RPM program. The second most important variable for the four treatment scenarios between 30 to 180 days was the average cost of a CHF readmission. When considering the 365-day RPM strategy the monthly costs of maintaining the RPM program replaced the average readmission costs as the second most important variable impacting expected revenues.

Tornado charts were created to display the findings of the deterministic sensitivity analyses. Tornado charts are horizontal bar charts that visually display the impact that varying an input has on the output of interest, with a vertical line that demonstrates the expected output if all the variables are kept at their baseline values. The variables that have the largest impact on the primary outcome of interest, when varied to their 10th and 90th percentile values while keeping the other variables constant, are then displayed in descending order in the Tornado chart. See Figures 1 through 5 for the Tornado charts for each of the five RPM scenarios (30-day, 60-day, 90-day, 180-day, 365-day).

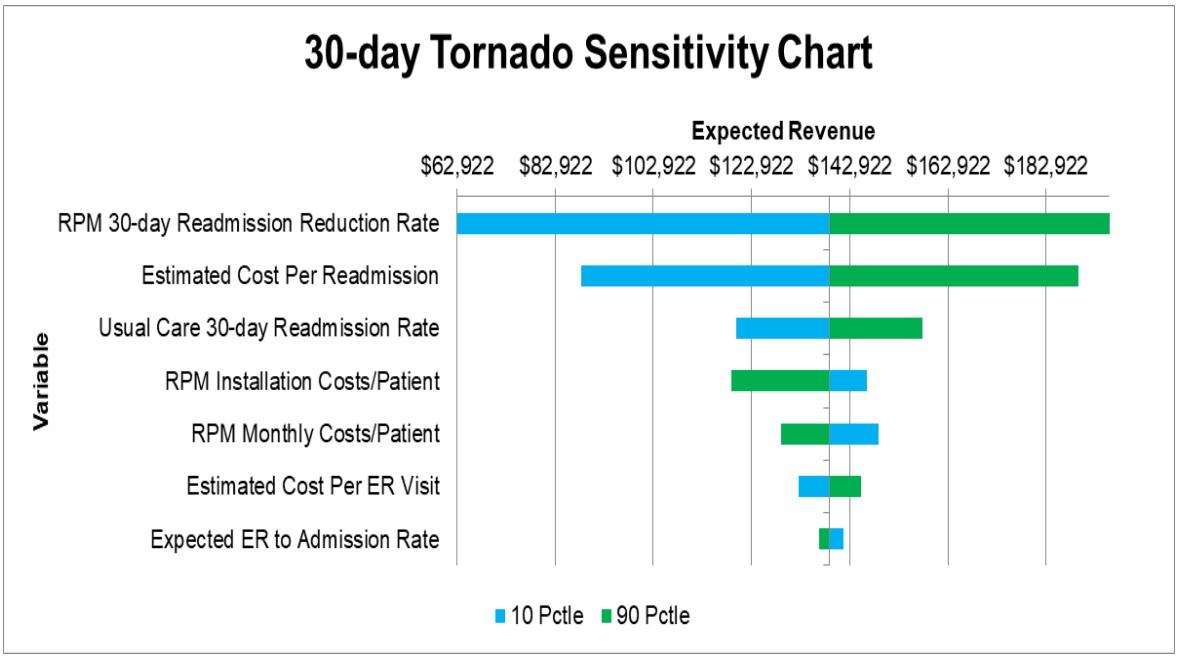

Figure 1 – Deterministic sensitivity analysis for 30-day RPM scenario. The length of the bars for each variable corresponds to the relative importance of that variable on expected revenue. The 10th and 90th percentile values can be viewed in Table 1.

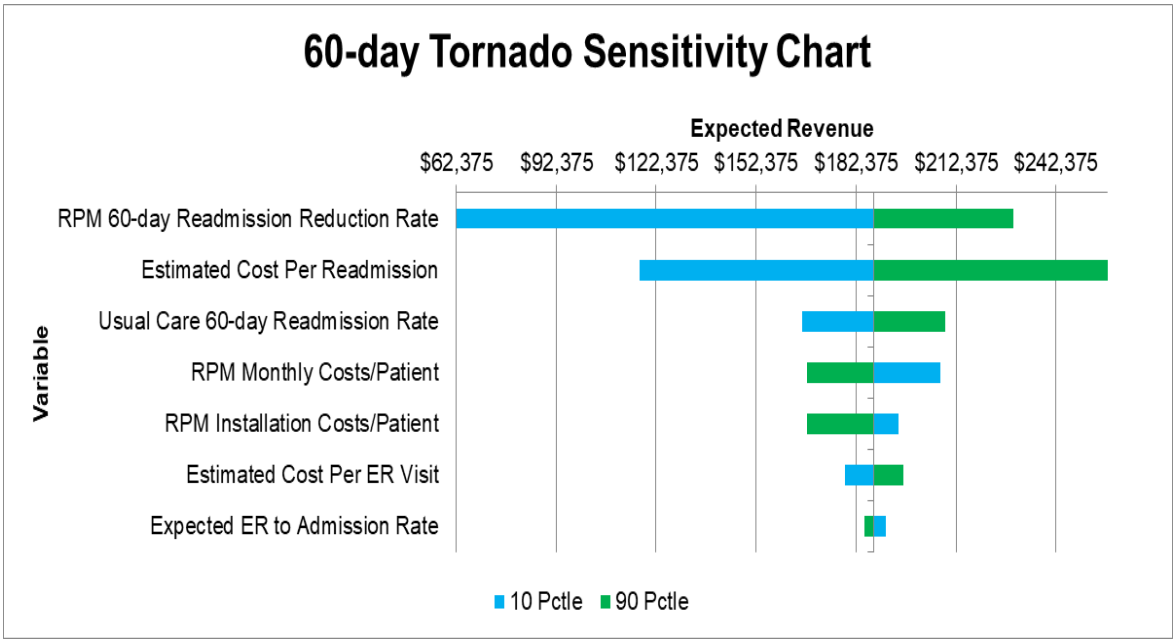

Figure 2 – Deterministic sensitivity analysis for 60-day RPM scenario. The length of the bars for each variable corresponds to the relative importance of that variable on expected revenue. The 10th and 90th percentile values can be viewed in Table 1.

