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Use of digital health kits to reduce readmission after cardiac surgery

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ARTICLE INFO

Article history:
Received 3 February 2016
Received in revised form
19 March 2016
Accepted 15 April 2016
Available online xxx

Keywords:
Surgical readmissions
Cardiac surgery
Digital health kits
Patient satisfaction
Readmission reduction
Telehealth
Outcomes

ABSTRACT

Background: Unintended rehospitalizations after surgical procedures represent a large percentage of readmissions and have been associated with increased morbidity and cost of care. Beginning in 2017, Medicare will expand diagnostic categories subject to financial penalties for excess postoperative readmissions to include coronary revascularization procedures. Arrhythmias and pulmonary complications comprise the largest categories for readmission after cardiac surgery. Technologic advances in remote monitoring have led to the use of web-based digital health kits (DHK) aimed at reducing readmissions and improving postoperative outcomes. The present study was performed to determine the added benefit of incorporating DHK's into a formal readmissions reduction program (RRP) in preventing 30-d readmissions and to evaluate patient and provider satisfaction with the use of these devices.

Materials and methods: This was a prospective study of all adult patients who underwent cardiac surgery at our institution from March 2014 to June 2015. During the study period, 443 adult patients (mean age, 65 ± 14, 33% female) were identified and participated in the formal RRP, 27 of whom also received a DHK after discharge (416 control group). In addition to providing a live video link to a provider specializing in cardiac surgery, the DHK also allowed for automatic daily transmission of weight, oxygen saturation, heart rate, and blood pressure. Patients also completed a daily health survey targeting symptoms concerning for heart failure, poor wound healing, poor ambulation, and nonadherence to medications. Abnormal vitals or survey responses triggered automatic notifications to the healthcare team. Satisfaction surveys were administered to participants and members of the healthcare team. Pearson χ^2 test and the Welch's *t*-test were used to assess statistical differences in baseline characteristics and outcome variables.

Results: During the study period, the readmission rate for the DHK and control groups were similar (7.4% *versus* 9.9%, $P = 0.65$). The use of DHKs led to 1649 alerts and 144 interventions, with the highest number of alerts occurring during d 5-9. The majority of alerts (64%) were prompted by abnormal biometric measurements, and a significant correlation was noted between abnormal biometrics and required intervention ($r = 0.62$, $P < 0.001$). No correlation was seen between alerts because of health survey responses ($r = 0.07$, $P = 0.71$) or missed check-ins ($r = 0.06$, $P = 0.76$) and required interventions. Poststudy satisfaction surveys

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0022-4804/$ – see front matter Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.jss.2016.04.028

showed an overall satisfaction rating of 4.9 ± 0.5 for DHK patients and 4.9 ± 0.2 for members of the care team (scale 1-5, 5 = agree).

Conclusions: In our study, adding DHKs to a formal RRP was not associated with a significant decrease in 30-d readmission rates. We also found that notifications because of abnormal biometric measures were significantly correlated with required interventions. In contrast, notifications due to abnormal health survey responses were not associated with increased interventions. Both patients and members of the healthcare team were highly satisfied with this technology. DHKs appear to extend care beyond the inpatient period and provide a portal for telemonitoring of surgical patients. However, this modality is highly resource intensive and may not significantly reduce readmissions. Further studies are warranted to evaluate the efficacy of such kits in reducing readmissions and costs of care.

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Introduction

Postoperative readmission reported to occur in 17.4% of coronary revascularization patients[1] is associated with increased mortality, reduced patient satisfaction,[2] and significant increases in healthcare costs.[3] With recent evidence suggesting that readmission rates may be correlated with quality of care,[4,5] a Hospital Readmissions Reduction Program was implemented under the Affordable Care Act requiring the Centers for Medicare and Medicaid services to reduce payments to institutions with "excess readmissions." These financial penalties, which may be as high as 3% of the total institutional Centers for Medicare and Medicaid services payment, are currently applicable to the following diagnoses: acute myocardial infarction, heart failure, chronic obstructive pulmonary disease exacerbations, pneumonia, and joint replacements. With imminent plans to expand the list to include coronary artery bypass grafting in 2017, some state organizations such as the California Coronary Artery Bypass Grafting Outcomes Reporting Program have already mandated public reporting of readmission rates.[6,7]

Innovative strategies aimed at reducing readmission rates have been used in the postdischarge management of patients. A number of studies have demonstrated the variable success of these programs, which have focused primarily on patient education, assisted medication administration, and organized coordination of care after discharge.[8,9] Paradoxically, Kwok *et al.*[10] noted higher readmission rates after implementation of home visits by nurses. Nevertheless, it is generally accepted that fragmentation of care after discharge plays a vital role in unplanned rehospitalizations.[11,12] Wireless health technologies including video and telemonitoring of vital signs have recently been used to improve continuity of care. Despite success in nonsurgical patients, the impact of telemonitoring in reducing readmissions has not been previously evaluated in those undergoing cardiac surgery.

