REGIONALIZED SURGICAL CARE:

PUBLIC PERSPECTIVE AND

A NOVEL MOBILE HEALTH INTERVENTION

A Thesis

Presented to the Faculty of the Weill Cornell Graduate School

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Master of Science

by

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ABSTRACT

Background

The relationship between high surgical volume and improved perioperative outcomes has been well documented in many contexts. This finding has led to efforts to regionalize surgical care, restricting complex elective surgery to centers with high volume. The process of regionalizing care has proceeded largely without exploring what barriers patients experience when attempting to access such high-volume surgical care. Additionally, there is a lack of interventions available to improve patient recovery during the immediate postoperative period. We sought to identify the public's perceived barriers to regionalized surgical care, and to create a smartphone based mobile health application that could be used to speed recovery of patients immediately after surgery. Such an application could be used by patients regardless of their distance from a regional center.

Methods

We participated in the Cornell National Social Survey, a random-digit-dial telephone survey of 1000 households in the United States. Participants answered questions about their willingness to seek regionalized care in a hypothetical scenario requiring elective abdominal surgery for cancer. We compared their responses and demographic characteristics. We also performed a geospatial analysis of respondent proximity to hospitals, and a qualitative analysis of perceived barriers to regionalization. To test an intervention to improve regionalized care, we performed a pilot study of a novel mobile health application in adults undergoing major abdominal surgery. Patients

undergoing colorectal surgery were recruited from a single center. They were given the mobile health app, and used it to report their pain, answer surveys, and photograph their wound. They were periodically reminded to stay hydrated, and used a Fitbit™ device to track their mobility. Concerning responses triggered alerts for further evaluation. Patients were followed postoperatively for 30 days and compliance with app use was tracked.

Results

Cooperation rate was 48.1% in the household survey. Survey participants were average 50 years old and 48.9% female. 49.6% stated unwillingness to travel five hours or more to seek regionalized care for improved survival. Age >70yo (OR 0.34 95% CI 0.19-0.60) and perceived travel to a center >30 minutes (OR 0.60 95% CI 0.41-0.86) were associated with decreased willingness to seek regionalized care, while high income (OR 2.09 95% CI 1.39-3.16) was associated with increased willingness. Proximity to a major center was not associated with willingness to travel (OR 0.92 95% CI 0.67-1.22). 6 major perceived barriers to regionalization were identified including: transportation, life disruption, social support, socioeconomic resources, poor health, and remoteness.

For the mobile app intervention portion of the study, 31 patients undergoing colorectal surgery participated. Most were female (58%), and white (61%). 19% had an ostomy as part of their surgery. 83.9% of patients completed at least 70% of the app-related tasks they were given. 89% said using the app was easy to use. Patients generated an average of 1.1 alerts. One patient was readmitted and generated 7 alerts

prior to re-admission. Patients participated most in collecting Fitbit data (84.8% of days) and completing a single-item photoaffective meter, but had more difficulty uploading photographs (51.4% completed). 89% of patients found the application easy to use.

Conclusions

Americans are divided on whether the potential for improved survival with regionalization is worth the additional travel effort. Older patients and those with lower income are less willing to travel for regionalized care. However, the travel burden of regionalized care might be reduced with mobile health technology. It is feasible to use a novel mobile health app to monitor patient recovery from major abdominal surgery. The app is easy to use, and has the potential to improve outcomes. Patients can use this app regardless of their proximity to a high-volume center.

BIOGRAPHICAL SKETCH

Matthew Symer earned a Bachelor of Arts in biochemistry from Tufts University and an MD degree from Stony Brook University in 2013. Matthew's research interests include surgical outcomes and surgical education. He anticipates completing a residency in General Surgery at NewYork-Presbyterian/Weill Cornell Medicine in 2020.

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CHAPTER ONE

Barriers to Regionalized Surgical Care: Public Perspective Survey and Geospatial Analysis*

*Symer M, Abelson J, Yeo H. Barriers to Regionalized Surgical Care: Public Perspective Survey and Geospatial Analysis. Annals of Surgery. 2017.

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Introduction:

Over the past 15 years, there has been a growing body of evidence demonstrating better surgical outcomes when patients are treated at high-volume centers.[1–4] Initiatives such as those of the Leapfrog Group and the "Take the Volume Pledge" aim to leverage these improved outcomes by eliminating low-volume surgery.[5] An eventual consequence of these initiatives would be concentration of complex surgical oncologic care at a smaller number of regional centers. If enacted wisely regionalization might facilitate broader access to the expertise of the best centers. However, a number of significant challenges to regionalization have not yet been addressed.[6,7]

The United States is geographically large, socioeconomically diverse, and access to care for many patients is already burdensome.[8,9] For some, regionalization will impose an additional strain of cost, time, pain and stress of travel.[10] Longitudinal care, from the pre- to post-operative period, will need to adapt to minimize the travel burden while still identifying and treating complications. Patient attitudes and perceived barriers to regionalized care have only been explored in limited contexts and populations.[11,12] It is unclear if patients are willing or able to travel for surgical care, and what they feel stands in their way. An accounting of the barriers that patients perceive would help inform policies designed to improve surgical outcomes.

In order to understand these barriers, we performed a mixed-methods study of adults residing in the U.S. We evaluated participants' willingness to travel, knowledge of their proximity to a regional center compared to their actual location, and their

perceived barriers to traveling for surgical care. We hypothesized that subjects overall would be willing to travel for improved survival, but that socioeconomic factors play a major role in their ability to do so. We also hypothesized that participants may not know if they live near a major referral center.

Methods:

Data source

We developed questions as part of the Cornell National Social Survey (CNSS), an annual survey of American households administered by the Cornell Survey Research Institute. CNSS includes questions on basic demographics as well as a range of topics from politics to healthcare. The survey used random digit dialing of continental U.S. phone exchanges. Participants were contacted via mobile phone, landline, or internet phone and were excluded if they were <18 years old or non-English speaking. In addition to demographic information, participants were asked questions related to regionalization of care (Table 1.1).

Table 1.1. Survey prompts, questions, and possible responses

Prompt / Question	**Response options**
Do you live within 30 minutes of a major referral or regional hospital, for example a large university-affiliated hospital or a cancer specialty hospital?	1. Yes 2. No 3. Don't know

Table 1.1 Continued

"For the following questions, please assume that you have recently been diagnosed with cancer and you are recommended to undergo complex major abdominal surgery."	
Would you be willing to drive past a small community hospital if a major referral or regional hospital offered you a better chance to be alive after 5 years?	1. Yes 2. No (skip next question)
How far would you be willing to travel to get to a major referral or regional hospital for surgery to increase your chance to be alive after 5 years?	1. <1 hour 2. 1-2 hours 3. 2-5 hours 4. 5 hours or more
Would you be willing to drive past a small community hospital if a major referral or regional hospital offered a lower risk of complications after surgery?	1. Yes 2. No (skip next question)
How far would you be willing to travel to get to a major referral or regional hospital for surgery to lower your risk of complications after surgery?	1. <1 hour 2. 1-2 hours 3. 2-5 hours 4. 5 hours or more
What are barriers you foresee to traveling to a major referral or regional hospital for surgery?	Open ended response

After a pilot survey allowing for question refinement, the final survey was conducted from September to December 2016 until a total of 1000 interviews were completed. Individuals with incomplete information were excluded from quantitative analysis but

included in the qualitative portion of the study. The study was approved by the Cornell University Institutional Review Board #1402004459.

