Economic Analysis of the Smart Program; A Remote Patient Monitoring Intervention for Patients with Chronic Obstructive Pulmonary Disease and Chronic Heart Failure

Wanrudee Isaranuwatchai¹,², PhD
Olwen Redwood³, BScN
Adrian Schauer⁴, MASc
Tim Van Meer⁴, HBBA
Jonathan Vallee⁴, MSc
Patrick Clifford⁵, MSW, RSW

¹St. Michael’s Hospital, Toronto, Ontario, Canada
² Institute of Health Policy, Management and Evaluation, University of Toronto, Toronto, Ontario, Canada
³ Canadian Back Institute, Toronto, Ontario, Canada
⁴ AlayaCare, Toronto, Ontario, Canada
⁵ Southlake Regional Health Centre, Newmarket, Ontario, Canada

Corresponding author
Wanrudee Isaranuwatchai, PhD
Director - Centre for Excellence in Economic Analysis Research (CLEAR)
The HUB | Li Ka Shing Knowledge Institute | St. Michael’s Hospital
Assistant Professor - Institute of Health Policy, Management and Evaluation | University of Toronto
T: 416-864-6060 ext. 77074; F: 416-864-5978
E: IsaranuwatcW@smh.ca
Economic analysis of the Smart RPM program

Abstract

Background
Exacerbations of chronic obstructive pulmonary disease (COPD) and chronic heart failure (CHF) are associated with high health care costs due to increased emergency room (ER) visits and hospitalizations. Remote patient monitoring (RPM) interventions aim to improve monitoring of symptoms to detect early deterioration and provide self-management strategies. As a result, RPM aims to reduce health resource utilization. Studies have inconsistently reported the benefits of RPM in chronic illnesses. The Smart Program is a RPM intervention that aims to provide clinical benefit to patients and economic benefit to health care payers.

Objective
This study aims to describe the study population and economically evaluate the potential benefits of the Smart Program in terms of hospitalizations and ER visits, and thus associated health care costs from the perspective of public healthcare system.

Methods
Seventy-four patients with a diagnosis of COPD or CHF from one hospital site were included in this one-group pre-post study. The study involved a secondary data analysis of de-identified data collected during the study period (from three months before program initiation (baseline), during the program, to three months after program completion (follow up)). Descriptive analysis was conducted for the study population characteristics at baseline, the clinical frailty score at baseline and 3-month follow up, client satisfaction at 3-month follow up, and number and costs of ER visits and hospitalizations throughout the study period. Additionally, the cost of the Smart Program over a 3-month period was calculated from the perspective of the Local Health Integration Network (LHIN) (the potential funder).

Results
The baseline characteristics of the study population (n = 74) showed that majority of the patients had COPD (68%), were female (57%), and had an average age of 72 years (± 12). Using the Wilcoxon signed-rank test, the number of ER visits and hospitalizations including their associated costs were significantly reduced between baseline and 3-month follow up (P < .001). The intervention showed a potential 68% and 35% reduction in ER visits and hospitalizations respectively between the 3-month pre- and 3-month post-intervention period. The average cost of ER visits reduced from $243 at baseline to $67 during the follow up, and for hospitalizations, reduced from $3,842 to $1,399.

Conclusions
In this study, the number and cost of ER visits and hospitalizations appeared to be significantly reduced for patients with COPD or CHF when comparing data before and after the Smart Program implementation. Recognizing the limitations of the one-group pre-post study design, RPM requires up-front investment but it has potential to reduce health care costs to the system.
over time. This study represents another piece of evidence to support the potential value of RPM among patients with COPD or CHF.

**Keywords:** Remote patient monitoring; emergency department visits; hospitalizations; economic analysis; health service utilization; chronic obstructive pulmonary disease; chronic heart failure; costs.
Introduction

Chronic obstructive pulmonary disease (COPD) and chronic heart failure (CHF) are associated with high burden (i.e., high health care cost) to the system [1, 2]. The cost of one hospital stay for COPD and CHF was estimated to be $6,038 and $6,222, respectively [3]. Therefore, innovative interventions aimed to reduce the burden to our system (e.g., reduce hospitalization) would be beneficial. An example of such interventions is remote patient monitoring (RPM) which aims to provide the “appropriate care at the appropriate time and place in the most appropriate manner” [1], focusing on better disease management [4, 5].