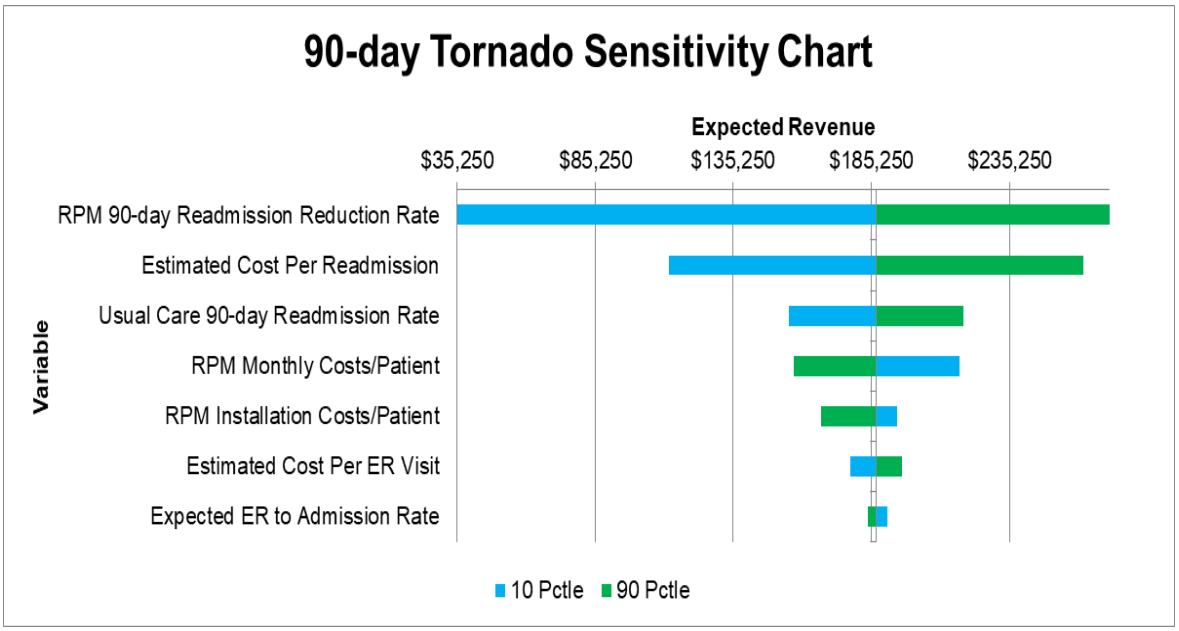

Figure 3 – Deterministic sensitivity analysis for 90-day RPM scenario. The length of the bars for each variable corresponds to the relative importance of that variable on expected revenue. The 10th and 90th percentile values can be viewed in Table 1.

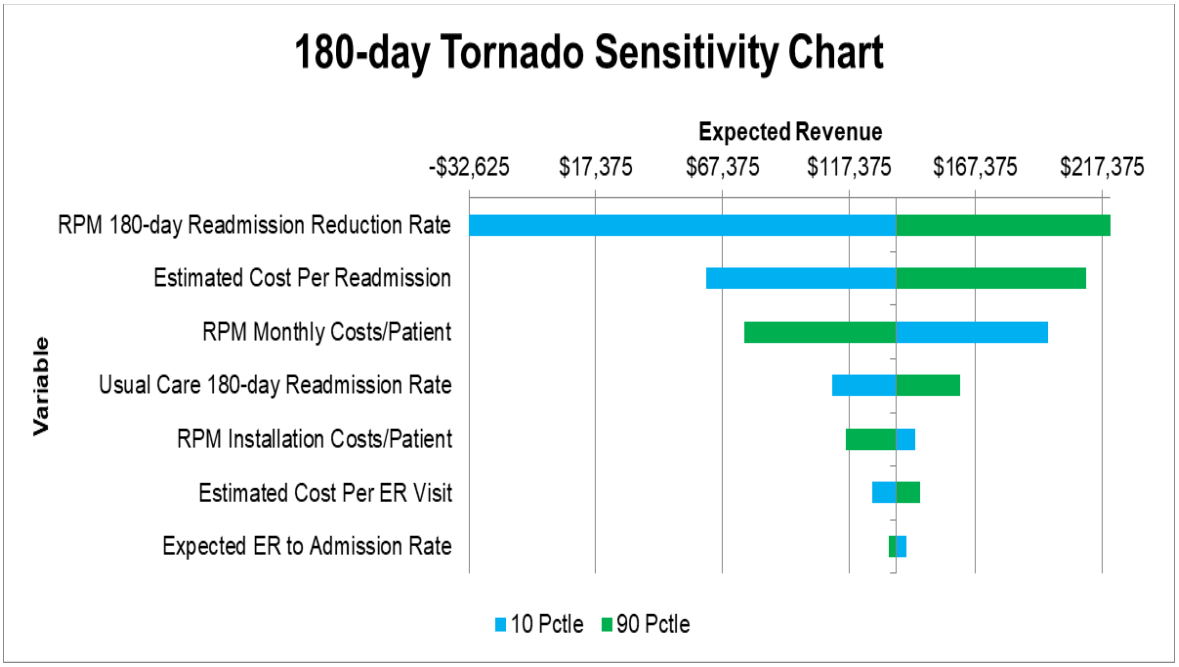

Figure 4 – Deterministic sensitivity analysis for 180-day RPM scenario. The length of the bars for each variable corresponds to the relative importance of that variable on expected revenue. The 10th and 90th percentile values can be viewed in Table 1.

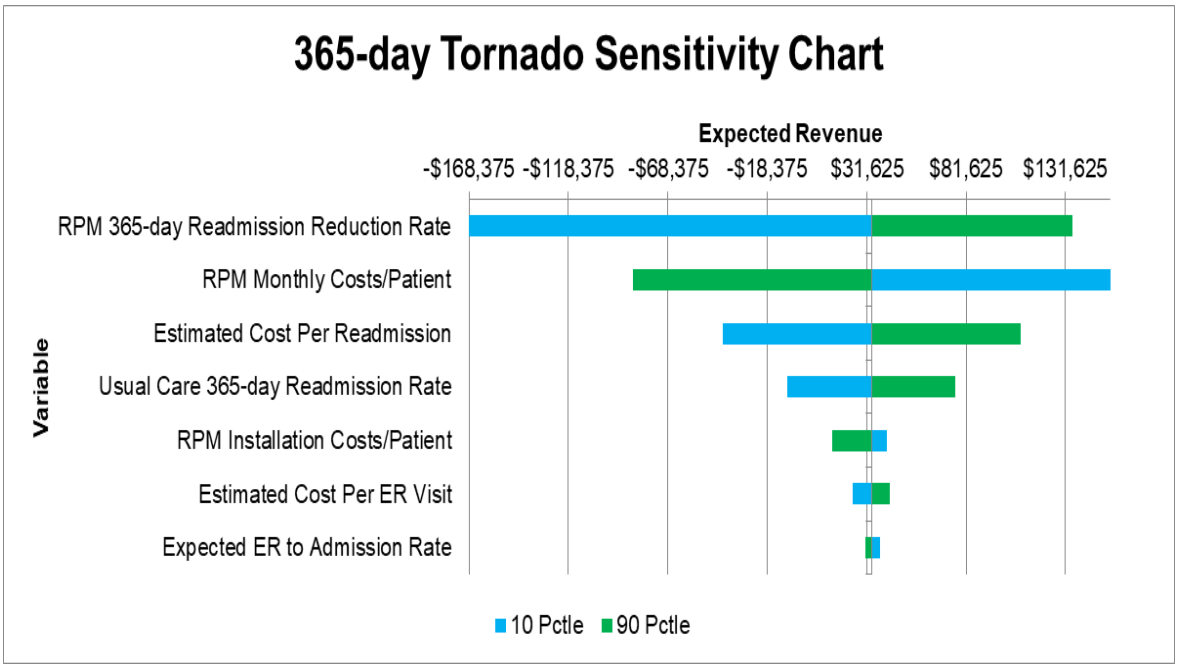

Figure 5 – Deterministic sensitivity analysis for 365-day RPM scenario. The length of the bars for each variable corresponds to the relative importance of that variable on expected revenue. The 10th and 90th percentile values can be viewed in Table 1.