Quantitative analysis

We performed a quantitative analysis of participant demographics and responses to four questions regarding regionalization. Each question assessed participants' willingness to travel to a major referral hospital to increase their five-year survival or to reduce their risk of having a complication. Our primary outcome was participants' willingness to travel for surgical care. Baseline characteristics were compared using Chi-squared or Kruskal Wallis test. Multiple logistic regression was used to identify demographic features associated with willingness to seek regionalized care. Odds ratios and 95% confidence intervals are reported. Statistical significance was defined as $p<0.05$. Analyses were performed with R v3.3.2.[13]

Geospatial analysis

Geospatial drive-time models for 30 and 60 minute drives were created from major academic medical centers using ArcMap (v10.2.2)(Figure 1.1).

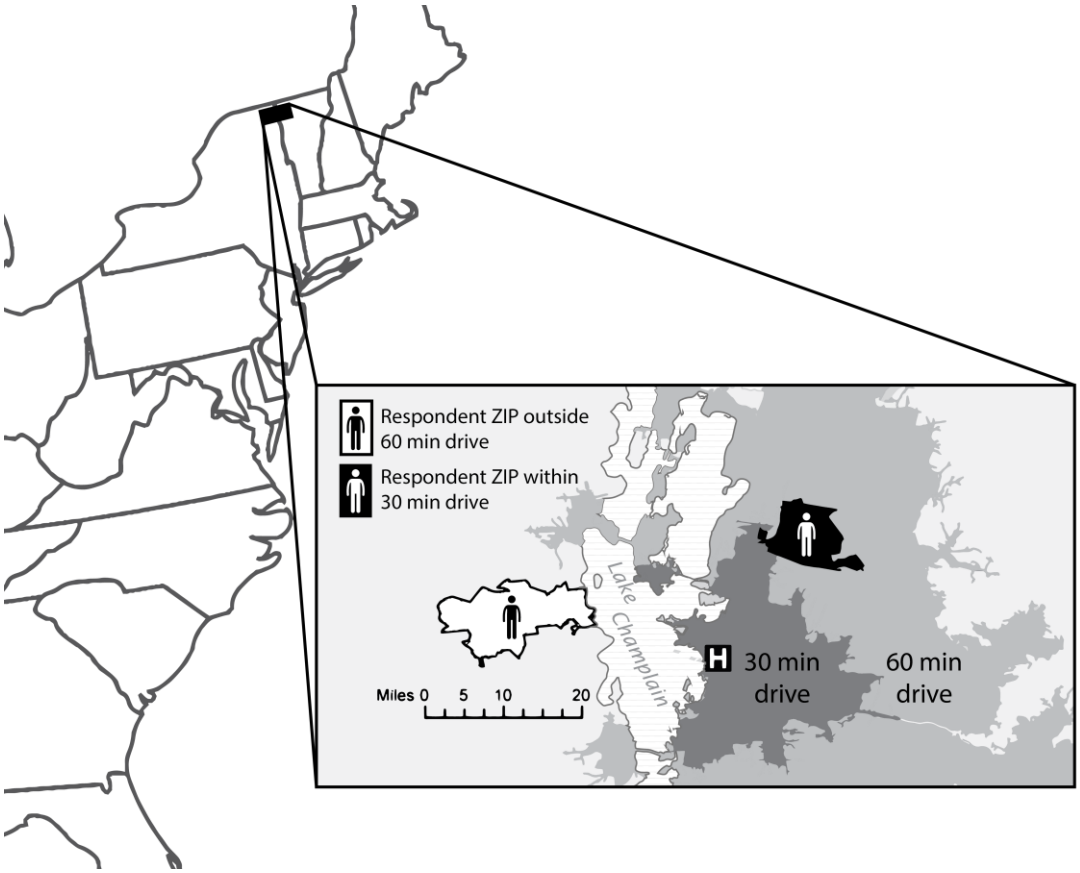

Figure 1.1. Example of a drive-time buffer model around Burlington, Vermont. Dark and light grey areas represent 30-minute and 60 minute drives from the hospital. H = Regional academic center. Black = Respondent ZIP Code intersecting (within) the 30-minute buffer. White = Respondent ZIP Code outside of both 30- and 60-minute buffers despite the short geographic distance, due to Lake Champlain.

Participants were asked to provide their ZIP Code and if they thought they lived within 30 minutes of a major referral hospital. Respondents whose ZIP Code boundary intersected with a drive-time buffer were considered to be within that buffer. We defined a major referral hospital as a University-affiliated center with ≥4

residency programs or a specialty hospital or clinic (e.g. Memorial Sloan Kettering Cancer Center or the Lahey Clinic), but excluded VA centers.[14–16] Cohen's Kappa was used to calculate concordance of survey response with geospatial analysis.

Qualitative analysis

Participants were given a hypothetical scenario in which they were diagnosed with a cancer and needed complex major abdominal surgery. We then asked participants what barriers they foresaw to traveling to a major referral hospital. Participant responses were transcribed by trained survey administrators. Three researchers independently analyzed 75 responses and collaboratively developed a codebook which two authors then used to independently code the remaining responses. Discrepancies in coding were evaluated by the two researchers and any disagreement was adjudicated by the third author. Responses were grouped into categories and thematically analyzed using grounded theory.[17,18] Counts and percentages of each theme are reported with respect to number of participants, as each response could be coded with multiple categories or themes.

Results:

Participant characteristics

2080 eligible subjects were reached, of whom 1000 completed the phone interview (48.1% cooperation rate; Table 1.2).

Table 1.2. Number of phone calls and outcomes

Call outcome	**n**
Bad or inactive number	9,510
Completed interview	1,000
Refused participation	448
Business number / not a household	361
Language barrier	187
Age <18 yo (minor's cell phone)	61
Incapable/ too ill to participate	23
Total:	11,590

959 participants provided qualitative responses and 893 had complete information including a valid ZIP Code permitting quantitative and geospatial analysis.

Overall, survey respondents were an average of 50 years old (IQR 35-63), and 48.9% female (Table 1.3).

Table 1.3. Respondent characteristics for the overall survey cohort and stratified by whether they were willing to drive 5 hours for either increased survival or reduced complications. [a]Based on geospatial analysis of respondent ZIP Code to nearest referral center. [b]Based on survey response. VoIP = voice over internet protocol.