Historically, the rate of readmission after cardiac surgery has varied between 16% and 22%. With an initial focus on identifying factors contributing to readmissions,[13] we have developed targeted interventions to reduce unplanned rehospitalizations at our institution. Our Readmissions Reduction Program (RRP) was developed with the purpose of improving patient education and the coordination of postdischarge care. The purpose of the present study was to evaluate the added benefit of incorporating a telehealth-based component to the RRP in reducing readmissions after cardiac surgery.

Materials and methods

Patients undergoing cardiac surgery at our institution between March 2014 and June 2015 were eligible for inclusion in this study. Transplantation, extracorporeal membrane oxygenation, and ventricular assist device insertion were indications for exclusion from analysis. All patients participated in the RRP, which was developed by a multidisciplinary committee consisting of physicians, nurses, and case coordinators. Figure 1 provides a detailed description of the components included in the RRP. As part of the protocol, patients participated in a formal preoperative education program consisting of face-to-face sessions with the health team. Topics such as preoperative preparation, expected hospital course, proper medication administration, and potential postoperative complications were discussed at these sessions, with educational material provided for patients and their caregivers. Postoperatively, patients received daily education and reinforcement on topics pertaining to at-home care. The second focus of the RRP was to improve postdischarge care. A plan was developed to ensure all necessary home medications were dispensed, and all follow-up appointments were scheduled before discharge. At last, patients were required to identify trusted individuals who would serve as a primary caregiver at home.

In addition to the formal RRP, patients enrolled in a telehealth pilot study also received a digital health kits (DHK) consisting of a tablet linked to a Bluetooth-enabled pulse oximeter, heart rate monitor, blood pressure cuff, and weight scale. Tablets were equipped with software that provided patients with simple illustrated instructions on how to obtain real-time data of vitals including oxygen saturation, heart rate, blood pressure, and weight (Fig. 2). Patients also completed daily digital questionnaires aimed at identifying symptoms consistent with heart failure, poor wound healing, as well as data on ambulation and adherence to medications (Fig. 3). Abnormal biometrics (O_2 saturation<92%, heart rate >95 or <60 beats per minute, systolic blood pressure >150 mm Hg or <90 mm Hg, or weight change greater than two pounds), concerning survey responses, and a missed digital check-in, triggered an automated notification to the healthcare team.