The final step for this CBA analysis was to conduct a two-way sensitivity analysis for each scenario using the 10th and 90th percentile values. A two-way sensitivity analysis is performed by varying the value of two variables away from their baseline values at the same time and determining the effects on the outcome of interest. When conducting a two-way sensitivity analysis all the other variables are kept at their baseline value(s).

The two-way sensitivity analysis for the 30-day RPM strategy shows that an RPM program is expected to generate revenues across the anticipated range of readmission costs if the RPM can achieve at least a 15% reduction in readmissions as compared to usual care (Figure 6).

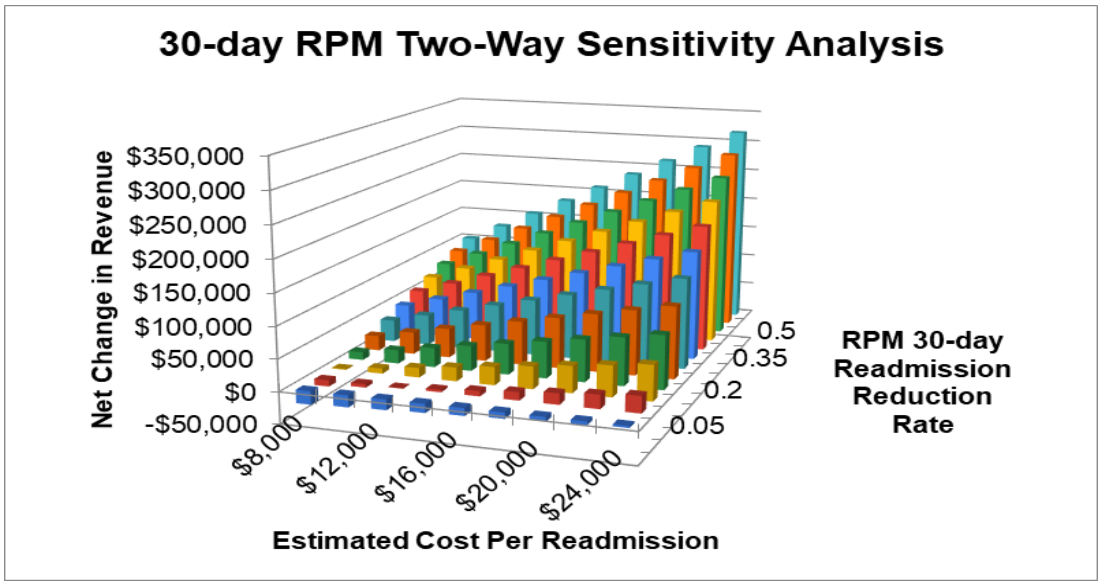

Figure 6 – 30-day two-way sensitivity analysis results. Net Change in Revenue figures are based on 100 patients input into the CBA tool.

When considering both a 60-day and 90-day RPM scenario (Figures 7 and 8), a 15% reduction in readmissions resulted in a profit except for the lowest considered average readmission cost of $8,000.

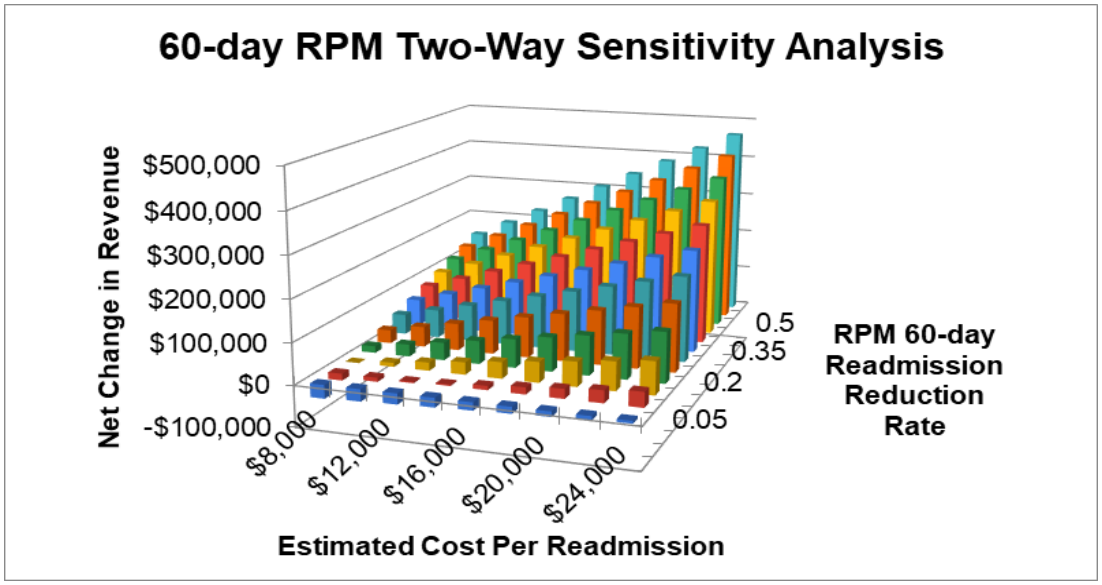

Figure 7 – The 60-day two-way sensitivity analysis results. Net Change in Revenue figures are based on 100 patients input into the CBA tool.