	For Improved Survival			**For Reduced Complications**		
	Unwilling or <5h	Willing to drive ≥5h	p value	Unwilling or <5h	Willing to drive ≥5h	p value
n=	443(49.6)	450(50.4)		513(57.4)	380(42.6)	
Age years, n(%)						
Overall mean(sd)	52.5(18.2)	47.5(16.3)	<0.01	52.0(18.0)	47.3(16.4)	<0.01
18-35	107 (24.2)	126 (28.0)	<0.01	123 (24.0)	110 (28.9)	<0.01
36-55	121 (27.3)	169 (37.6)		146 (28.5)	144 (37.9)	
56-70	143 (32.3)	126 (28.0)		169 (32.9)	100 (26.3)	
>70	72 (16.3)	29 (6.4)		75 (14.6)	26 (6.8)	
Female n(%)	221 (49.9)	216 (48.0)	0.62	253 (49.3)	184 (48.4)	0.84
Race n(%)			0.81			0.57
Hispanic, any race	42 (9.5)	42 (9.3)		46 (9.0)	38 (10.0)	
Non-Hispanic White	316 (71.3)	324 (72.0)		370 (72.1)	270 (71.1)	
Non-Hispanic Black	39 (8.8)	31 (6.9)		45 (8.8)	25 (6.6)	
Non-Hispanic Asian	13 (2.9)	17 (3.8)		17 (3.3)	13 (3.4)	
Other / multiple	33 (7.4)	36 (8.0)		35 (6.8)	34 (8.9)	
Education n(%)			0.05			0.03
HS grad or less	129 (29.1)	97 (21.6)		147 (28.7)	79 (20.8)	
Some college	127 (28.7)	130 (28.9)		149 (29.0)	108 (28.4)	
College grad	104 (23.5)	124 (27.6)		124 (24.2)	104 (27.4)	
Post-graduate or higher	83 (18.7)	99 (22.0)		93 (18.1)	89 (23.4)	
Annual Household income			<0.01			<0.01
<$40k	102 (23.0)	73 (16.2)		118 (23.0)	57 (15.0)	
$40-$75k	200 (45.1)	159 (35.3)		225 (43.9)	134 (35.3)	
>$75k	141 (31.8)	218 (48.4)		170 (33.1)	189 (49.7)	
Born in U.S. n(%)	395 (89.2)	404 (89.8)	0.85	459 (89.5)	340 (89.5)	1.00
Political Ideology n(%)			0.09			0.08
Liberal	123 (27.8)	139 (30.9)		146 (28.5)	116 (30.5)	
Moderate	138 (31.2)	158 (35.1)		159 (31.0)	137 (36.1)	
Conservative	182 (41.1)	153 (34.0)		208 (40.5)	127 (33.4)	

Table 1.3 Continued

Employment n(%)			<0.01			<0.01
Employed	243 (54.9)	321 (71.3)		296 (57.7)	268 (70.5)	
Not Employed	76 (17.2)	58 (12.9)		85 (16.6)	49 (12.9)	
Retired/disabled	124 (28.0)	71 (15.8)		132 (25.7)	63 (16.6)	
Marital status n(%)			0.45			0.26
Married	240 (54.2)	252 (56.0)		279 (54.4)	213 (56.1)	
Divorced/Separated/Widowed	84 (19.0)	71 (15.8)		98 (19.1)	57 (15.0)	
Single	119 (26.9)	127 (28.2)		136 (26.5)	110 (28.9)	
Contact method n(%)			0.20			0.07
Landline	181 (40.9)	158 (35.1)		208 (40.5)	131 (34.5)	
Cell	259 (58.5)	288 (64.0)		303 (59.1)	244 (64.2)	
VoIP	3 (0.7)	4 (0.9)		2 (0.4)	5 (1.3)	
Geospatial analysis n(%)						
>30 minute drive[a]	238 (53.7)	217 (48.2)	0.12	267 (52.0)	188 (49.5)	0.49
>60 minute drive[a]	143 (32.3)	125 (27.8)	0.16	158 (30.8)	110 (28.9)	0.60
Survey: Nearest regional center? n(%)			<0.01			0.02
>30min[b]	104 (23.5)	66 (14.7)		113 (22.0)	57 (15.0)	
<30min[b]	337 (76.1)	381 (84.7)		398 (77.6)	320 (84.2)	
Unsure	2 (0.5)	3 (0.7)		2 (0.4)	3 (0.8)	

The cohort was primarily born in the United States (89.5%) and of non-Hispanic White race (71.7%). 9.4% reported a Hispanic ethnicity. 25.3% had attained a high school education or less, while 20.4% had a post-graduate or professional degree. 19.6% had an annual household income less than $40,000, whereas 40.2% had an annual household income greater than $75,000. 63.2% of subjects were employed full-time and 55.1% were married. A majority were contacted via mobile phone (61.3%).

Willingness to travel for improved outcomes

Overall 50.4% were willing to travel 5 hours or more to increase their chance of being alive after five years; 42.6% were willing to travel 5 hours or more to decrease their risk of having a complication (Figure 1.2).

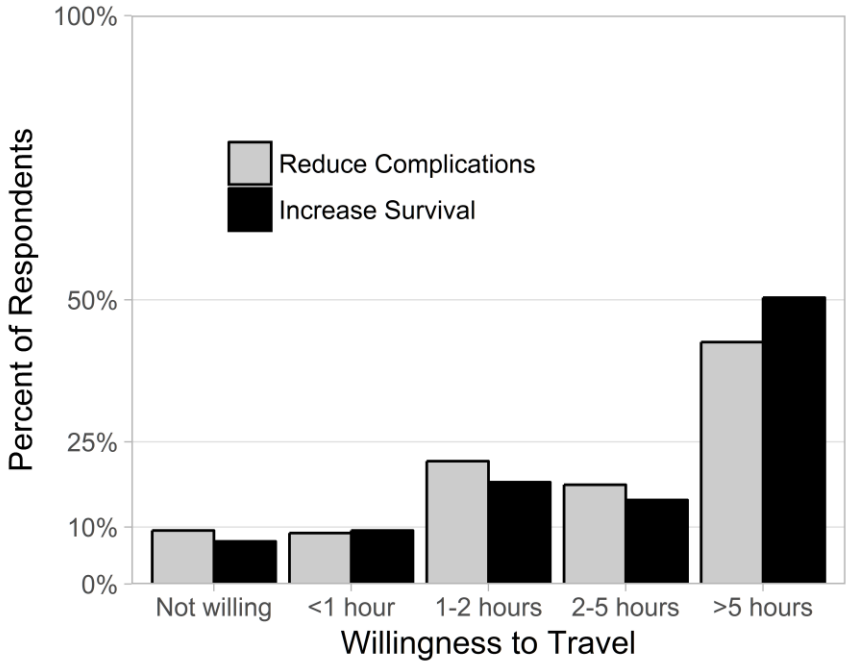

Figure 1.2. Time respondents were willing to travel to reduce complications (grey bars) or for increased survival (black bars). p=0.92 by Wilcoxon rank sum test for complications versus survival.

Compared to those willing to travel the longest to improve survival (≥5 hours), participants who were less willing to travel were older on average (47.4 years vs 57.0 years, p<0.01) (Table 1.3). A strong correlation was observed with willingness to travel and income, education, and employment. Compared to those willing to travel the longest, respondents unwilling to travel were less likely to have income >$75,000 per year (48.4% vs. 31.8%, p<0.01), be employed full-time (71.3% vs. 54.9%, p <0.01), or have a post-graduate education (22.0% vs. 18.7%, p=0.05). No significant differences in willingness to travel were noted with respect to gender, contact method,

marital status, political ideology, or race. Similar trends in subject characteristics were observed in willingness to travel long distances to reduce their risk of complications.

In a multiple logistic regression model, high household income (>$75,000/year) was correlated with willingness to travel for better survival (OR 2.09 95%CI 1.39-3.16), whereas age >70 (OR 0.34 95%CI 0.19-0.60), was negatively correlated with a willingness to travel (Table 1.4).