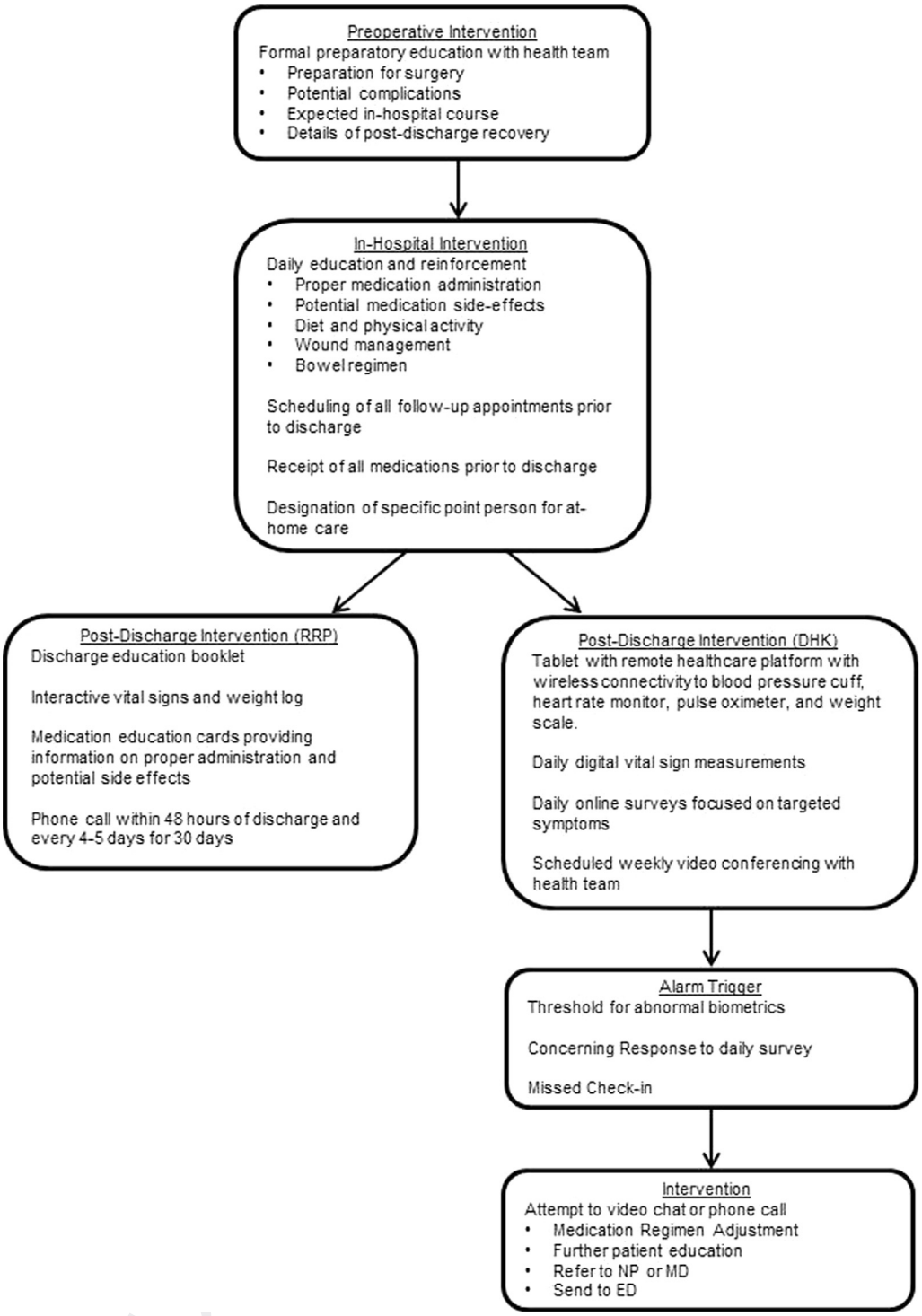

Fig. 1 – Details of the RRP and telehealth pilot study (DHK).

Patients were subsequently contacted by a healthcare provider via video conference or telephone prompting a potential intervention such as medication dosage adjustment, further patient education, or triaging as necessary.

Patients who were enrolled in the telehealth program comprised the intervention group (DHK), whereas patients in the formal RRP served as a control. The primary outcome of this study was postoperative readmission within 30 d of surgery. In addition, surveys were administered to participants and members of the healthcare team to assess their satisfaction with the telehealth component of the program.

For analysis, the Pearson χ^2 test and the Welch's *t*-test were used to assess statistical differences in baseline characteristics and outcome variables. Correlational analyses were

Fig. 2 – Sample of remotely measured vital signs.

completed using Pearson's (r) coefficient to assess the relationship between alert notifications and required interventions. All statistical analyses were performed using STATA 12 (StataCorp LP), and results with a P value ≤ 0.05 were deemed statistically significant. The study protocol was approved by the institutional review board at the University of California, LA.

Results

Of the 443 patients (mean age: 65 ± 14, 33% female) who underwent cardiac surgery during the study period, 27 (6.1%) were enrolled in the telehealth pilot study. Patient characteristics were relatively similar for the two groups, with significant differences noted in gender and incidence of dialysis (Table 1). Postoperatively, patients in the RRP had significantly higher rates of pneumonia and sepsis (Table 2). However, total length of stay was relatively similar between the two groups. Overall, 9.7% of patients ($n = 41$) were readmitted within 30 d of surgery. No significant difference was found in the rate of readmission between the RRP group and the DHK group (9.9% *versus* 7.4%, $P = 0.65$). Reasons for readmission are noted in Table 3. Although patients in the RRP group were readmitted for a range of cardiovascular and respiratory complications including arrhythmias, heart failure, and effusions, the only two DHK readmissions were due amiodarone toxicity and for a syncopal episode.