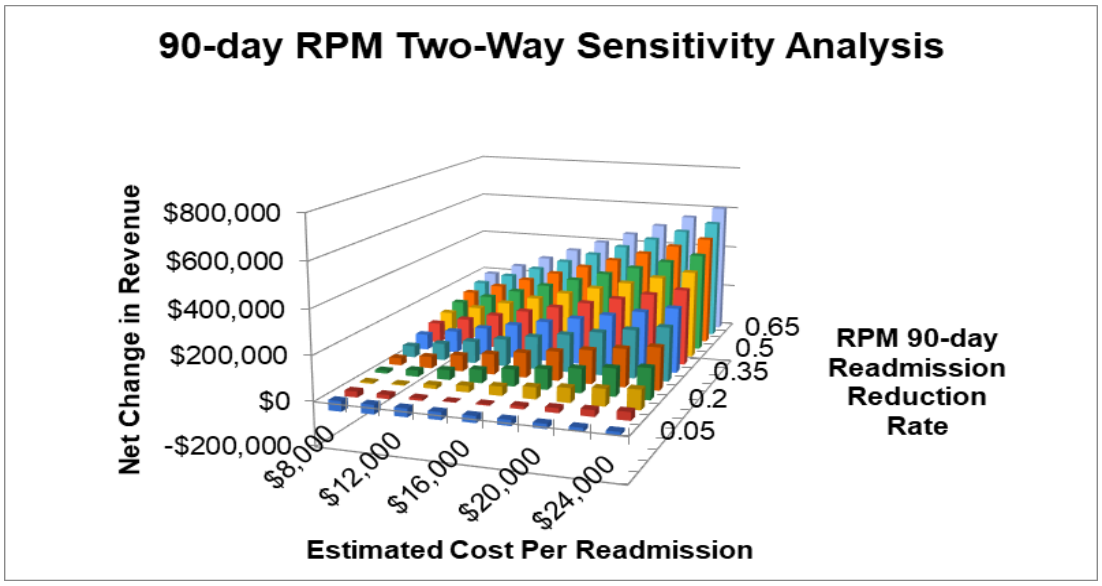

Figure 8 – The 90-day two-way sensitivity analysis results. Net Change in Revenue figures are based on 100 patients input into the CBA tool.

The 180-day sensitivity analysis (Figure 9) was notable for the program only becoming profitable across all readmission costs if the RPM program was able to reduce admits by 25% compared to usual care.

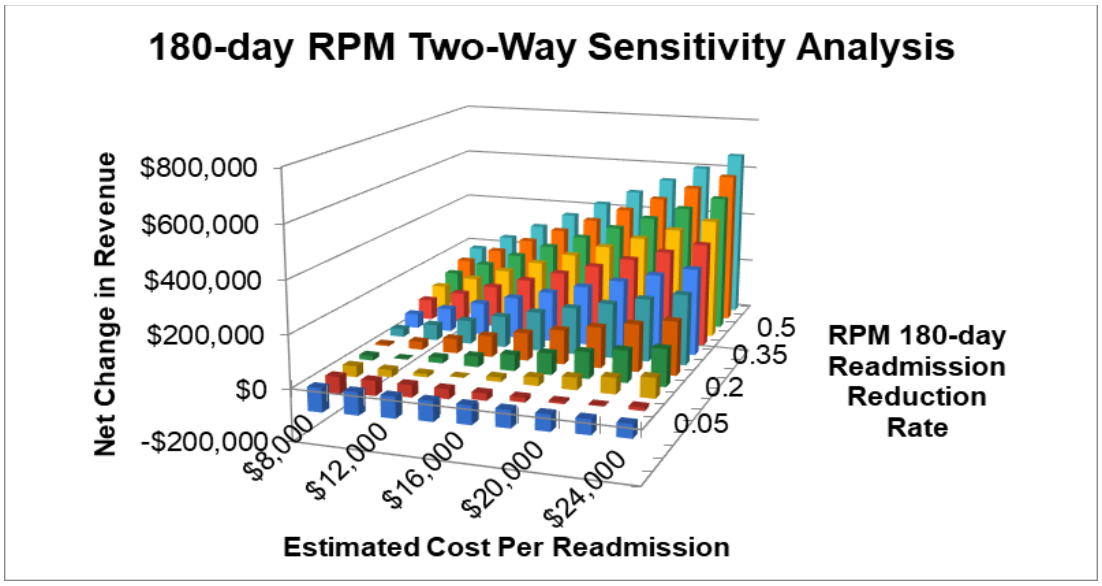

Figure 9 – The 180-day two-way sensitivity analysis results. Net Change in Revenue figures are based on 100 patients input into the CBA tool.

Based on the previously conducted deterministic sensitivity analysis, the 365-day two-way sensitivity analysis was conducted with the estimated cost of readmission and the estimated RPM monthly costs per patient as the two most important variables. This sensitivity analysis showed that an organization would need to achieve a 40% reduction in readmissions to be profitable across all considered average readmission costs or at least a 25% reduction in readmissions when inputting the default average readmission cost of $15,000 (see Figure 10).

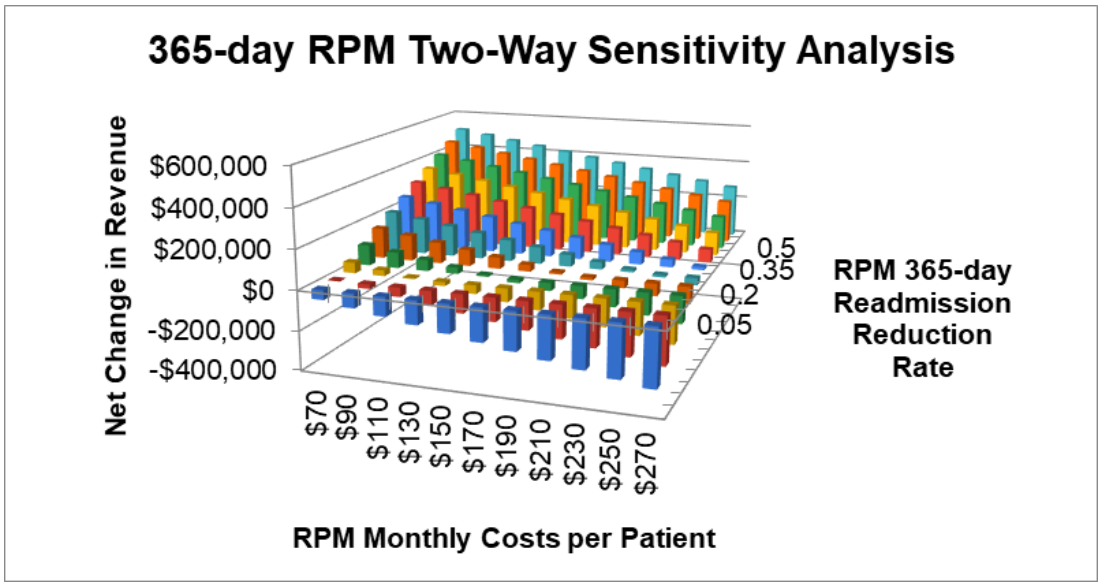

Figure 10 – The 365-day two-way sensitivity analysis results. Net Change in Revenue figures are based on 100 patients input into the CBA tool.

All the outputs and associated graphs from the deterministic sensitivity analysis and the two-way sensitivity analysis for the CBA model are included in the Excel file under the "Tornado Charts Baseline Values" and "Two Way Sensitivity Results" tabs, respectively.

Discussion

Based on cost estimates from published literature, implementation of an RPM program for CHF patients is projected to be economically beneficial for a healthcare organization. However, socio-technical considerations and the resources and methods used to deploy an RPM program are also important. A critical step in launching a new RPM program is to determine the details of implementation, as the implementation decisions will have a tremendous impact on both the financial and clinical success of such a program.