There has been an increasing amount of literature on the potential value of RPM for patients with COPD and/or CHF; however, literature has shown both supportive and opposing evidence for RPM [1, 6, 7]. For example, RPM has been shown to reduce health service utilization and costs (e.g., hospitalization and emergency room (ER) visits) among patients with CHF [2, 8-12], whereas other studies did not find similar findings [6, 7, 13, 14]. Furthermore, some studies reported inconclusive findings [15-17]. Among COPD patients, evidence was also inconclusive where RPM was found to be an economically attractive option in some studies but not in others [6, 18-23]. A number of studies also reported the need for more research [24, 25].

The objective of the study was to build on and contribute to the current literature by showing a potential value of RPM. Understanding the impact of a health intervention on cost of hospitalization and ER visits may increase understanding regarding how the intervention will affect the health care system.

The question of interest was “What was the cost of hospitalization and emergency room visits of patients receiving remote patient monitoring over the study period among patients diagnosed with chronic obstructive pulmonary disease or chronic health failure?” Specifically, based on this one-group pre-post study design, we aimed to: 1) describe the study population; and 2) report the use and cost of ER visits and hospitalizations over the study period (from three months before program initiation (baseline) to three months after program completion (follow up)) from the perspective of a public healthcare system in Ontario, Canada.

Methods

This study received a research ethic approval from Southlake Regional Health Centre and St. Michael’s Hospital.

Study population and setting

The study population was 74 patients diagnosed with COPD or CHF in one hospital site. Inclusion criteria included: being 18 years of age or older; having a diagnosis of either COPD or CHF for a minimum of 6 months; ability to communicate in English; and being cognitively
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capable to give consent. Patients who were unable to provide consent or had a life expectancy of less than six months were excluded from the study.

**Intervention**

The Smart Program, a type of RPM, was the intervention under study. The RPM is a form of health care that allows patients to use medical devices in the comfort of their home to perform routine tests and send results automatically to their home health care professional. This digital software aims to improve the management of patients’ chronic illness through multisource self-management techniques including patient self-identification of symptoms and problem solving strategies that will result in stabilization of their illness status.

**Data collection and management**

Data were collected by nurses at the point of care via the AlayaCare mobile application or by patients themselves via the AlayaCare RPM application and was stored in AlayaCare’s secure cloud application. Data were collected at three time points: 1) baseline (within three months before program initiation); 2) during the program; and 3) follow up (at three months after program completion). The de-identified patient-level data was transferred to the research team using encryption and secure internet transmission, and used for the economic analysis.

**Variables**

The economic analysis conducted in this study was a secondary data analysis that employed de-identified data that were collected for the study. Specifically, we descriptively reported patients’ age, sex, medication use, regular medical follow ups, and number of patients with at least one alert for blood pressure, blood oxygen, and weight including a score from the clinical frailty scale (Table 1).

**Table 1. Definition of each level on a clinical frailty scale**

<table>
<thead>
<tr>
<th>Level</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very fit</td>
</tr>
<tr>
<td>2</td>
<td>Well</td>
</tr>
<tr>
<td>3</td>
<td>Well, with treated comorbidities</td>
</tr>
<tr>
<td>4</td>
<td>Apparently vulnerable</td>
</tr>
<tr>
<td>5</td>
<td>Mildly frail, some dependence on others for ADL(^a)</td>
</tr>
<tr>
<td>6</td>
<td>Moderately frail, help needed with instrumental ADL</td>
</tr>
<tr>
<td>7</td>
<td>Severely frail</td>
</tr>
</tbody>
</table>

Note:

