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Consumer Wearables Data Impact Pediatric Surgery Clinicians' Management: A Multi-Institutional Scenario-Based Remote Simulation Study

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Abstract

Background: At present, parents lack objective methods to evaluate their child's postoperative recovery following discharge from the hospital. In result, clinician's are dependent upon a parent's subjective assessment of the child's health status and the child's ability to communicate their symptoms. This subjective nature of home-monitoring contributes to unnecessary emergency department (ED) utilization as well as delays in treatment. However, the integration of data remotely collected using a consumer wearable device has the potential to provide clinicians with objective metrics for postoperative patients to facilitate informed longitudinal, remote assessment.

Objective: This multi-institutional study evaluated the impact of adding objective recovery data remotely collected by a consumer wearable device to postoperative telephone encounters on clinicians' management.

Methods: Three simulated telephone scenarios of post-appendectomy patients were presented to clinicians at five children's hospitals. Each scenario was then supplemented with wearable data concerning for or reassuring against a postoperative complication. Clinicians rated their likelihood of ED referral prior to and after the addition of wearable data to evaluate if it changed their recommendation. Clinicians reported confidence in their decision-making.

Results: Thirty-four clinicians participated. Compared to the scenario alone, the addition of reassuring wearable data resulted in decreased likelihood of ED referral for all three scenarios ($p<0.01$). When presented with concerning wearable data, there was increased likelihood of ED referral for two of three scenarios ($p=0.72$, $p=0.02$, $p<0.001$). At the institutional level, there was no difference between the five institutions in how the wearable data changed the likelihood of ED referral for all three scenarios. With the addition of wearable data, 76-88% of clinicians reported increased confidence in their recommendations.

Conclusions: The addition of wearable data to simulated telephone scenarios for post-discharge pediatric surgery patients impacted clinicians' remote patient management at five pediatric institutions and increased clinician confidence. Wearable

devices are capable of providing real-time measures of recovery which can be employed as a post-operative monitoring tool to reduce delays in care and avoidable health care utilization.

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Background: At present, parents lack objective methods to evaluate their child's postoperative recovery following discharge from the hospital. In result, clinician's are dependent upon a parent's subjective assessment of the child's health status and the child's ability to communicate their symptoms. This subjective nature of home-monitoring contributes to unnecessary emergency department (ED) utilization as well as delays in treatment. However, the integration of data remotely collected using a consumer wearable device has the potential to provide clinicians with objective metrics for postoperative patients to facilitate informed longitudinal, remote assessment.

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Results: Thirty-four clinicians participated. Compared to the scenario alone, the addition of reassuring wearable data resulted in decreased likelihood of ED referral for all three scenarios ($P<.01$). When presented with concerning wearable data, there was increased likelihood of ED referral for one of three scenarios ($P=0.72$, $P=0.17$, $P<.001$). At the institutional level, there was no difference between the five institutions in how the wearable data changed the likelihood of ED

referral for all three scenarios. With the addition of wearable data, 76-88% of clinicians reported increased confidence in their recommendations.

Conclusion: The addition of wearable data to simulated telephone scenarios for post-discharge pediatric surgery patients impacted clinicians' remote patient management at five pediatric institutions and increased clinician confidence. Wearable devices are capable of providing real-time measures of recovery which can be employed as a post-operative monitoring tool to reduce delays in care and avoidable health care utilization.

KEYWORDS

Care, postoperative; Telehealth; Consultation, remote; Appendectomy; Pediatric hospitals; Children; Wearable devices; Surgery; Minimally invasive surgery

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INTRODUCTION

When children are discharged from the hospital after surgery, clinicians depend on caregivers' surveillance of the patient and analysis of their recovery to initiate communication with

the health care team. When a caregiver contacts the surgical team with concerns, clinicians rely on the caregiver's narrative of the patient's experience post-discharge in order to triage the patient. Currently, caregivers lack objective methods to evaluate recovery post-discharge. In result, they are dependent upon their subjective assessment of the child's well-being and the child's ability to communicate their symptoms. It has been shown that the subjective nature of home-monitoring contributes to both avoidable healthcare utilization and delays in treatment [1-4].