RPM Implementation Details

A 2015 systematic review reported the results of a post-hoc analysis and compared implementation details of 97 CHF RPM programs and summarized findings for four RPM subtypes: automated device telemonitoring, video check-ins, interactive voice response, and web-based telemonitoring.[24] The only subtype that had statistically significant reductions in CHF hospitalizations was the automated-device telemonitoring group (relative risk: 0.77; 95% CI: 0.64 – 0.91, $p = 0.003$).[24] This subtype consisted of either automatic uploads of vitals or vitals with symptom questionnaires to web-based platforms.[24] The authors identified 5 RCT's with this subtype and determined there was no statistical difference between those automatically transmitting vitals alone or those transmitting vitals with symptoms.[24]

Subtypes that did not show a reduction in hospitalization compared to usual care include video consultation (which consisted of scheduled video check-ins with or without vital sign transmission), interactive voice response (the patient entered in vitals or symptom information via phone keypad with prompts from an automated questionnaire), and web-

based telemonitoring (the patient had to log-in to a secure website and manually enter vitals or answers symptom questionnaires).[24]

A meta-analysis, found that patients in a "tele-transmission" program (which consisted of the ability to send vitals electronically) had statistically significant improvements in all-cause mortality, CHF-related mortality, and CHF-related length of stay, while those in a "telephone supported group" (which consisted of scheduled phone check-ins by clinical staff) had no statistical improvements in these outcomes.[9] However, both groups had significant reductions in CHF-related admissions, compared to usual care, that were similar between the "tele-transmission" group (OR = 0.61, 95% CI 0.42 to 0.88, p = 0.008) and the "telephone supported" group (OR = 0.64, 95% CI 0.52 to 0.79, p < 0.001).[9]

Healthcare organizations must also be strategic in choosing the patient population that will be targeted in an RPM intervention. A cost-effectiveness study of multiple RPM strategies found that the greatest cost savings were achieved when RPM was utilized after hospitalization in a population of patients with "New York Heart Association" (NYHA) class II-IV heart failure.[25] This strategy resulted in an estimated incremental cost-effectiveness ratio (ICER) of $38,262 per quality-adjusted life year (QALY) gained and was given a 76.3% probability of being cost-effective at the typical threshold of an ICER of less than $50,000 per QALY gained.[25]

A prerequisite for use of a CBA tool is defining a clear strategy for which subset of patients will receive an RPM intervention. Indiscriminate use of RPM may have adverse financial outcomes for the organization as demonstrated by an economic modeling study

that determined applying an RPM solution to a low-risk cohort without any prior admission history would result in a healthcare cost increase of about $2,500 per person per year with only 0.01 QALY gained.[17]

Current studies reveal variation in the frequency of patient use of RPM tools in the home setting, suggesting this is an important topic for additional study. A CHF RPM study found that 42/58 (83%) of patients used the provided equipment at least once during the first week, but usage fell dramatically to 23/58 (46%) by the fourth week.[10] Another CHF RPM study defined adherence as the percent of patients who transferred data on a minimum of 70% of days and reported an overall adherence rate of 81% over 12 to 28 months.[26] Similarly, a study of use of RPM among patients with multiple chronic conditions asked participants if they would continue to use the RPM system if it was left in their house after study completion, and over 80% responded affirmatively.[12] The wide range of compliance across studies suggests that differences in the specifics of an RPM program, ease of use, and the presence or absence of patient coaching are important factors related to patient compliance.

Technical Considerations for RPM Implementation

While there is evidence that an RPM program consisting of manual entry of patient data combined with phone calls from a clinician can result in decreased CHF readmissions, this section will briefly review technical details for RPM programs designed to automatically upload data, relieving patients of this burden. There are numerous possible configurations for RPM systems and an extensive review of options is beyond the scope of this paper. However, this section will detail key decision points and commonly used

hardware and software in RPM programs that support automated data collection from the patient home environment.

A major decision point in an RPM program is determining whether patient data will flow into the healthcare system's electronic health record (EHR), or if the data will instead flow to a web-based portal. Having data flow directly into an EHR is likely to result in less disruption to healthcare provider's workflows, and by extension is expected to have a higher acceptability than solutions that require a healthcare provider to login to a separate portal. However, as will later be explained, integrating data into an EHR may result in additional steps compared to uploading data to a separate web-based portal.

Regardless of the destination of patient data, most remote patient monitoring solutions will use hardware that has Bluetooth enabled capability for data transmission.[27] The data transmission from the device, or wearable, can be broken down into a two-step process. Step one consists of the short range communication protocol, such as Bluetooth, transmitting the data from the scale to the nearest gateway node.[27] Common examples of gateway nodes include a smartphone, tablet, or computer.[27] It is worth noting that there are numerous other standards, besides Bluetooth, that can be used for this purpose. Some other short range communication protocol examples include ZigBee, ANT, Radio Frequency Identification (RFID), and Wireless Fidelity (Wi-Fi).[27] Each healthcare organization will need to decide on their communication protocol based on their organization's policies and procedures, and possibly preferences of their technical team.

In the second step, the gateway node is responsible for the long-range transmission of data to a distant server associated with the healthcare organization.[27] Before the data is

transmitted it is possible that the gateway node will conduct some form of advanced data processing or display of the data as well.[27]

This long-range communication stage can occur over either an internet or cellular communication network.[27] Regardless of channel, use of a secured communication channel with strong encryption and authentication technology is imperative when exchanging personal medical data.[27] A discussion of encryption details is beyond the scope of this paper, but the authors of a detailed technology review on this subject recommend using techniques such as Public Key Infrastructure (PKI) or Secure Sockets Layer (SSL) for enhanced security of data transmission.[27]

When choosing a device for remote monitoring it is advisable to choose one that conforms to the Institute of Electrical and Electronics Engineers (IEEE) medical device standards.[28] IEEE 11073 device standards have various specifications for different types of sensors but the main purpose is "an openly defined, independent standard for converting the information profile of personal health devices into an interoperable transmission format so the information can be exchanged to and from personal telehealth devices and compute engines."[29]

A 2018 study described the basic setup required for automatic transfer of patient generated data from various wearables and devices, such as weight scale, to a secure physician web-portal.[28] In this study the authors used the ZigBee communication protocol and IEEE 11073 devices as the basis for remote monitoring.[28] Raw data collected by the wearables or devices were automatically transmitted via the ZigBee short-range communication protocol to a simple gateway, which did not require any patient

involvement other than plugging it into a power source.[28] Data were then sent from the gateway to a clinical server located in a secure data center via a secure private mobile network.[28]

While technical specifications will depend on the capabilities of an organization's EHR and devices used for monitoring, RPM programs that transmit patient data automatically into an EHR generally require more complex planning and implementation than programs that send data to a separate web portal. One potential solution is to use 3rd party services called "middleware" that collect, analyze, and process data from devices via their proprietary Application Programming Interfaces (APIs) and provides this data in a standardized format that is readable by an EHR.[30] A 2020 review article named current popular examples of middleware, such as, Shimmer, Tidepool, and Glooko.[30]

Examples of Integrating RPM Data Directly into an EHR

It is also possible for healthcare organizations to create their own application (app) that has the capability to share data automatically to the EHR. A 2018 study from Icahn School of Medicine at Mount Sinai developed an app that could submit data into their organization's Epic EHR via a Bluetooth equipped peak flow meter.[10] While this study automatically uploaded data for asthma patients, the same concepts would apply to uploading CHF patient data.