During the 30-d study period, information gathered via the DHKs led to 1649 alerts, with a median of 49 alerts per day (IQR 45-58) and the highest number of alerts occurring during d 5-9 (Fig. 3). Per patient, this amounts to a median of 54 alerts during the study period (IQR 45-78). The majority of alerts (64%) were prompted by abnormal biometric measurements, whereas 25% were triggered by responses to daily survey questions, 6% by patient requests for additional video chat sessions, and 5% by notifications of patient noncompliance with daily monitoring. Notifications led to 144 subsequent interventions by the care team, amounting to an average of 13.5 alerts per intervention when analyzed at the patient level. Medication adjustments were required in 14% of cases, a referral to a nurse practitioner or physician was required in 10%, and additional patient education was required in 76% of required interventions. On analysis, a significant correlation was noted between abnormal biometrics and requiring intervention ($r = 0.62$, $P < 0.001$) as displayed Figure 5. However, no correlation was seen between alerts due to survey responses ($r = 0.07$, $P = 0.71$) or missed check-ins ($r = 0.06$, $P = 0.76$) and requiring intervention.

CABG (Post op week 1)								
Is your pain well controlled?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Are you experiencing any chest pain, palpitations, fast heartbeat, dizziness or lightheadedness?	No	No	No	No	Yes	No	No	No
Do you have a new or worsening cough?	No	No	No	No	No	No	No	No
Have you had fever, chills, nausea, vomiting or diarrhea?	No	No	No	No	Yes	No	No	No
What is your temperature?					Less			
Around your incision, do you have any redness, drainage, swelling, tenderness or wound separation?	No	No	No	No	No	No	No	No
Did you notice an increase in swelling in your feet or ankles yesterday?	No	No	No	No	No	No	No	No
While at rest, how was your breathing yesterday?	No shortnes	A little short of	A little short of	No shortnes	No shortnes	No shortnes	No shortnes	No shortnes
Did you sleep in a chair or propped up on extra pillows last night?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Did you wake up with shortness of breath last night?	No	No	No	No	No	No	No	No
Did you take all of your medicines yesterday?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
While performing activities, how was your breathing yesterday?	A little short of	A little short of	A little short of	No shortnes	No shortnes	A little short of	A little short of	No shortnes
Were you able to take 5 to 10 minute walks at least 3 to 4 times yesterday?	No	Yes	Yes	Yes	No	Yes	Yes	Yes

Fig. 3 – Sample of targeted digital patient questionnaire evaluating clinical symptoms.

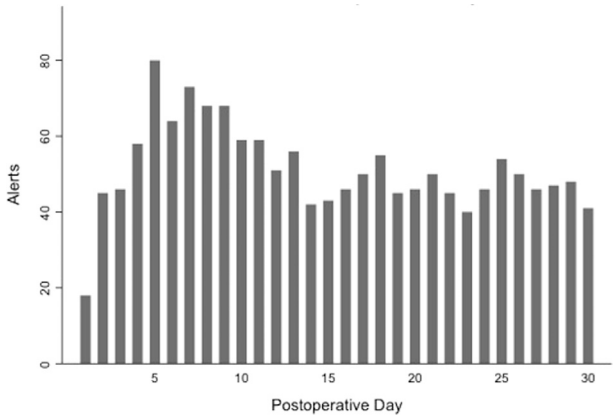

Fig. 4 – Distribution of total alerts by postoperative day.

To assess patient and provider satisfaction with the telehealth component of the RRP, surveys were administered at the conclusion of the study using a 5-point Likert scale (1 = disagree, 5 = agree) with a 74% completion rate among patients and 100% among providers. A summary of patient and provider survey responses are displayed in Figure 6 and Figure 7 respectively. Overall, patients and healthcare providers reported satisfaction scores of 4.9 ± 0.5 and 4.9 ± 0.2, respectively. Patients also reported feeling more confident in the quality of care they received during the recuperation period.

Discussion

Although preliminary, the use of DHKs was not associated with an incremental decrease in 30-d readmission rates when added to a formal RRP. However, user satisfaction ratings were high among both patients and healthcare providers participating in the telehealth program. With rapid expansion of mobile platforms and anticipation of widespread use of DHK's, it is crucial to evaluate their incremental efficacy at reducing postoperative readmissions.

As the healthcare system in the United States moves toward value-based purchasing and cost containment, a number of policies including the Hospital RRP and Bundled Payments for Care Improvement Initiative are being implemented. All such initiatives aim at reducing the cost of care

Table 1 – Patient characteristics.