In the United States (US), laparoscopic appendectomy is the most common inpatient procedure in children, with approximately 80,000 to 100,000 performed annually [5]. Nearly 20% of appendectomies result in Emergency Department (ED) visits or readmissions within 90 days post-operatively, and greater than 40% of these ED presentations are potentially avoidable [6]. Clinician access to objective recovery data offers the potential for improved patient triage in the post-operative setting and would serve to reduce delays in care and unnecessary health care utilization. Consumer wearable devices, e.g., the Fitbit, have the ability to provide continuous objective measurements of recovery which include heart rate, step count and sleep assessment (i.e., "wearable data"). Furthermore, these data can be made available to clinicians in near-real time. With such features, wearable devices have the potential to assist clinicians in the remote evaluation and triage of post-operative patients after discharge [7-10].

Within our institution, we previously demonstrated that the addition of wearable data to simulated scenarios of unplanned post-operative episodes of health care utilization impacted pediatric surgery clinicians' decision-making, including a significant difference in the likelihood of recommending immediate presentation to the ED and increased confidence in clinicians' decision-making [10]. However, the results may not be generalizable to other institutions which are not as familiar with the use of wearable devices in the post-operative setting. Therefore, the objective of this multi-institutional study was to evaluate whether the addition of actual and simulated objective data derived from a consumer grade wearable device to telephone encounters derived from actual

post-operative patient encounters impacted the decision-making of a diverse cohort of pediatric surgery clinicians when presented in a simulation environment.

METHODS

The Institutional Review Board at all participating sites rendered this study appropriate for exemption status. To evaluate the clinical utility of wearable data, we presented three simulated post-discharge telephone scenarios to pediatric surgery clinicians. The three scenarios were based on actual patients who underwent laparoscopic appendectomy for acute appendicitis at an urban, tertiary children's hospital. All three patients had worn the Fitbit Inspire, a consumer grade wearable device, for 21 days after surgery as part of a previous study [8]. Surgeon authors (SL, CD and FA) selected these three patients to feature the most common postoperative complications following laparoscopic appendectomy, surgical site infections, and clinical scenarios which could have been clarified with the addition of wearable data [11]. The three scenarios presented were: (1) a thirteen-year-old female who underwent laparoscopic appendectomy for complicated appendicitis, and on post-operative day seven her caregiver called reporting two days of abdominal pain, loose stools and incisional drainage; (2) a ten-year-old female who underwent laparoscopic appendectomy for simple appendicitis, and on post-operative day three her caregiver called with report of two days of fevers, abdominal pain and peri-umbilical erythema; and (3) a nine-year-old male who underwent laparoscopic appendectomy for complicated appendicitis, and on post-operative day ten his caregiver called with report of two days of purulent drainage from one of his surgical incisions.

Daily step counts and heart rate data were measured by the Fitbit and recorded in Fitabase, a third party, Health Insurance Portability and Accountability Act (HIPAA) compliant database, designed to track data provided by an enrolled Fitbit device. The Fitbit data, in addition to information from the patient's electronic medical record, including actual documented encounters between caregiver and pediatric surgery clinicians and the documented descriptions of the patient's

symptoms as reported by the caregiver, were utilized to generate the simulated telephone scenarios. For each scenario, the patient's wearable data were utilized to create a daily heart rate graph and a daily step count graph, both of which included data from post-operative day one through the date of the telephone encounter. Additionally, the patient's average, minimum and maximum heart rate in the five minutes, one hour, four hours and twenty-four hours leading up to the encounter were displayed in a table. Using Fitbit data collected during our previously published study, the age and sex adjusted step counts collected from patients with an uncomplicated post-operative course after the same surgery were included as a normative reference for the clinician evaluating the patient's scenario [8].

The study team evaluated the patient's actual data at the time of telephone encounter and classified it as concerning if the patient's heart rate was elevated and physical activity reduced relative to the normative reference data. Contrarily, wearable data were classified as reassuring if the heart and physical activity were approximate to the normative reference data. The study team then created simulated wearable data for each scenario that were opposite to the actual data, i.e., simulated wearable data were concerning (elevated heart rate and low step count) when the patient's actual wearable data were reassuring (heart rate and step count within normal range for age). The source of the wearable data and the classification as concerning or reassuring was not shared with the clinicians who participated in the study. Representative concerning and reassuring wearable data for the 24 hours preceding the time of encounter for the three scenarios are demonstrated in **Table 1**.

Table 1: Concerning and reassuring wearable data for the 24 hours preceding the simulated telephone encounter for scenarios 1-3.