Table 1.4. Odds ratios (95%CI) for willingness to travel five or more hours for improved survival or reduced complications.

	For Improved Survival	For Reduced Complications
Female (vs. male)	1.08(0.82-1.43)	1.14(0.86-1.51)
Age (years)		
18-35	Ref	Ref
36-55	1.06(0.71-1.58)	1.00(0.67-1.50)
56-70	0.68(0.45-1.04)	0.62(0.41-0.95)
>70	0.34(0.19-0.60)	0.42(0.23-0.74)
Race/Ethnicity		
Hispanic	Ref	Ref
White	1.24(0.76-2.03)	1.05(0.64-1.72)
Black	0.90(0.46-1.74)	0.78(0.40-1.51)
Asian	1.04(0.43-2.54)	0.72(0.30-1.73)
Other/multiple	1.39(0.71-2.71)	1.52(0.78-2.98)
Annual Household Income		
<$45k	Ref	Ref
$45k-70k	1.18(0.80-1.82)	1.31(0.88-1.97)
>$70k	2.09(1.39-3.16)	2.35(1.55-3.60)
Marital status		
Married	Ref	Ref
Divorced/Widowed/Separated	1.21(0.80-1.81)	1.10(0.72-1.67)
Single	1.11(0.76-1.63)	1.14(0.78-1.68)
Geospatial analysis: >30min drive	0.92(0.67-1.22)	1.04(0.78-1.38)
Survey: Think >30min from center	0.60(0.41-0.86)	0.63(0.43-0.91)

Age of 56-70 was also associated with lower willingness to travel for reduced complications (OR 0.62 95%CI 0.41-0.95). Race, gender, and marital status were not significantly associated with willingness to travel.

Geospatial analysis

80.4% of respondents stated that they lived within 30 minutes of a major referral center. However, only 69.9% of all respondents' ZIP Codes were within a more liberal 60-minute buffer of a major center based on drive-time analysis. Of those who stated that they lived near a major center, 44.3% were in fact within 30 minutes of one. 24.1% of those who did not think they lived near a major center did in fact live within 30 minutes of one (Figure 1.3).

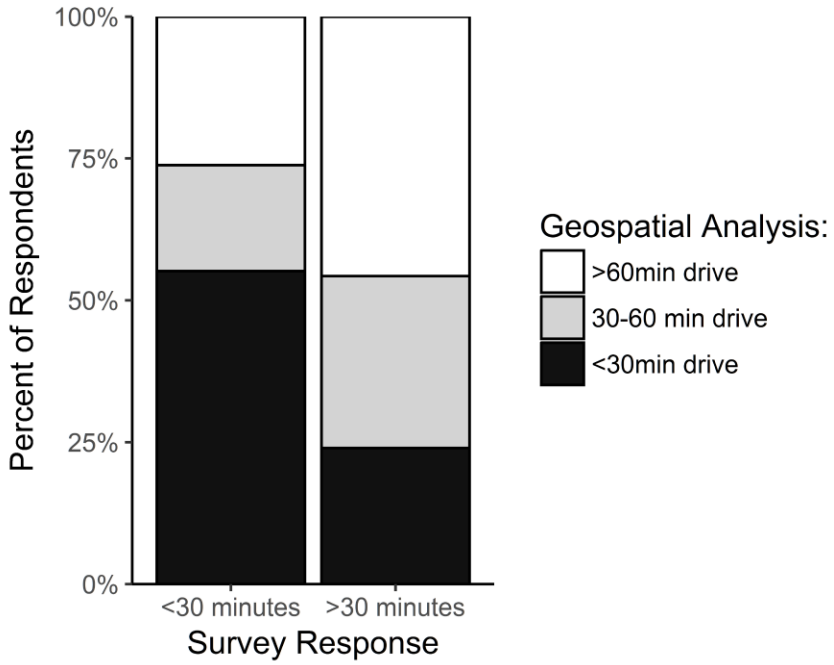

Figure 1.3. Concordance of survey response to "Do you live within 30 minutes of a major referral or regional hospital?" and real-world geospatial analysis based on drive-time to known regional centers

Cohen's kappa measuring the agreement between participant location and self-reported distance to a major referral center was 0.176 ($p<0.001$) suggesting weak concordance (Table 1.5).

Table 1.5. Survey response concordance with geospatial analysis.

Cohen's Kappa = 0.176, $p<0.001$.

		Geospatial Analysis: drive-time			
		<30 min	**30-60min**	**>60min**	**Total**
Survey Response	**≤30min**	396(44.3%)	134(15.0%)	188(21.1%)	718(80.4%)
	>30min	41(4.6%)	50(5.6%)	79(8.8%)	170(19.0%)
	Unsure	1(0.1%)	3(0.3%)	1(0.1%)	5(0.6%)
	Total	438(49.0%)	187(20.9%)	268(30.0%)	893(100.0%)

On multivariable analysis, participants who thought they lived farther than 30 minutes from a major center were less willing to travel for improved survival (OR 0.60 95%CI 0.41-0.86) or complications (OR 0.63 95%CI 0.43-0.91), but the real-world geospatial analysis was not correlated with willingness to travel (OR 0.92 95%CI 0.67-1.22)(Table 1.4).

Qualitative themes

Qualitative analysis of public perceptions of barriers to regionalization identified 39 categories within six major themes: transportation, life disruption, tangible social support, socioeconomic barriers, poor health, and remoteness (Table 1.6).

Table 1.6. Qualitative analysis of barriers to regionalization. Main themes, frequently mentioned categories, and select key quotes. Infrequent categories are omitted.

Main Theme	Major Categories	Key Quote
Life disruption	Work Obligations	*"I don't know if I could drive long distances and keep my job."*
	Family Obligations	*"I have a disabled son, so that would be an issue. Who would be caring for him while I'm traveling?"*
	Burden of follow up	*"Post-op care is probably better if you're local and can still travel once a year for checkups."*
	Too much additional effort	*"I am too darn lazy to drive more."* *"It would be difficult to be away from your normal life that you need to take care of."*
Transportation	Access to transportation	*"There is no public transportation in this town. I see this as a barrier."*
	Cost of transportation	*"I would rather go to a local hospital because of the gas to get there and back."*
	Traffic, parking, other barriers	*"I would say the traffic more than anything, especially going into Chicago."*
Lack of socioeconomic resources	Financial constraints	*"It all comes down to money. It would cost a lot of money."*
	Lodging for visitors or themselves	*"I could see other people having problems with housing themselves at a hotel or coming up with money for hotels."*
	Insurance coverage	*"I think one barrier would be if they didn't accept my healthcare provider. Obviously, I would have to pay hundreds and thousands of dollars if they didn't accept it. That would hinder my feelings about this."*
	Difficulty accessing care	*"A referral for doctor at a certain hospital would be the biggest deterrent."*