The basic steps involved the patient downloading and enrolling in both the researcher's developed "Asthma Health" app and also the Epic "MyChart" patient portal app.[10] The patient then needed to enable sharing between the "Asthma Health" and "MyChart" apps via their iPhone's "Health" app.[10] After these steps were completed the data from the

"Asthma Health" app could pass to the "MyChart" patient app.[10] Any patient generated health data was then transferred and stored in the patient's individual Epic chart, and periodic summaries and notifications for abnormal results were sent to providers directly via their Epic views.[10] All of the data transfers in this study were based off of the "Fast Healthcare Interoperability Resources" (FHIR) standards.[10] It is important to note that even with this setup the providers still needed to place an order in Epic for this data pull to complete.[10]

Another example of patient collected data integration into an EHR comes from a 2016 study conducted at Stanford's Children Hospital located in Palo Alto, CA.[31] This study enrolled 10 pediatric patients with insulin dependent diabetes and integrated the glucose readings obtained from a commercially available continuous glucose monitor, Dexcom, directly into the Epic EHR.[31] The basic flow of data was that the Dexcom implantable device would collect glucose levels and then upload the results to the "Dexcom Share2" app (available for iPhone).[31] After a Federal Drug Administration (FDA) mandated three hour delay, the data would then be transferred to the iPhone's native "Health Kit" app.[31] The data would then passively flow into the Epic "MyChart" app only after the patient had downloaded this app and activated it and after the patient's healthcare provider placed an order in Epic to generated a data pull request.[31]

Another feature of note from this study is that the researchers also created a custom web-service embedded in the Epic EHR to create visualizations for the glucose readings that were obtained by this automatic monitoring setup.[31] A discussion of such a "sidecar" application is beyond the scope of this paper, but it is an interesting concept that healthcare organizations may want to consider to display effective visualizations to the

providers that will be interpreting and acting on the patient collected data from an RPM program.

Socio-Technical Implications of RPM Programs

Because an RPM program can be considered a complex health information technology (HIT) solution, it is valuable to review some recommendations from Sittig and Singh's seminal article proposing an 8-dimensional model to assist with the design, implementation, use, and evaluation of such solutions.[32] Before reviewing each dimension in detail it is helpful to understand that this model moves from purely technical considerations into the human-computer interaction and then into progressively larger and complex human systems factors such as workflows and communications and systems considerations.

Also, although it is practical to delve separately into each aspect of the model, it is important to note that the authors themselves state, "A major assumption of our model is that the 8 dimensions cannot be viewed as a series of independent, sequential steps. As with other components of complex adaptive systems, these 8 interacting dimensions must be studied in relationship to each other."[32] With this caveat in mind, each of the eight dimensions will be briefly reviewed and related to the design and deployment of a CHF RPM project.

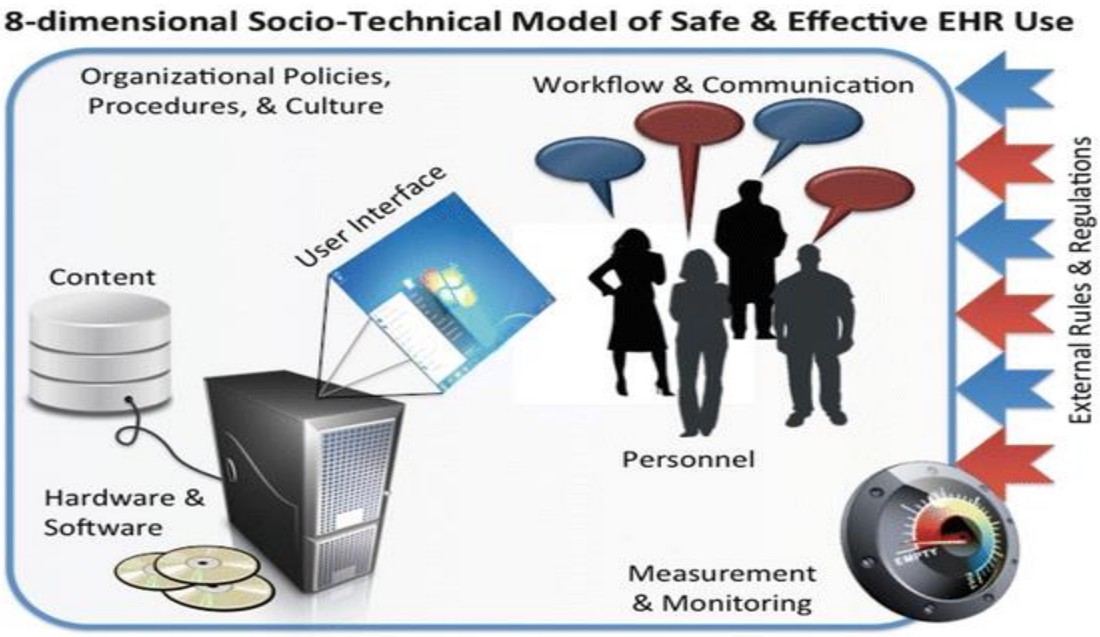

Figure 11 - Socio-Technical Model for Health Information Technology Projects[33]

1. Hardware and Software Computing Infrastructure

The hardware and software computing infrastructure dimension focuses on the hardware, software, and ancillary features such as power supplies that are required to run the HIT application.[32] It also includes all the data storage devices and networking equipment that is needed to both retrieve and store patient data.[32]

As covered above the basic hardware for a CHF RPM program would include at a minimum a weight scale that is Bluetooth, or other short-range communication standard, enabled. Hardware would also include the computers used by the healthcare system providers to receive and monitor the patient generated data. Basic software technical specifications have been covered in the above section and would vary based on both the type of data collected, and on if this data is routed to a secure web-based server or directly into the healthcare system's EHR.

2. Clinical Content

This dimension includes everything on the "data-information-knowledge spectrum" that will be stored on the system.[32] Representative examples of data include structured or unstructured text, images, or material scanned into the system. Information can include anything from patient demographics to descriptions of the patient status, such as physician or nursing notes. An example of a component of knowledge would be clinical decision support tools.

For most CHF RPM programs, the data focus will be on vital signs, primarily weight, and so any system will need capability to collect, store, and transmit such data. It is also possible to design an RPM program to collect patient symptom reports or scores, and if this is part of the RPM program, the designers will need to decide if patient symptoms will be stored in the form of structured or unstructured data. Information will consist of specific patient demographics and knowledge could include clinically meaningful trends in symptoms or weights that suggest a higher readmission risk.