	Concerning	Reassuring
Scenario 1 – 13 year-old, POD 7		
Average Heart Rate (bpm)	86	86
Minimum Heart Rate (bpm)	63	63
Maximum Heart Rate (bpm)	121	103
Step Count	1100	6100
Scenario 2 – 10 year-old, POD 3		
Average Heart Rate (bpm)	80	80
Minimum Heart Rate (bpm)	60	60
Maximum Heart Rate (bpm)	142	105
Step Count	650	5100
Scenario 3 – 9 year-old, POD 10		
Average Heart Rate (bpm)	109	92
Minimum Heart Rate (bpm)	93	78
Maximum Heart Rate (bpm)	144	113
Step Count	2100	5050

Five pediatric institutions, located throughout the US, elected to participate in this study. The institutions which participated were diverse in practice setting; however, all were associated with an academic institution. Pediatric surgery clinicians, including attending surgeons, resident surgeons and advanced practice providers were recruited from the five participating institutions. Poll Everywhere (San Francisco, CA) audience response software was utilized for survey participation. At the start of the survey, the participants were oriented to wearable data from a patient with an uncomplicated post-operative course following laparoscopic appendectomy. The three telephone scenarios were then presented to the clinician participants in three formats. First, the scenario was presented without wearable data and participants were asked to triage the patient and determine the urgency for follow-up care, including seek care immediately, prescribe a medication with outpatient follow-up, outpatient follow-up alone, and provide reassurance without the need for follow-up. Clinicians were then asked to rate their "likelihood to recommend the patient present to the ED immediately" utilizing a 10-point Likert scale, with 1 representing "not at all likely to recommend ED presentation" and 10 representing they "definitely would recommend ED presentation."

The participants were then shown the telephone scenario with concerning and reassuring wearable data in random sequence and without revealing the classification to the respondents. Participants were asked their likelihood of recommending ED presentation utilizing the same 10-point Likert scale for both sets of wearable data. They were then asked to report if the wearable data increased their confidence in their recommendation and, if provided the wearable data alone, they would initiate contact with the patient and caregiver to assess their recovery. Participants were only offered the opportunity to respond to each multiple-choice question once. In total, the participants were asked to score their likelihood of recommending ED presentation for all three scenarios without wearable data, with concerning wearable data and with reassuring wearable data for a total of nine

recommendations for ED presentation.

Statistical Analysis

Survey responses were determined to be non-parametric by Shapiro-Wilk testing. Descriptive analyses were performed and included frequencies of response and median and interquartile ranges (IQR). Wilcoxon Rank Sum was performed comparing the clinician's recommendation for ED presentation without wearable data to their recommendation with concerning wearable data and reassuring wearable data. The likelihood of ED referral without wearable data was then subtracted from the likelihood of ED referral with wearable data to evaluate how a clinicians' management recommendation changed. A positive change was consistent with an increased likelihood of ED referral while a negative change was consistent with a decreased likelihood of ED referral. No difference indicated no change in likelihood of ED referral. To evaluate for institutional variation, the proportion of survey respondants at each institution who were more likely, less likely and did not change their likelihood of ED referral with the addition of wearable data was determined for each scenario and compared by Fisher's exact test. Statistical significance was defined as $P<.05$.

RESULTS

Thirty-four clinicians voluntarily participated in the study (**Table 2**). Site 3 contributed the greatest complement with twelve participants accounting for 35% of the study cohort. The smallest contributing site was site 1 with four participants accounting for 12% of the study cohort. Twenty-two (65%) of the participants were attending surgeons while 5 (15%) were advanced practice providers, 5 (15%) were surgery residents and 2 (6%) did not report clinician type. Response rates ranged from 23 (68%) to 29 (85%) responses per survey question.

Table 2: Survey participants by institution and clinician-type.