	RRP (n = 416)	DHK (n = 27)	P value
Age, mean (SD), y	65.9 (14.1)	62.9 (9.8)	0.14
Male gender, % (n)	65.9 (274)	85.2 (23)	0.01
Body mass index, mean (SD), kg/m^2	28.6 (19.8)	31.2 (14.0)	0.37
Tobacco use, % (n)	32.9 (137)	33.3 (9)	0.97
Hypertension, % (n)	55.3 (230)	70.4 (19)	0.12
Diabetes mellitus, % (n)	24.0 (100)	25.9 (7)	0.83
Dyslipidemia, % (n)	42.1 (175)	44.4 (12)	0.82
Previous myocardial ischemic event, % (n)	24.5 (102)	25.9 (7)	0.88
Previous cardiac intervention, % (n)	36.8 (153)	37.0 (10)	0.98
Ejection fraction, mean (SD), %	53.7 (14.3)	52.7 (12.8)	0.74
Preoperative atrial fibrillation, % (n)	11.3 (47)	22.2 (6)	0.20
Peripheral vascular disease, % (n)	7.0 (29)	3.70 (1)	0.41
Chronic lung disease, % (n)	10.4 (43)	11.1 (3)	0.90
Cerebrovascular disease, % (n)	12.5 (52)	7.41 (2)	0.35
Liver disease, % (n)	6.5 (27)	3.70 (1)	0.48
Dialysis, % (n)	5.3 (22)	0 (0)	<0.01
Preoperative hematocrit, mean (SD), %	36.2 (7.9)	38.8 (8.2)	0.13
Operative status, % (n)			0.24
Elective	46.2 (192)	63.0 (17)	
Urgent	49.0 (204)	33.3 (9)	
Emergent	4.8 (20)	3.70 (1)	
Operation type, % (n)			0.10
CABG	26.4 (110)	18.5 (5)	
Valve	41.6 (173)	59.3 (16)	
CABG + valve	13.0 (54)	18.5 (5)	
Other cardiac	19.0 (79)	3.7 (1)	

SD = standard deviation; CABG = coronary artery bypass grafting.

Table 2 – Postoperative outcomes.

	RRP ($n = 416$)	DHK ($n = 27$)	P value
Postoperative complication, % (n)			
Prolonged ventilation	8.2 (34)	0 (0)	0.12
Surgical site infection	2 (0.5)	0 (0)	0.16
Pneumonia	1.2 (5)	0 (0)	0.03
Sepsis	1.8 (8)	0 (0)	0.01
Reoperation	7.0 (29)	11.1 (3)	0.51
Cerebrovascular accident	0.2 (1)	0 (0)	0.32
Atrial fibrillation	15.4 (64)	29.6 (8)	0.9
Renal failure	4.1 (17)	3.7 (1)	0.13
Total length of stay, mean (SD), d	9.1 ± 9.0	8.7 ± 3.6	0.65
30-d mortality*, % (n)	1 (0.3)	0 (0)	0.32

SD = standard deviation.
*30-d mortality rate includes only patients who survived to discharge.

while improving patient satisfaction and quality of care. Unplanned readmission rate after index surgical hospitalization is now considered a quality metric and used by Centers for Medicare to levy penalties on hospitals with higher than expected readmission rates. With a growing body of research evaluating the reasons for readmission, it appears that care fragmentation and complications not related to the original procedure are major contributors to the problem of readmissions.[14] Therefore, extended monitoring of the patients' cardiopulmonary and fluid status appears to be logical adjuncts to programs aimed at care coordination and patient education.

Q5 In the present study, we used a commercially available, HIPAA compliant, web-based mobile system that used a tablet to interact with patients. In addition, parameters such as heart rate, blood pressure, transcutaneous oxygen saturation, and weights were automatically transmitted to the healthcare providers. Since many of the readmissions after cardiac surgery are related to mobility, surgical wounds, and the cardiopulmonary condition of the patient, this particular DHK

Table 3 – Reason for readmission.

	RRP ($n = 416$)	DHK ($n = 27$)
Arrhythmia/heart block, % (n)	15 (6)	0
CHF exacerbation, % (n)	7 (3)	0
Pericardial effusion/tamponade, % (n)	2 (1)	0
Respiratory complication, % (n)	15 (6)	0
Infection, % (n)	17 (7)	0
Deconditioning/syncope, % (n)	7 (3)	50 (1)
Anticoagulation/bleeding complication, % (n)	7 (3)	0
Gastrointestinal complication, % (n)	10 (4)	0
Noninfectious wound complication, % (n)	7 (3)	0
Other, % (n)	7 (3)	50 (1)