Table 1.6 Continued

Poor health	Poor current health	*"I have COPD so it might be difficult to travel."*
	Health in the future	*"If my health were really poor, driving might be tough."*
	Discomfort or pain of travel	*"It's kind of hard to drive that far if you're very ill. I recently had complication with a tumor, and it was difficult to drive an hour to get to the hospital just because of how I felt."*
	Risk of complications	*"The major barrier in case of complication would be the time and effort to get back to original hospital."*
Remoteness and geography	Time & distance	*"The barrier we have in our community is mostly because we are so far from hospitals; they are so far."*
	Weather	*"The mountain passes are full of snow."*
Tangible social support	Lack of help	*"I think for me the barrier would be that I'm single so it's making arrangements for my house while I'm gone."*
	Burden to others	*"It would be hard for family to take care of me."*
	Isolation from visitors	*"Nothing physical would be a barrier for me. I just wouldn't want to be far from my family…I would personally want to be closer to my family during a time like that."*
	Need of someone to drive	*"My concern would be how I would get there. I would need someone to drive me there."*
Other	Age	*"Being almost 80 years old is somewhat of a barrier."*
	Health literacy	*"I think another barrier is knowing who is the best in the field and how to get to them…knowing who is the best doctor in the field and how to get in touch with that person."*
	Preference for palliative care	*"I've already had cancer. I just want to go as peacefully as I can at this point; I'm not trying to complicate anything."*
	Don't see the benefit of larger centers	*"Whenever you are in a big hospital you get treated like a number. You don't get the personal attention aspect of it."*

Transportation was the most frequently mentioned perceived barrier to regionalized care (Figure 1.4).

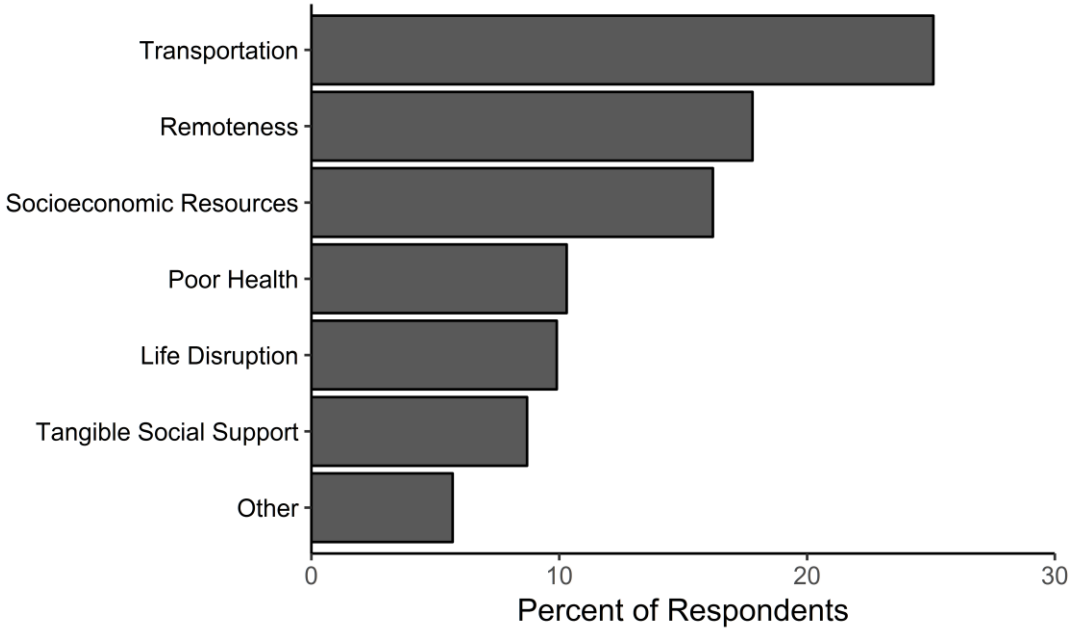

Figure 1.4. Frequency that each major theme was mentioned in participant responses. Frequencies do not sum to 100%, as responses could be coded with multiple themes.

Subjects mentioned transportation barriers in the context of cost, as well as access to transportation itself (Table 1.6): “There is no public transportation in this town. I see this as a barrier.” Remote geography or bad weather were also barriers frequently raised by participants.

Life disruption from increased travel was expressed in several different areas. Some participants noted work or family obligations that would be disrupted, “I have a disabled son, so that would be an issue. Who would be caring for him while I'm

traveling?" Life disruption was also expressed as difficulty with follow up, or simply the extra effort, "I am too darn lazy to drive more."

Socioeconomic pressure was an important perceived barrier for some. Financial constraints, worries about insurance and access to care, and hotel lodging at a regional center could all inhibit a patient from seeking regionalized care: "It all comes down to money. It would cost a lot of money."

Paradoxically, health problems themselves were perceived as a barrier by some participants. Either poor current health ("I have COPD"), or the discomfort of traveling while ill could be problematic. Several participants also speculated that the increased distance would be a problem if a complication arose after discharge: "The major barrier in case of complication would be the time and effort to get back to [the] original hospital."

Indirectly, many subjects noted the need for social support. Some were concerned with the increased isolation from visitors from traveling farther, while others were concerned with the logistics of finding someone to drive them, "I would need someone to drive me there."

Some participants rejected the premise that regionalized care would be better for them. Those participants saw larger centers as more impersonal, "Whenever you are in a big hospital you get treated like a number. You don't get the personal attention aspect of it." Others simply didn't think that outcomes really would be better, "One barrier would be if I didn't expect the level of care to be better." A few noted that even if the premise were accurate, they would not want aggressive treatment, "I've already

had cancer. I just want to go as peacefully as I can at this point; I'm not trying to complicate anything."

Theoretical Framework

Based on a thematic analysis of the qualitative data we developed a theoretical framework of barriers to regionalized surgical care from the public's perspective (Figure 1.5).

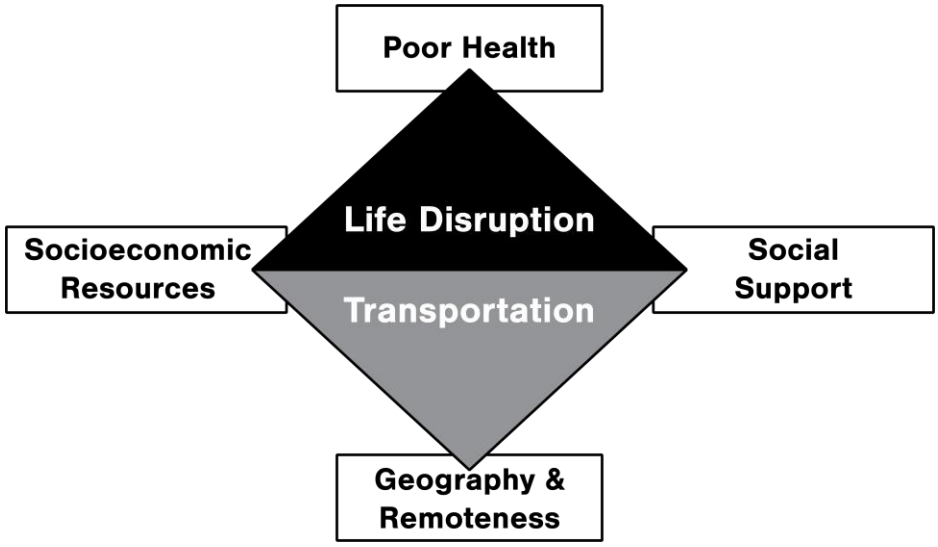

Figure 1.5. Theoretical framework for qualitative analysis

Central to this framework are the barriers of transportation and life disruption, which were either explicitly or implicitly mentioned in most responses. The theme of life disruption is related to secondary themes of socioeconomic resources, poor health, and social support. Transportation is interrelated with the themes of socioeconomic resources and social support, as well as remoteness and geography.