Institution	Attending	APN	Resident	Not Reported	Total
Site 1	N=4 (100%)	N=0 (0%)	N=0 (0%)	N=0 (0%)	N=4 (12%)
Site 2	N=4 (67%)	N=2 (33%)	N=0 (0%)	N=0 (0%)	N=6 (18%)

Site 3	N=4 (33%)	N=1 (8%)	N=5 (42%)	N=2 (17%)	N=12 (35%)
Site 4	N=5 (100%)	N=0 (0%)	N=0 (0%)	N=0 (0%)	N=5 (15%)
Site 5	N=5 (71%)	N=2 (29%)	N=0 (0%)	N=0 (0%)	N=7 (21%)
All sites	**N=22 (65%)**	**N=5 (15%)**	**N=5 (15%)**	**N=2 (6%)**	**N=34**

Scenario One

When scenario one was presented without wearable data, seventeen of twenty-eight respondants (61%) recommended outpatient follow-up while ten (36%) recommended they seek care immediately and one (4%) recommended reassurance without follow-up. When asked to rank the likelihood of recommending ED presentation, median recommendation was 5 (IQR 3-7). When presented with reassuring wearable data, median recommendation for ED presentation was 2 (IQR 1-3) with a median change from when no wearable data were available of -2 (IQR -4- -1, $P<.001$). ED referral was less likely for twenty-four of twenty-eight respondants (86%) in response to the reassuring wearable data while two (7%) did not change their recommendation and two (7%) were more likely to recommend ED presentation. Twenty-two of twenty-six respondants (85%) reported increased confidence in their recommendation with the addition of the reassuring wearable data while six of twenty-five (24%) reported that if they had been presented the reassuring wearable data alone, they would have initiated contact with the patient/caregiver in order to evaluate for a post-operative complication.

When the scenario was presented with concerning wearable data, the median recommendation for ED presentation was 5 (IQR 3-7) with median change of 0 (IQR 0-2, *P*=.72). Nine of twenty-five respondants (36%) were more likely to recommend ED referral in response to the concerning wearable data while twelve (48%) had no change in their recommendation and four (16%) were less likely to recommend ED referral. Twenty-one of twenty-four participants (88%) reported increased confidence in their recommendation, and twenty-two of twenty-six (85%) reported they would reach out to the patient/caregiver if presented the wearable data alone. Survey responses for scenario one are summarized in Table

3 and Figure 1. Response to the addition of reassuring and concerning wearable data by institution is demonstrated in Figure 2. There was no difference between institutions in how they responded to the addition of reassuring (*P*=.10) or concerning wearable data (*P*=.18).

Table 3: Simulated remote management recommendations from pediatric surgery clinicians at five institutions in response to telephone scenario one presented without wearable data, then with reassuring and concerning wearable data.

Scenario One *13-year-old female who is postoperative day 7 following laparoscopic appendectomy for complicated appendicitis now with 2 days of abdominal pain, loose stools & incisional drainage*			
	No Wearable Data	**Reassuring Wearable Data**	**Concerning Wearable Data**
Initial recommendation, N (%)			
Seek care immediately	N=10 (36%)		
Prescription & outpatient follow-up	N=0 (0%)		
Out-patient follow-up	N=17 (61%)		
Reassurance & no follow-up	N=1 (4%)		
Likelihood of ED referral, median (IQR)	**5 (3-7)**	**2 (1-3)**	**5 (3-7)**
Change in likelihood of ED referral, median (IQR)		-2 (-4 - -1)	0 (0-2)
P-value		***P*<.001**	*P*=.72
Increased confidence, N (%)		N=22 (85%)	N=21 (88%)
Would reach out to patient/caregiver, N (%)		N=6 (24%)	N=22 (85%)

Scenario Two

When scenario two was presented without wearable data, fourteen of twenty-eight respondants (50%) recommended outpatient follow-up while seven (25%) recommended a prescription and outpatient follow-up and seven (25%) recommended the patient should seek care immediately. Median likelihood of recommending ED presentation was 4 (IQR 2-6.75). When reassuring wearable data was presented with the patient scenario, the median likelihood of recommendation for ED presentation decreased to 2 (IQR 1-4). This represented a median change in score of -1 (IQR -2.5-0, *P*<.001). ED referral was less likely for sixteen of twenty-six respondants (62%) in response to the reassuring wearable data while seven (27%) did not change and three (12%) were more likely to recommend ED presentation. Twenty-three of twenty-seven respondants (85%) reported increased confidence in their recommendation when the reassuring wearable data were added. Only seven of twenty-three (30%) reported they would initiate contact with the patient/caregiver in response to the reassuring wearable data alone.