\(^a\) ADL: activities of daily living

**Health service utilization and cost**

Health service utilization data were collected at three time points: 1) baseline (within three months before program initiation); 2) during the program; and 3) follow up (at three months after
program completion). The main types of health service of interest included hospitalization and ER visit, which can be expressed in monetary terms (i.e., ER visit cost and hospitalization cost). Subsequently, we converted health service utilization to health care cost using: 1) data on health service utilization from the study; and 2) standard costing sources for information on unit cost of hospitalization and ER visit. The unit cost of one ER visit was estimated to be $159 and was obtained from the Canadian Institute of Health Informatics [26]. A general cost for one hospital stay in Ontario was estimated to be $5,364 [3, 27]. All costs were reported in 2016 Canadian dollars (CAD). Costs from other years were converted to 2016 CAD using Consumer Price Index under Health Care category published by Statistics Canada [28].

Statistical analysis
Descriptive analysis on baseline variables were conducted on age, sex, medication use, regular medical follow ups, and number of patients with at least one alert for blood pressure, blood oxygen, and weight. Descriptive findings on the clinical frailty score were reported at baseline and 3-month follow up, client satisfaction at 3-month follow up, and number and costs of ER visits and hospitalizations throughout the study period. The Wilcoxon signed-rank test [29, 30] was used to compare the number and cost of ER visits and hospitalizations between baseline and 3-month follow up, recognizing that the data were from same individuals. The test focused on the difference in values for each pair of observations. The chosen statistical analysis, the Wilcoxon signed-rank test, adjusted for the non-normality of health service utilization and cost data [29, 30]. Over the study period, the patients’ health service utilization and costs were examined.

In addition, cost description of the program was conducted from the perspective of the Local Health Integration Network (LHIN), the potential funder, to report the total cost of delivering the program over a 3-month period. The costs associated with delivering the program captured in this study were personnel, and supplies and miscellaneous costs.

Results
Our study reports descriptive findings on: 1) baseline characteristics of the study population; 2) clinical frailty score at baseline and 3-month follow up; 3) client satisfaction with the intervention at 3-month follow up; 4) health service utilization that includes the number and costs of ER visits and hospitalizations at baseline, during program, and follow up; and 4) cost description of delivering the program over a 3-month period.

Seventy-four patients were enrolled in the program at baseline. However, at 3-month follow up, only 67 patients completed the data collection, as 2 people died and 5 others were lost to follow up.
The following table (Table 2) reports the baseline characteristics of the study population. The majority of the patients had COPD (n = 50/74 or 68%). The average age of the patients was 72 years (± 12), where 42 patients (57%) were female. Sixty patients (81%) were on at least 1 medication with the number of medications ranging from 1 to 26. For alerts, 29 patients (39%) had at least 1 weight alert, 68 (92%) had at least 1 blood pressure alert, and 68 (92%) had at least 1 blood oxygen alert during the program. More than 85% (n = 64/74) of patients had regular medical follow ups.

Table 2. Baseline characteristics of the study population

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)(^a) or n(^b) (%)</th>
<th>range from minimum to maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>71.6 (12.0), range 44 to 98</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>42 (57%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>32 (43%)</td>
<td></td>
</tr>
<tr>
<td>Medications</td>
<td>60 (81%)</td>
<td></td>
</tr>
<tr>
<td>Had at least 1 medication</td>
<td>60 (81%)</td>
<td></td>
</tr>
<tr>
<td>Number of medications (SD, range)</td>
<td>10.0 (5.2), range 1 to 26</td>
<td></td>
</tr>
<tr>
<td>Have regular medical follow ups</td>
<td>64 (86%)</td>
<td></td>
</tr>
<tr>
<td>Had at least 1 weight alert</td>
<td>29 (39%), range 1 to 29</td>
<td></td>
</tr>
<tr>
<td>1 alert</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>2 alerts</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3-5 alerts</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>6-10 alerts</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>10+ alerts</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Had at least 1 blood pressure alert</td>
<td>68 (92%), range 1 to 59</td>
<td></td>
</tr>
<tr>
<td>1-5 alerts</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>6-10 alerts</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>11-20 alerts</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>20+ alerts</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Had at least 1 blood oxygen alert</td>
<td>68 (92%), range 1 to 89</td>
<td></td>
</tr>
<tr>
<td>1-5 alerts</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>6-10 alerts</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>11-20 alerts</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>20+ alerts</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