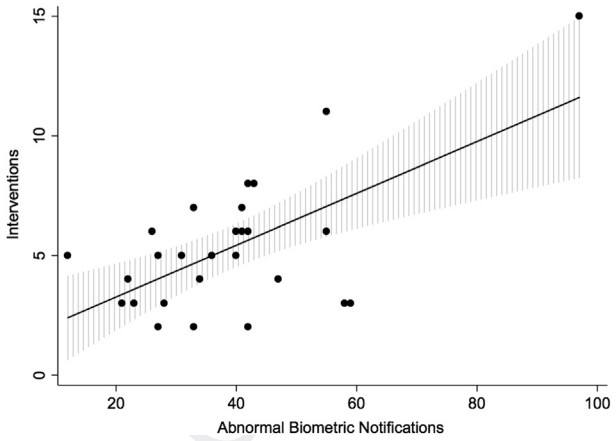

Fig. 5 – Relationship between abnormal biometric measures and required interventions. Q7

was programmed to address these issues and generate alerts for the healthcare team. In addition, we used providers that were fully trained in the postoperative care of cardiac surgery patients to optimize patient care. The DHK system provided many alerts and led to 144 interventions in 27 patients. However, these interventions did not translate into a significant reduction in readmission rates at our institution. This finding may be explained by the fact that all patients participate in a RRP that has significantly reduced our readmission rates.

Satisfaction with the use of DHK's was found to be high among the patients and healthcare providers. This perhaps is a relevant finding, as patient experience and satisfaction with medical care may translate into improved long-term outcomes and adherence.[2,15] The ease of use given the tablet platform and preconfigured connectivity may have enhanced the user experience. Perhaps, a system that could deliver personalized alert set points and questions would further enhance satisfaction.

Our study has several limitations. Due to an initially limited amount of DHK available, we were only able to monitor five patients at once. Moreover, since all patients participated in the RRP, we were not able to assess the independent value of the DHKs alone. Nevertheless, we believe our preliminary results provide basis for future large-scale

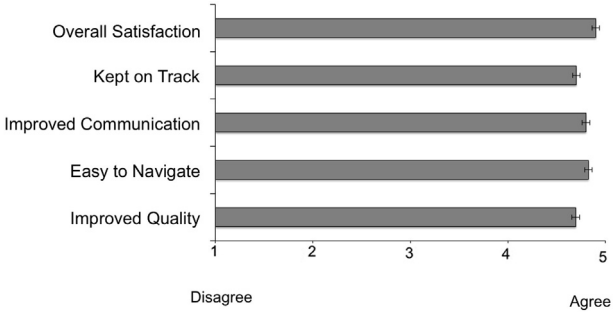

Fig. 6 – Results of patient satisfaction survey with digital health kits.

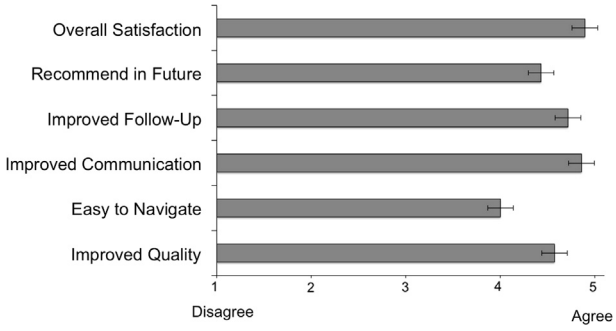

Fig. 7 – Results of care team satisfaction survey with digital health kits.

interventional studies to assess the benefits of continued outpatient follow-up via wireless health technology. Information gathering was also disrupted when pieces of the DHK would malfunction and had to be replaced during the 30-d window.

In summary, DHK show potential in providing a reasonable adjunct to postoperative care that would further improve the readmissions reduction program implemented at our university. Further adjustments to the monitoring capabilities and increased personalization will likely not only improve patient satisfaction and adherence but also quality of care.

Uncited section

Figure 4.

Acknowledgment

Author's contributions: I.M. helped in study design, data collection, data analysis, data interpretation, and article drafting. S.S. carried out study design, data collection, data analysis, data interpretation, article drafting, and critical revisions. A.Z. did study design, data analysis, data interpretation, and article drafting. G.M. and H.W. helped in study design and data collection. M.N. has done data collection and data analysis. R.S. helped in study concept, study design, data interpretation, and critical revisions. P.B. was study concept, study design, data analysis, data interpretation, article drafting, and critical revisions.

Disclosure

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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