Discussion:

This is the first study to examine patient's perceived barriers to regionalized surgical care on a national level. Using a mixed methods survey of 1,000 adults in the United States we observed varied attitudes toward traveling long distances for regionalized cancer care. Willingness to travel is strongly correlated with high income and younger age. Based on a geospatial analysis many participants were unaware of their proximity to a major regional center, with 24% of those who didn't think they lived near a major center actually living within 30 minutes of one. We identified six major perceived barriers to regionalization that need to be overcome to effectively implement regionalization and developed a theoretical framework synthesizing these themes for future work.

Patient perspectives on regionalized surgical care have not been well evaluated. One study in Veterans Affairs patients awaiting elective surgery noted that 45% of patients still preferred local care even if it might double their operative mortality.[11] Another small Canadian study showed that only 9% of patients would be unwilling to seek regionalized care for lower operative mortality, although 85% of participants were within two hours of the tertiary center.[12] Our results are roughly in line these findings, as in our cohort only 16.9% were unwilling to travel one hour for lower mortality. Additionally, we showed that subjects are also willing to travel for reduced complications.

There was poor concordance between our geospatial analysis of participant location and self-reported distance to a major regional center. This discrepancy likely reflects the challenge that patients have in identifying high volume centers. Although

there are consensus definitions of high volume surgery for some procedures, such as in pancreatectomy, this is not the case for many complex procedures and these definitions may be challenging to interpret even for clinicians.[19,20]

The six major barriers to use of a regional hospital that participants identified have important implications for the feasibility of regionalization. While barriers such as transportation may be straightforward to address, others will prove more stubborn. Some solutions like telehealth interventions are readily available and may be particularly well suited to improving regionalized care systems.[21–23] Similarly, mobile health applications can decrease the burden of travel for patients while maintaining effective patient-surgeon dialogue regarding recovery. However, other barriers to regionalization, such as the discomfort of travel, geographic remoteness of many patients, and the additional life disruption associated with more travel are important but challenging to address. Social support is an important determinant of health, but there are limited interventions to improve social support generally.[24,25] Further research in regionalization will need to include patient reported outcomes to capture these issues. These factors should also be considered when designing and implementing regionalization policy initiatives.

Our results must be interpreted with regard to a few limitations. Our survey method excludes those without phones, non-English speakers, and those too sick to respond, groups at particularly high risk of marginalization in a regionalized system. Our cooperation rate was 48.1%, and there is some risk of selection bias due to this. We also asked respondents to imagine a hypothetical scenario requiring surgery. A few respondents explicitly mentioned facing a similar situation, but for others their

survey responses might differ from their actions if confronted with a need for surgery. There is disagreement even in the literature as to what constitutes a high volume or "major referral center," and our respondents' answers about their proximity to such a center may reflect this uncertainty rather than a lack of knowledge.[26–28]

Some Americans are willing to travel long distances to undergo major cancer surgery at a regional academic center. However, knowledge of the proximity of such centers was limited for many participants. Additionally, we found that age and socioeconomic status are major determinants of willingness to travel for care. Americans perceive that transportation, life disruption, geographic remoteness, poor health, socioeconomic resources, and social support are barriers to seeking regionalized surgical care. If complex surgical care is shifted exclusively to high volume centers these barriers will need to be addressed. Further research should characterize patient preferences with greater depth, particularly in vulnerable populations.

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CHAPTER TWO

A Mobile Health Application to Track Patients After Gastrointestinal Surgery: Results from a Pilot Study*

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Introduction:

Readmission after gastrointestinal surgery is common with consequences for both patients and the healthcare system.[1,2] As many as 23% of patients are readmitted within 90 days after colorectal surgery, incurring extensive additional healthcare costs.[3,4] Many readmissions are potentially preventable and occur due to dehydration, ileus or obstruction, and surgical site infection, with dehydration being the most common after colectomy.[5–8] As lengths of stay are shortened, readmission rates may also continue to increase.[9]

Several resource-intensive follow-up protocols have used to coordinate care, prevent readmissions, and improve function and satisfaction.[10–13] However, these programs are costly and difficult to disseminate in a widespread manner. Mobile health is a scalable and relatively low-cost technology that could accomplish many of the same aims.[14–16] Most adults own a smartphone regardless of socioeconomic status, and prospective patients are willing to use mobile health technology to improve their health.[17,18] Mobile health technology has been used in medical patients to decrease length of stay, improve glycemic control, and enhance medication compliance.[19–21] Despite this, mobile health has not been widely adopted in surgery.[22]

Over the past three years our team has worked with developers at our tech campus to create a novel smartphone application to track patients after gastrointestinal surgery. We report here results from our pilot study on the feasibility and usability of the app in a busy colorectal surgery practice. We demonstrate the type of information collected and how it can be used to describe the average patient recovery. We also

report on several areas identified for improvement and patient satisfaction with using the application.

Materials and Methods:

Application Development

With a focus on readmission in older adults, we began application development with literature review and interviews of key stakeholders in postoperative recovery including patients, surgeons, nurses, enterostomal therapy nurses, and office staff. We explored currently available applications, design elements which improve patient compliance, and validated survey instruments related to recovery. The smartphone application was then created, iteratively tested, and refined to improve the interface and streamline data processing for researchers (Figure 2.1).

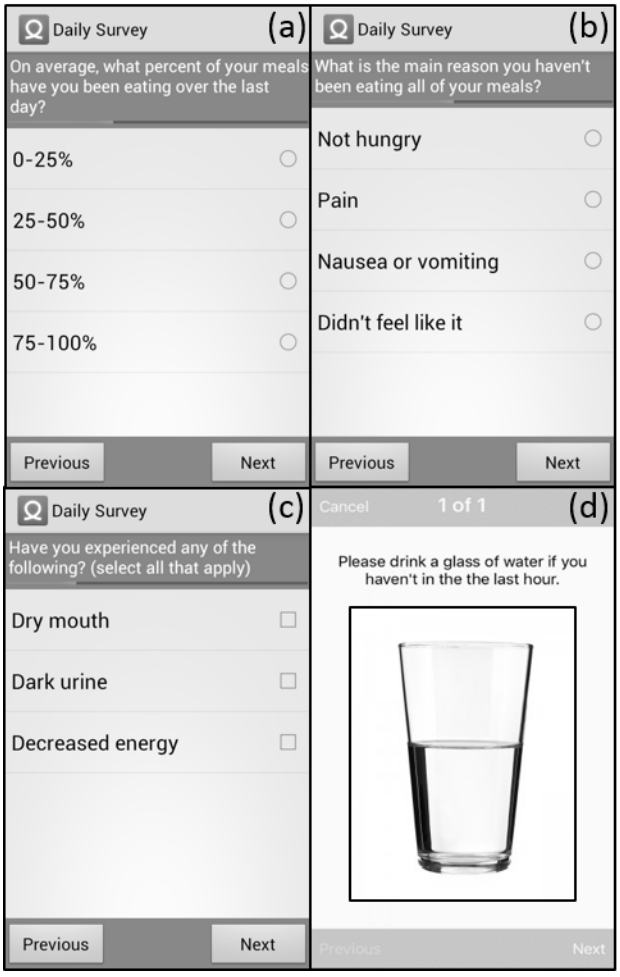

Figure 2.1. Sample screenshots of the mobile health application surveys.