Note:
\(^a\)SD: standard deviation
\(^b\)n: number of participants
Clinical frailty
At baseline, the majority of patients (n = 50/74 or 68%) reported clinical frailty score to be between 3 (well, with treated co-morbidities) and 4 (apparently vulnerable). The level 3 clinical frailty score increased from 27% (n = 20/74) at baseline to 39% (n = 26/67) at 3-month follow up (Figure 1).

**Figure 1.** Clinical frailty score at baseline and 3-month follow up

Between the two time points (baseline and follow up), the majority of patients (65%) reported same score of clinical frailty scale. Approximately 20% of patients reported improved score on the frailty scale, while 5% reported worsen score.
Satisfaction
For patient satisfaction with the Smart Program, 91% (n = 61/67) of patients responded at 3-month follow up. Almost 70% (n = 42/61) of patients strongly agreed that they felt more confident managing their signs and symptoms related to diagnosis. Ninety-seven percent (n = 59/61) recognized when they should be going to the emergency department, when they could monitor at home, or when they should go to see their physician before a flare up. Ninety percent (n = 55/61) of patients rated their satisfaction with the Smart Program as very good or excellent, whereas just over 55% (n = 35/61) rated their satisfaction with use of equipment as very good or excellent. All patients agreed (either somewhat or strongly) that the Smart Program has helped them learn more about their disease, the Smart Program has made a positive difference in their life, and that they would recommend the program to a friend or family member.

Health service utilization
For ER visits, 96% (n = 71/74) of patients had at least 1 ER visit during the 3-month period before the program started at baseline. This percentage dropped to 28% (n = 19/67) at 3 months after the program finished. At baseline, exacerbation of chronic disease accounted for the majority of hospitalizations (69% or n = 51/74)) with falls and infections being the other reasons for hospitalization.

During the program, 22% (n = 16/74) of patients had at least 1 ER visit and 9% (n = 7/74) of patients had at least 1 hospitalization. The number of ER visits and hospitalizations ranged between 0 to 4 and 0 to 3, respectively. The exacerbation of chronic disease accounted for almost 40% of ER visits, and more than 70% of hospitalizations. Other reasons included falls and infections.

The following figure (Figure 2) presents the number of ER visits over the study period. At baseline, the number of visits ranged from 0 to 5, whereas the range was from 0 to 3 at follow up. At baseline, the majority of patients had at least 1 ER visit, whereas the majority of patients had 0 visits during the program and at 3-month follow up.
Figure 2. Number of ER visits over the study period

Note: n at baseline (3 months before program) = 74, during program = 74, at 3-month follow up = 67

The flowing figure (Figure 3) presents the number of hospitalizations over the study period. At baseline, the number of hospitalizations ranged from 0 to 4, whereas the range was from 0 to 2 at follow up. At baseline, the majority of patients (57% or n = 42/74) had at least 1 hospitalization, whereas the majority of patients had 0 hospitalizations during the program and at 3-month follow up (i.e., only 22% (n = 15/67) of patients had at least 1 hospitalization).
The total number of ER visits and hospitalizations appeared to decline over time in this study population. The number of ER visits and hospitalizations were 71 and 42, respectively at baseline, and 19 and 15 respectively at 3-month follow up.
The following table (Table 3) summarizes the costs of ER visits and hospitalizations over the study period. Between baseline and 3-month follow up, the number of ER visits and hospitalizations including their associated costs were significantly different \( (P < .001) \) in the direction of lower cost in the follow up period (Figure 4). Specifically, the average cost for ER visit reduced from $243 at baseline (3 months before the program started) to $67 during the follow up (3 months after the program finished). Similarly, the average hospitalization cost reduced from $3,842 to $1,399. When considering only patients with at least one visit, the average costs of ER visit and hospitalization was similar across the three time points (Figure 5).