When concerning wearable data were presented with the scenario, the median recommendation for ED presentation was 5.5 (IQR 3-7.75) representing a median change of 0 (IQR 0-2, *P*=.17). With the addition of concerning wearable data, twelve of twenty-seven respondants (44%) were more likely to recommend ED referral while fourteen (52%) had no change in their recommendation and one (4%) was less likely to recommend ED referral. In addition, nineteen of twenty-five (76%) reported increased confidence with this recommendation and eighteen of twenty-three (80%) reported they would reach out to the patient/caregiver if presented the concerning wearable data alone. Survey responses for scenario two are summarized in **Table 4** and **Figure 1**. Response to the addition of reassuring and concerning wearable data for scenario two by institution is demonstrated in **Figure 3**. There was no significant difference between institutions in their response to the addition of reassuring (*P*=.90) or concerning wearable data (*P*=.053).

Table 4: Simulated remote management recommendations from pediatric surgery clinicians at five institutions in response to telephone scenario two presented without wearable data, then with reassuring and concerning wearable data.

Scenario Two *10-year-old female who is postoperative day 3 following laparoscopic appendectomy for simple appendicitis now with 2 days of fevers, abdominal pain, peri-umbilical erythema*			
	No Wearable Data	**Reassuring Wearable Data**	**Concerning Wearable Data**
Initial recommendation, N (%)			
Seek care immediately	N=7 (25%)		
Prescription & outpatient follow-up	N=7 (25%)		
Out-patient follow-up	N=14 (50%)		
Reassurance & no follow-up	N=0 (0%)		
Likelihood of ED referral, median (IQR)	**4 (2-6.75)**	**2 (1-4)**	**5.5 (3-7.75)**
Change in likelihood of ED referral, median (IQR)		-1 (-2.5–0)	0 (0-2)
P-value		***P*<.001**	*P*=.17
Increased confidence, N (%)		N=23 (85%)	N=19 (76%)
Would reach out to patient/caregiver, N (%)		N=7 (30%)	N=20 (80%)

Scenario Three

When scenario three was presented without wearable data, eighteen of twenty-eight (64%) recommended outpatient follow-up while six (21%) recommended the patient seek care immediately, and four (14%) recommended a prescription with outpatient follow-up. When asked the likelihood of

recommending ED presentation, median score was 3 (IQR 1-4.5). When reassuring wearable data were added, the median recommendation dropped to 2 (IQR 1-3) representing a median decrease in recommendation of 0 (IQR -2-0, *P*=.002). ED referral was less likely for thirteen of twenty-seven (48%) in response to the reassuring wearable data while thirteen (48%) did not change and one (4%) was more likely to recommend ED presentation. Twenty-three of twenty-seven clinicians (85%) reported increased confidence in their recommendation when the reassuring wearable data were added while six of twenty-five (24%) reported they would reach out to the patient/caregiver if presented the reassuring wearable data alone.

When presented concerning wearable data, the median recommendation for presentation to the ED increased to 7 (IQR 5-8), a median increase of 3 (IQR 0.5-5, *P*<.001). With the addition of concerning wearable data, twenty-two of twenty-nine respondants (76%) were more likely to recommend ED referral while five (17%) had no change in their recommendation and two (7%) were less likely to recommend ED referral. Twenty-two of twenty-five (85%) reported increased confidence in their recommendation when concerning wearable data were present. In addition, twenty-three of twenty-four (96%) reported they would initiate contact with the patient/caregiver if presented the concerning wearable data alone. Survey responses for scenario three are summarized in **Table 5** and **Figure 1**. Institutional response to the addition of reassuring and concerning wearable data for scenario three is demonstrated in **Figure 4**. There was no significant difference between institutions in their response to the addition of reassuring (*P*=.20) or concerning wearable data (*P*=.57).

Table 5: Simulated remote management recommendations from pediatric surgery clinicians at five institutions in response to telephone scenario three presented without wearable data, then with reassuring and concerning wearable data.