The application runs on both Android and iOS devices and has five main components: (1) surveys with both general questions and questions tailored to surgery type (e.g. with or without questions about stoma output); (2) alerts to both patient and clinician when survey responses were concerning as well as reminders to drink water; (3) patient-provided photographs of their surgical site, ostomy if present, and urine; (4) step-count tracking via a Fitbit™ Charge HR device, and (5) a single item visual measure of affect (the photoaffective meter or PAM) [23]. The PAM is a validated

tool based on the PANAS survey (Positive And Negative Affect Schedule), which provides participants with a matrix of randomly distributed pictures, each of which reflects an emotional state.[24] Once a day, the participant chooses a photo which most reflects their current emotional state.

Survey questions used branching logic and several different questions types, such as linear scales, multiple choice responses, and single item questions. Questions were designed to identify nascent common causes of preventable readmission such as dehydration and poor oral intake. Answer options utilized clear numeric cutoffs whenever possible to minimize subjectivity in responses (for example, fever was defined as temperature greater than 38.5°C and high ostomy output as greater than 1200cc per day). Responses to our end of study survey were anonymous and surgeons were blinded to the responses of their patients. The study was approved by the Weill Cornell Institutional Review Board # 1402014799.

Study population

Adult colorectal surgery patients (≥18 years old) were recruited from our institution between September 2015 and January 2017. Patients were recruited from the colorectal surgery clinics of six surgeons at a busy university hospital, and they underwent either laparoscopic or open abdominal surgery for a variety of benign or malignant conditions. Patients were excluded if did not own or could not use an Android or iOS smartphone or were non-English speaking.

Intervention

A research assistant helped each patient install the application on their smartphone and instructed them in its use. Patients were provided with a Fitbit™ device for daily step count tracking, and two days of preoperative Fitbit™ data were collected. During their hospital stay, patients were instructed to practice using the application and they continued using it after discharge from the hospital until postoperative day 30.

To minimize excessive alerts, warnings were designed to be triggered only by serious conditions likely to require intervention. Such conditions included vomiting, fever, and excessive ostomy output, and were based on the most common causes of readmission (ileus/obstruction, dehydration, surgical site infection and excessive ostomy output).[25] Abnormal patient responses to survey questions (e.g. fever, vomiting, or poor oral intake) triggered two alerts: one instructing the patient to contact the surgeon's office and one informing a clinician of the patient's abnormal response. A surgeon reviewed the patient-submitted photographs on a secure portal on a daily basis, while the research team reviewed any alerts generated from the surveys, and alerted the nursing staff to any concerns about individual patients. Appropriate contact and follow-up could then be coordinated by the clinical team. Other patient-submitted data including results of the photoaffective meter, and step count were reviewed by a clinician and member of the research team.

Outcomes and definitions

Primary outcome was feasibility of mobile application use to track patient recovery, which we defined as the percent of patients who completed a daily survey-related

tasks. Our *a priori* definition of feasibility was >75% of patients completing at least one task within the app greater than 70% of the possible days. Secondary outcomes included the overall percent completed of individual types of tasks, number of days until return to baseline activity (determined by return to preoperative number of daily steps taken), trends in postoperative pain scores (measured on a 0-10 scale), patient satisfaction with application use (measured by an end-of-study patient-reported survey using a Likert scale), and number of days with a technological problem preventing data acquisition or analysis. Demographic variables including age, gender, race and ethnicity were collected for each patient. Readmissions during the study period were tracked via patient self-report and chart review. Events and percentages are reported based on eligible patients who participated in the study. Analyses were performed with R v3.3.2.[26]

Results

Patient Characteristics

41 patients consented, with 31 participating in the study. Seven patients withdrew after surgery but prior to study commencement, one was lost to follow-up, one was ineligible because of emergent surgery at another institution, and one was ineligible because their phone was incapable of running the application due to data storage availability. Of those who completed the trial, mean age was 51.7y (range 21-75), 18(58.1%) were female, and 19(61.3%) were white (Table 2.1).

Table 2.1. Overall cohort characteristics.

ASA = American Society of Anesthesiologists

Patient Demographics	N=31 n(%)
Age mean(range), years	51.7y(21-75)
Female	18(58.1)
Ethnicity	
Hispanic	5(16.1)
Non-Hispanic	26(83.9)
Race	
White	19(61.3)
Black	5(16.1)
Asian	1(3.2)
Other	6(19.4)
ASA class	
II	22(71.0)
III	9(29.0)
Laparoscopic surgery	27(87.1)
Diagnosis	
Colorectal cancer	15(48.4)
Diverticulitis	9(29.0)
Inflammatory bowel disease	5(16.1)
Other	2(6.5)
Stoma created	6(19.4)
Length of stay median(IQR), days	4d(4-6)
30-day readmission	1(3.3%)
Smartphone Operating System	
Android	14(46.7)
iOS	17(54.8)

17(54.8%) of patients used an iPhone to access the application. Six colorectal surgeons contributed patients to the study, 6(19.4%) of patients had an ostomy, and 27(87.1%) had a laparoscopic surgery. Most were American Society of Anesthesiologists Class II, and median length of stay was 4 days (interquartile range 4-6 days).

Application use

Of those who participated, all completed some component of the survey questions. During the 30 postoperative days 26(83.9%) of patients interacted with the app by completing a survey or taking a photo at least 70% of the time, our definition of feasibility. On a daily basis, average completion of tasks at the end of 30 days was highest for the Fitbit™ and lowest for photos (84.8% vs. 51.4%) (Figure 2.2).

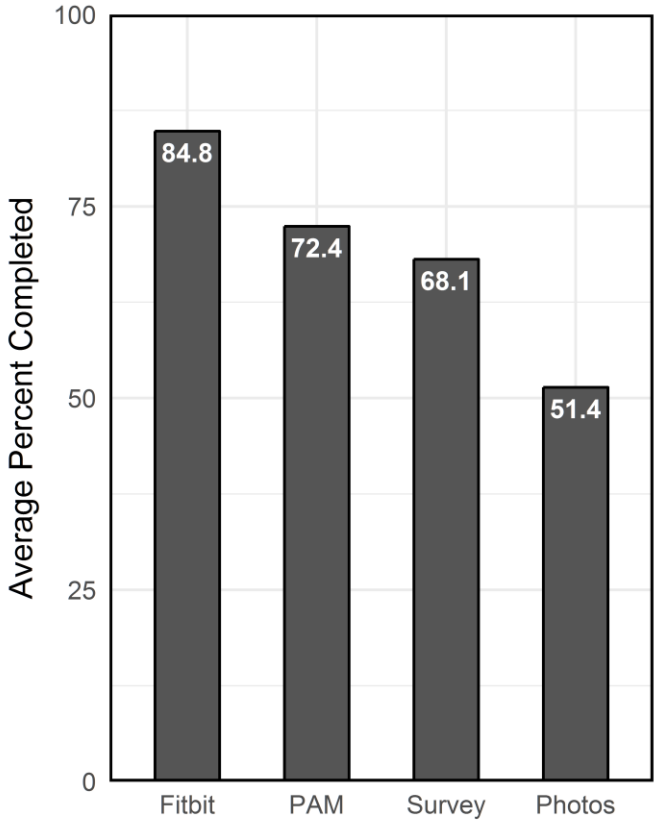

Figure 2.2. Average daily survey completion rates during first 30 postoperative days. PAM = photoaffective meter.