**Table 3.** Costs of emergency room visit and hospitalization over the study period

<table>
<thead>
<tr>
<th>Cost at each time point</th>
<th>Mean cost ± standard deviation (CAD) (^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At baseline</strong></td>
<td></td>
</tr>
<tr>
<td>ER(^b) visit cost</td>
<td>$243 ± $137</td>
</tr>
<tr>
<td>ER visit cost among users (n^c = 71)</td>
<td>$253 ± $131</td>
</tr>
<tr>
<td>Hospitalization cost</td>
<td>$3,842 ± $4,306</td>
</tr>
<tr>
<td>Hospitalization cost among users (n = 42)</td>
<td>$6,769 ± $3,566</td>
</tr>
<tr>
<td><strong>During program</strong></td>
<td></td>
</tr>
<tr>
<td>ER visit cost</td>
<td>$58 ± $130</td>
</tr>
<tr>
<td>ER visit cost among users (n = 16)</td>
<td>$268 ± $150</td>
</tr>
<tr>
<td>Hospitalization cost</td>
<td>$797 ± $2,763</td>
</tr>
<tr>
<td>Hospitalization cost among users (n = 7)</td>
<td>$8,429 ± $4,220</td>
</tr>
<tr>
<td><strong>At 3-month follow up</strong></td>
<td></td>
</tr>
<tr>
<td>ER visit cost</td>
<td>$67 ± $129</td>
</tr>
<tr>
<td>ER visit cost among users (n = 19)</td>
<td>$243 ± $134</td>
</tr>
<tr>
<td>Hospitalization cost</td>
<td>$1,399 ± $2,858</td>
</tr>
<tr>
<td>Hospitalization cost among users (n = 15)</td>
<td>$6,437 ± $2,221</td>
</tr>
</tbody>
</table>

Note:
\(^a\)CAD: Canadian dollars
\(^b\)ER: emergency room
\(^c\)n: number of participants
**Figure 4.** Costs of ER visit and hospitalization over the study period

![Bar chart showing costs of ER visit and hospitalization over the study period.](image)

**Figure 5.** Costs of ER visit and hospitalization over the study period among those with at least one visit and/or hospitalization

![Bar chart showing costs of ER visit and hospitalization among those with at least one visit and/or hospitalization.](image)
Cost description
Over a 3-month period, the total cost to deliver the program was $649 per patient. This amount accounted for both personnel, and supplies and miscellaneous costs. Personnel costs were composed of salary and benefits for a telehealth nurse. Supplies and miscellaneous costs included hardware, RPM software, case conferences (two times per patient), and wireless data. The cost of providing the Smart Program over a 3-month period is reported in the table below (Table 4).

Table 4. Cost components of the Smart Program per patient over a 3-month period

<table>
<thead>
<tr>
<th>Cost component</th>
<th>Unit cost</th>
<th>Number of unit</th>
<th>Total cost (CAD)(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telehealth nursing cost</td>
<td>$34.81/hour</td>
<td>9.4 hours</td>
<td>$327.21</td>
</tr>
<tr>
<td>Hardware amortized over 3 years</td>
<td>$41.87</td>
<td></td>
<td>$41.87</td>
</tr>
<tr>
<td>RPM(^b) software</td>
<td>$105</td>
<td></td>
<td>$105</td>
</tr>
<tr>
<td>Case conference (twice per patient)</td>
<td>$65</td>
<td>2</td>
<td>$130</td>
</tr>
<tr>
<td>Wireless data</td>
<td>$15/month</td>
<td>3 months</td>
<td>$45</td>
</tr>
<tr>
<td><strong>Total cost over a 3-month period</strong></td>
<td></td>
<td></td>
<td><strong>$649</strong></td>
</tr>
</tbody>
</table>

Note:
\(^a\)CAD: Canadian dollars
\(^b\)RPM: remote patient monitoring
Discussion