3. Human Computer Interface

The combination of specific hardware and software come together to create a unique human computer interface (HCI) which includes aspects of the systems that the users can see, touch, or hear.[32] The HCI design typically starts with pilot testing a model created by the software designer and developer in the clinical environment.[32] The initial HCI design is likely to result in changes to the user's pre-existing workflows which leads to an iterative process of design and workflow refinement until finding an optimal HCI for the targeted task.[32]

Most CHF RPM programs should be able to use a simple Bluetooth enabled scale for patient users and ideally have the data flow into the provider's already existing EHR. Some design considerations for the elderly CHF patient population include ensuring that the scale is stable to prevent falls, has a large enough display for easy visualization, and has prolonged battery life. If the RPM program will also include the collection of patient symptoms, then this may also require a separate HCI design if the symptoms will be collected via a computer, tablet, or smartphone device. HCI design will also be important in the development of data displays or dashboards that the healthcare team will use to monitor and track patient generated data.

4. People

This dimension represents the people involved in all aspects of design, development, implementation, and use of the HIT solution.[32] The healthcare organization implementing the solution needs to ensure they have staff with the appropriate technical knowledge and skills to create a system that is safe, reliable, and protects patient data. The front line clinicians that will be viewing and acting on the RPM generated patient data should be involved in the planning and deployment of the RPM program and data display design.

The patients enrolled in the RPM program also fall under this category as they will at a minimum be interacting with a digital scale. Therefore, any solution needs to be designed to be simple to use for elderly CHF patients. As previously mentioned, multiple studies have shown a wide range of variability in patient compliance when enrolled in a CHF RPM program.[4,10,12,26] Any healthcare organization implementing such a program will need to remember that the patient population they are monitoring is an important

component of the people dimension and that their needs and preferences should be actively sought out to increase satisfaction and compliance with the program.

Indeed, many real-world successful RPM programs had a heavy reliance on human interaction. For example, the Flagstaff Medical Center had nurses call patients to record data on weight, blood pressure, and pulse oximetry but also conducted anywhere from 1 to 5 home visits per week, depending on patient acuity.[11] Geisinger Healthcare used a Bluetooth enabled scale to automatically upload patient weights into their EHR, but still had nurses call patients weekly to quarterly depending on patient acuity.[11] Sharp Healthcare had nurses conduct a 1.5 hour home visit upon delivery of the RPM scale and had nurses call the patient routinely during the RPM program based on their progress.[11]

The examples given above demonstrate the importance of the human dimension even when using a technology-focused solution like RPM. They also illustrate how healthcare is a complex adaptive system and how any change in one dimension can affect another dimension, in this case how changes to the people dimension may affect workflow and communication. Furthermore, the case examples given above illustrate how there is often overlap between different dimensions.

5. Workflow and Communication

The workflow and communication dimension focuses on work processes and aspects of social interaction.[32] This dimension accounts for all the adaptations in workflow and two-way communication that are needed to make sure each patient gets the appropriate care.[32] Also, this dimension acknowledges that often the HIT system does not match the clinical

workflows among a healthcare team and often leads to the need to either alter the HIT system or the existing clinical workflows.[32]

This may be one of the most important dimensions to consider prior to implementing a CHF RPM program. As discussed throughout this paper, there are numerous ways to structure a CHF RPM program, and each option will have varying effects on workflows and communications. Ultimately, any RPM program should have the goal of improved patient care without creating more work or less efficient communication for the healthcare team. It may be best to consider solutions that automatically monitor incoming patient data and generate alerts targeted to the appropriate clinical team member(s). Embedding RPM generated data directly into the EHR would also be expected to improve care coordination and communication of results. Workflows and communication protocols will also need to be put in place to deal with abnormal, concerning, or potentially erroneous remote monitoring data.

6. Internal Organizational Policies, Procedures, and Culture

This dimension specifies that any HIT solution will need to conform to any pre-existing organization policies and procedures.[32] Also, the organization's capital budget will determine what options are available when purchasing hardware, software, and data storage solutions.[32] The internal culture of an organization, specifically the support and enthusiasm, or lack thereof, of senior leaders towards informatics solutions will play a major role in the ultimate success of any HIT initiatives.

Organizational policies and procedures may dictate design decisions for a CHF RPM program such as which type of communication standard to use and if data will flow

directly into the EHR or to a secure web portal. It is worth reiterating that an organizational culture where executives enthusiastically champion HIT initiatives will be more likely to succeed than at organizations with a culture where technical solutions are not valued.

7. External Rules, Regulations, and Pressures

This dimension describes how any HIT solution must conform to applicable state or federal rules and regulations.[32] The exact implications for an individual CHF RPM program will vary based on location and the exact type of RPM enacted. One well known regulation that will apply to all RPM programs includes the Health Insurance Portability and Accountability Act (HIPAA). Any organization that has an RPM program in place will need to stay abreast with any CMS regulatory or payment changes related to such programs.

8. System Measurement and Monitoring

The system measurement and monitoring dimension strongly recommends that the effects of any HIT intervention need to be measured and monitored on a regular basis.[32] The authors advise four main measures to include: availability of the system, how the features are being used by clinicians, the effectiveness of achieving anticipated outcomes, and any unintended consequences of the HIT intervention.[32]

Taking each of the four main issues in turn, the question of availability would mean that an organization should track the percentage of successful transfers of patient data. To measure how the features are being used by clinicians an organization may want to

monitor the percentage of times that a clinician acknowledges and appropriately reacts to an RPM generated alert. The biggest measure for effectiveness of achieving anticipated outcomes would include revenue changes to the healthcare system and patient readmission rates. It may also be valuable to measure other patient outcomes such as mortality, changes in visit type and frequency, changes to medication expenses, and possibly quality of life measures. For the category of unintended consequences a healthcare organization may want to measure provider productivity before and after implementation of the RPM program and total medical expenditures for enrolled patients to monitor for changes in provider productivity or increasing patient care costs in unexpected areas.[32]

It is important to re-emphasize that when designing a CHF RPM, the eight socio-technical dimensions should not be considered in isolation because small changes in one dimension have the potential for creating large changes in another. Indeed, the authors of this model state, "The key to our model is how the eight dimensions interact and depend on one another."[32] Ideally, healthcare organizations will use this socio-technical model while also incorporating best practices from previously successful CHF RPM programs when designing their own solution.

Top Recommendations for Successful RPM Programs

A white paper detailed eight recommendations from healthcare organizations that have created clinically and financially successful CHF RPM programs, and may be applied by other organizations when implementing a new CHF RPM program (Table 3).[11]

Eight RPM Best Practice Recommendations
1. Create exclusion criteria for RPM to maximize this limited resource
2. Balance the volume of biometrics monitored with their ease of use
3. Weigh trade-offs of creating a separate RPM data analysis role
4. Establish RPM data sharing practices with patient's physicians
5. Mitigate the need for initial home visits with in-person recruitment
6. Set flexible parameters on data upload
7. Anticipate variation in data accuracy
8. Outline program graduation principles as early as enrollment

Table 3 - Eight recommendations for successful CHF RPM Implementation

1. Create exclusion criteria for RPM to maximize limited resources

Most successful RPM programs target patients that struggle with chronic disease self-management, even if enrolled in a traditional care management program. Many organizations that successfully implemented RPM discovered that patients need some baseline physical and cognitive function to benefit from RPM. Because of this need for some level of baseline functioning many organizations will exclude patients with significant physical limitations, cognitive impairments, or those with unmanaged behavioral health issues.