On average, 68.1% of participants completed a survey every day for 30 days, and a single item measure of affect (the photoaffective meter) was completed 72.4% of those days. 5.7% of patient-days had a technological problem that prevented data analysis. Examples of technological issues included wireless connectivity problems, difficulty uploading photos at the appropriate time, and server-sided problems with clinicians viewing patient data. Patient utilization of the application and survey participation did not change during the 30 postoperative days ($p=0.54$ by Cochran-Armitage test for trend).

Recovery

Patients returned to baseline activity, as measured by return to preoperative daily step count, in an average of 30 days. Median pain scores peaked on postoperative day 5 and remained below 3 out of 10 after postoperative day 10 (Figure 2.3).

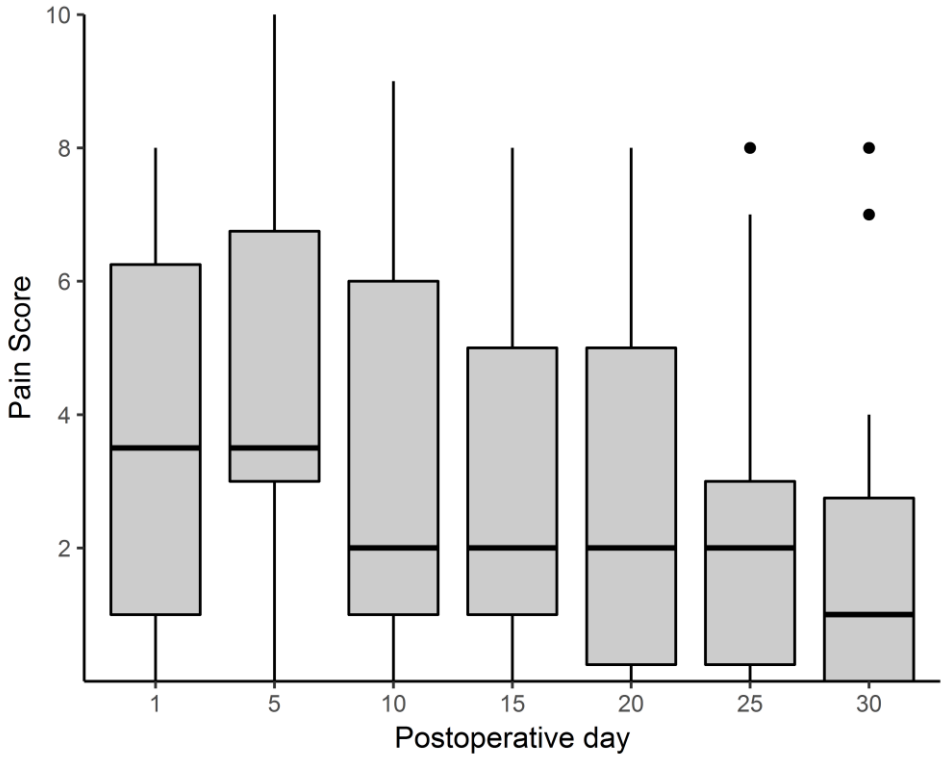

Figure 2.3. Boxplot of patient reported pain during the first 30 postoperative days, based on a scale from 0 to 10.

Eight patients (26.7%) generated alerts based on concerning responses, for an overall average of 1.1 alerts per patient. One patient was readmitted for gastroenteritis, generating seven alerts which initiated patient-provider contact prior to eventual readmission.

Patient satisfaction

At the end of the study period, 89.3% of patients reported that the application was easy to navigate and 88.9% found the survey questions easy to answer. 85.2% of patients thought that the survey questions were relevant for identifying problems related to

readmission, 66.7% found the reminders to drink water useful, and 92.9% would recommend the application to a friend who was undergoing surgery (Table 2.2).

Table 2.2. Patient reported satisfaction with the mobile health application at study conclusion. Responses reported are based on a 5-point Likert scale. Not all participants completed all survey questions.

Question	**n(%) Responding easy/useful/willing**
Did you find the application itself easy to use, understand, and navigate?	25(89.3)
Did you find the questions easy to understand and respond to?	24(88.9)
Did you find the content of the questions to be relevant and useful for the purposes of identifying potential problems that may lead to readmission?	23(85.2)
Did you find the reminders to be useful?	18(66.7)
Did you find the application to be useful overall, and would you be willing to recommend it to other patients?	26(92.9)

Discussion:

Our results demonstrate that it is feasible and easy to use a novel mobile health application to track postoperative recovery in patients after major abdominal colorectal surgery. The vast majority of patients (83.9%) contributed data at least 70% of the time during the first 30 postoperative days, and the number of patients participating did not decline with time. We collected many different types of data relevant to recovery including wound photographs, step-counts, and pain scores.

Overall, patients overwhelmingly found the application easy to use and would recommend it to a friend.

Despite the rapid expansion of the field of mobile health there have been limited studies in surgical patients. One recent trial in breast reconstruction patients reduced the number of outpatient visits with the use of a mobile application, but did not report on participants' compliance with app use.[22] Other applications have incorporated aspects of patient reported outcomes, activity tracking, or wound photographs in postoperative patients.[27–30] Our application is unique in the breadth and variety of relevant data that it is able to capture.

Readmissions are difficult to predict at the time of hospital discharge and often are the result of post-discharge complications.[31,32] This uncertainty reinforces the need for ongoing, early identification of post-discharge problems. The judicious use of pre-specified alerts allows us to rapidly identify problems that might require patient-provider contact. Improved triage to the appropriate setting may reduce readmissions as well as the amount of care that occurs at outside institutions.[33] Providers interested in adopting this technology may worry that it will lead to onerous patient-provider contact. We found on average each patient generated only 1.1 alerts in 30 days, limiting the burden to the staff monitoring patient recovery. There are numerous other potential benefits of this system including reduced length of stay and improved patient satisfaction with the recovery process.

We are limited by the single-center nature and size of our study. 5.7% of patient days had a technological problem which prohibited data collection, mostly due to connectivity issues. We have since enhanced both connectivity and security by

providing a secure hotspot router for inpatients enrolled in the trial, and by having data more frequently pushed to the server. We have also continued to iteratively refine the application to enhance reliability and incorporate patient feedback. Subsequent application versions give participants greater flexibility to upload stored photographs, such as from their last wound care nursing visit. While this version of the application is focused on the postoperative period, subsequent versions will incorporate preoperative bowel prep and oral antibiotic reminders into the application.[34,35] We have begun a randomized controlled trial in a more diverse range of general surgery patients using the next version of the application.

Conclusion:

It is feasible to track postoperative recovery after major gastrointestinal surgery using a novel mobile health application. The application has a wide range of functionalities including collecting patient-reported outcomes, generating alerts for concerning symptoms, transmitting photos of surgical incisions, and recording daily step count with a Fitbit. Despite the extent of information gathered, patients found the application easy to use. As such, we believe further studies are warranted to demonstrate the ability of healthcare apps to improve outcomes and study important endpoints such as readmission rates.

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