This study analyzed the baseline characteristics of the study population and examined the number and cost of ER visits and hospitalizations over the study period from the perspective of a public healthcare system in Ontario, Canada. Of the 74 patients included in the study, a majority had COPD (68%), were female (57%), and had an average age of 72 years (± 12). Approximately 80% were on at least 1 medication, and more than 85% of patients had regular medical follow ups. For alerts, 39% had at least 1 weight alert, 92% at least 1 blood pressure alert, and 92% had at least 1 blood oxygen alert during the program. The proportion of patients with the clinical frailty score of 3 (well, with treated co-morbidities) also increased from 27% at baseline to 39% during the 3-month follow up period, which showed favorable outcomes with the use of the Smart Program.

Among patients diagnosed with chronic illness of COPD or CHF, the number and cost of ER visits and hospitalizations appeared to be significantly reduced when compared between the 3-month period before the program started and the 3-month period after the program finished. The average cost of ER visit reduced from $243 in the baseline to $67 in the follow up, and for hospitalizations, reduced from $3,842 to $1,399. These reductions were partly due to the findings that the number of ER visits and hospitalizations reduced, while this intervention costs approximately $649 to implement for one patient over a 3-month period. It is important to note that when considering only patients with at least one visit, the average costs of ER visit and hospitalization was similar across the three time points.

The RPM literature provides both supportive and opposing evidence to verify the value of RPM. For example, a reduction in direct health care cost was found in a review by Seto (2008) to be between 1.6% and 68.3% [2], and in a study by Scalvini to be approximately 10% [10]. Our study reports the reduction of hospitalization to be 35% and of ER visits to be 68%. These differences could be due to a number of factors such as target population, range of supports provided as part of the RPM, and settings.

Strengths and limitations

This study has strengths and limitations. As the literature has recommended RPM which can support more than one condition [31], our study shows that a RPM system targeting more than one condition can be successfully implemented. A review [32] suggested that more details on cost including amortization should be made explicit as we have done here. This study represents another case study to support the potential value of RPM by examining both costs and outcomes of RPM where the outcomes (measured in hospitalization and ER visits) have been converted to monetary values.

Given the nature of the study design (one-group pre-post study design), the findings contributed only to the trends of health service utilization and cost over the study period. Future research could build on this work and design a study with a comparator group to comprehensively
examine the potential impact of RPM in the study population. Additionally, future research could
explore the options to conduct the analysis with a longer follow up time from another perspective
which could include other costs (e.g., costs to patients and caregivers, which has been suggested
to be an important element [33]), and other outcomes such as quality of life and productivity
loss. Subgroup analysis (e.g., patients with comorbidities) could also be explored to validate the
impact of RPM.

Conclusion
In summary, RPM may require up-front investment but it has potential to reduce health care
costs to the system over time. This study represents another piece of evidence to support the
potential value of RPM among patients with COPD or CHF. This intervention shows a potential
68% reduction in ER visits and 35% reduction in hospitalizations between the 3-month pre- and
3-month post-intervention period. RPM could be an economically attractive option for our health
system in savings from reductions in ER visits and hospitalizations among patients with COPD
or CHF.
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Authors contribution (study design, data collection, data analysis, manuscript)
WI: study design, data collection, data analysis, manuscript writing
OR: project initiation, data collection
AS: project initiation, delivery of supporting IT system
TVM: data collection, project management
JV: project initiation, delivery of supporting IT system
PC: project initiation, data collection

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Conflicts of Interest
WI: None
OR: None
AS: AS is an employee of Alayacare who provided RPM software.
TVM: TVM is an employee of Alayacare who provided RPM software.
JV: JV is an employee of Alayacare who provided RPM software.
PC: None

Abbreviations
ADL activities of daily living
CAD Canadian dollars
CHF chronic heart failure
COPD chronic obstructive pulmonary disease
ER emergency room
LHIN Local Health Integration Network
n sample size
RPM remote patient monitoring
SD standard deviation
References