Healthcare organizations will still be responsible for preventing readmissions in this cohort of challenging patients. However, it may be best to consider alternatives to RPM for certain subsets of the patient population that may not be able to properly use or benefit from such a program.

2. Balance the volume of biometrics monitored with ease of use

As the authors of the white paper succinctly stated, “More information isn’t always better. Weight is widely viewed as the gold standard for measuring CHF symptom escalation.”[11] When designing a CHF RPM program it is advisable for the healthcare organization to have frontline clinicians work in tandem with the software engineers and data analysts to determine the optimum amount and type of data and also the frequency of data collection.

Monitoring for the smallest set of clinically relevant data that results in the objective of a significant reduction in readmissions should be a primary goal of CHF RPM design. Collecting, and presenting, too much data may overburden the clinical team with extraneous data and cause information overload or significant challenges in communicating results without any additional reductions in readmissions.

Regarding the ease of use portion of this recommendation, it is likely optimal for the clinical team to receive RPM data automatically into the EHR that is used during daily clinical workflows. Revisiting the “System Measurement and Monitoring” dimension from the socio-technical model[32], it is important to monitor for both intended and unintended consequences and use the results to iterate on the design of the RPM program in order to determine the optimal amount, type, frequency, and presentation of patient generated data.

3. Weigh trade-offs of creating a separate RPM data analysis role

It is both labor and resource intensive to have dedicated member(s) analyze incoming data. This again brings up the concept of incorporating RPM data directly into the organizations EHR and setting up a system that automatically flags any concerning trends or data points. Such a design may have higher upfront costs and complexity to integrate the data directly into the EHR but should reduce the ongoing costs of having employees manually reviewing incoming data.

If an organization implementing an RPM is unable to create a system that automates data collection and analysis they will need to determine if they have the personnel resources to analyze the incoming data. Even if they do, it may be more cost-efficient to outsource to a third party depending on the specifics of the RPM program. There are many companies, such as mTeleHealth[18], that offer bundle prices for implementing an RPM solution and monitoring the resultant data.

4. Establish RPM data sharing practices with patient's physicians

Healthcare organizations detailed in this white paper[11] consistently describe the importance of engaging primary care physicians (PCPs) in planning and execution of a new RPM program, and sharing patient-reported data with them to help coordinate care. Some organizations sent a "biometric trend summary" to a patient's PCP before scheduled PCP visits. Whenever possible RPM data should be integrated directly into the EHR to avoid the need for double documentation and separate logins.

5. Mitigate the need for initial home visits with in-person recruitment

This recommendation is focused on having the patient connect with a human before implementing the RPM in their home. This allows for the patient to have questions answered and so that they explicitly understand that real people will be on the other end monitoring and acting on the incoming data. This recommendation fits nicely with the "Workflow and Communication" and "People" dimensions of the socio-technical model[32] and is focused on communication with the patient to ensure they understand how the RPM program will work and have any questions or concerns answered as they are enrolled. It is important for healthcare organizations to ensure there is a human connection and level of understanding before trying to solve the complex problem of readmissions with a purely technical solution.

6. Set flexible parameters on data upload

It is advisable to allow for intermittent data uploads for those that are unable to perform daily data uploads, either due to living conditions or poor access to Wi-Fi or cellular service. Healthcare organizations still noticed benefits to RPM for CHF even if they were only getting weights 3 to 5 times per week instead of daily.[11] This is another consideration that can fall under the "System Measurement and Monitoring" dimension of the socio-technical model.[32] With measurement it may be possible to determine both a minimum and optimal frequency of data upload for a specific RPM program.

7. Anticipate variation in data accuracy

One concrete solution the authors recommended was to allow for adjustable alert ranges to ameliorate the risk of alert fatigue. This recommendation ties into three dimensions of the socio-technical model: “Hardware and Software Computing Infrastructure”, “People”, and “Workflow and Communication”.[32]

The hardware and software considerations are mostly related to ensuring that the healthcare organizations use digital weight scales that are as accurate as possible and can self-calibrate as needed. The people dimension means that clinicians, either PCPs or Cardiologists, should be able to adjust each patient’s alert range based on their clinical judgement. Some patients may be at risk of readmission with as little as a 1 to 2 pound weight gain, whereas others may tolerate higher fluctuations in weight without increased risk of readmission.

Any unexpected variances in incoming data will need to have workflow and communication considerations such as determining the optimum process to validate an unexpected data point. There are many options that are available such as, sending a nurse to the house for a manual weight check, having a nurse place a phone call, having a nurse or physician conduct a video visit, etc. The important point is that workflows and communication processes will need to be in place to address unexpected and potentially erroneous data.

8. Outline program graduation principles as early as enrollment

It is important to clearly communicate the goals of an RPM program with the patient before enrollment. Explicitly identifying the time frame of monitoring, the clinical targets a patient must achieve before "graduating" from RPM helps establish the expectation that a RPM is a temporary intervention.[11]

Limitations

The primary limitation of this paper is that the values for the CBA model are based on available published data. Any organization that uses this CBA tool should input their organization's healthcare data whenever feasible. The CBA model is not exhaustive in that it does not account for other possible costs related to CHF such as transportation, home or clinic visit costs, and medication costs that may be impacted by an RPM program. Furthermore, if investment in an RPM program is competing against other potential projects, an organization may want to compare alternatives with a common financial metric such as an internal rate of return (IRR) or another similar financial marker. The CBA tool is not currently constructed to calculate IRR or present value. However, this tool can be amended to add such features if desired.

RPM is not the only intervention that may support hospital readmission among CHF patients. Analysis of alternatives to RPM is beyond the scope of this paper. However, a CHF disease management program is an example alternative that is associated with a lower relative admission rate compared to usual care ($p = 0.03$).[34] Before investing in an RPM program it would be prudent for healthcare organizations to assess their own capabilities and the relative expected costs and benefits of alternate treatment options.

Summary and Conclusions

Both VBP and FFS organizations are under pressure to reduce healthcare costs, and particularly costs associated with patient hospitalization. RPM programs are effective in reducing costly CHF readmissions, but positive return on investment for an individual healthcare delivery organization cannot be assumed. The interactive CBA tool provided as a complement to this paper is designed for use by healthcare organizations who can input organization specific data into this tool to conduct a CBA prior to investing in an RPM program. A CBA analysis can evaluate the financial impact of an RPM program to prevent CHF patient readmissions. This paper also provides a review of general technical specifications and reviews the socio-technical framework and best practices to consider using when implementing an RPM program.

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