Scenario Three
9-year-old male who is postoperative day 10 following laparoscopic appendectomy for complicated appendicitis now with 2 days of purulent drainage from surgical port site

	No Wearable Data	Reassuring Wearable Data	Concerning Wearable Data
Initial recommendation, N (%)			
Seek care immediately	N=6 (21%)		
Prescription & outpatient follow-up	N=4 (14%)		
Out-patient follow-up	N=18 (64%)		
Reassurance & no follow-up	N=0 (0%)		
Likelihood of ED referral, median (IQR)	**3 (1-4.5)**	**2 (1-3)**	**7 (5-8)**
Change in likelihood of ED referral, median (IQR)		0 (-2-0)	3 (0.5-5)
P-value		***P*=.002**	***P*<.001**
Increased confidence, N (%)		N=23 (85%)	N=22 (88%)
Would reach out to patient/caregiver, N (%)		N=6 (24%)	N=23 (96%)

DISCUSSION

This study investigated the potential impact that post-operative objective measures of recovery collected by a consumer grade wearable device, the Fitbit, may have on the decision-making of pediatric surgery clinicians from five children's hospitals in the US. We found significant changes in recommendation for ED presentation when simulated telephone scenarios were supplemented with heart rate and step count data derived from the Fitbit. Clinicians reported increased confidence with their decision-making when supplemented with wearable data. Additionally, the majority of clinicians reported they would initiate contact with the patient and caregiver if they were presented concerning wearable data in isolation. How wearable data impacted clinicans' likelihood of ED referral did not differ between institutions. These findings support consumer wearables as a generalizable clinical tool and provide further impetus for their adoption as a low-cost and efficient post-operative post-discharge remote monitoring technology with the potential to decrease the burden of unnecessary health care utilization and delays in seeking care.

Our study demonstrates that when clinicians are supplied with objective data from a wearable device, they are able to interpret these data and incorporate them into their decision-making with significant changes in their recommendations for ED presentation compared to when no wearable data were provided. In the current practice model, a "worst-case" mindset is assumed. The clinician is blinded to any objective measure of recovery and is solely dependent on the subjective narrative provided to them by the caregiver and patient. Patient safety and the medicolegal system necessitates

this practice; however, it perpetuates health care saturation and associated costs as it often results in referral for in-person evaluation. The addition of objective data has the potential to reassure the clinician or reinforce—and even augment—clinical concern. For example, in scenarios one and two, there was no change in recommendation for ED presentation when concerning wearable data were added; therefore, the subjective information alone was concerning and the addition of objective data only stregthended confidence in this recommendation. However, when reassuring wearable data were supplied, the clinicians were significantly less likely to recommend ED presentation. As the subjective information for these scenarios did not change, this highlights the utility of objective measures of recovery and their value in clinical decision-making. Alternatively, when scenario three was presented with concerning wearable data, the clinicians' recommendation for ED presentation significantly increased; therefore, augmenting clinical concern for a post-operative complication. This demonstrates how delays in care may be avoided with the addition of wearable data.

Not only did the wearable data change the clinicians' assessment of post-operative post-discharge patients, but the data also gave the clinicians more confidence in their decisions. Greater than three-fourths of clinicians reported increased confidence in their recommendations when wearable data were added for all scenarios. This increase in confidence was reported regardless of whether wearable data were reassuring or concerning, and points to the incomplete information practitioners currently experience post-discharge, upon which practitioners are asked to make clinical decisions. Clinicians experience uncertainty regarding caregivers' ability to assess their child's recovery, and simple interventions to improve communication between the health care system and the caregiver reduce post-operative ED presentation by up to 50% [4, 10]. Moreover, with an enriched form of communication between the health care system, caregiver and patient, it is anticipated that unnecessary ED presentation could be reduced even further.

It is important to note that while these results indicate influence of wearable data on decision-making, it is not possible to determine, with certainty, from this study whether the addition of

wearable data influenced the clinicians' decision-making in a manner that can be delineated as correct. However, the changes seem to make clinical sense. Likewise, it is general practice for the institutions included in our study, and many others, that hemodynamically stable minor postoperative complications, such as a surgical site infection without systemic manifestations, be seen in the outpatient clinic if feasible to avoid the significant health care expenditure associated with the ED [6, 12]. Moreover, how the likelihood of ED referral changed in response to the addition of concerning or reassuring wearable data did not differ between institutions. This supports consistency in wearable data interpretation across diverse practice settings and despite expected variation in institutional practice patterns.

Avoidable ED use has become an important focus of quality improvement initiatives to decrease unnecessary health care expenditures and health care saturation [6, 13-15]. These initiatives were propagated by the adoption of digital health technology into clinical care. The momentum for this was largely propelled by the COVID-19 pandemic during which the US Centers for Medicare and Medicaid (CMS) equated reimbursement of in-person and telemedicine visits, which was accompanied by the alignment of third-party payers [16]. In result, many surgical departments implemented digital health platforms for post-operative patient care which have been shown to be effective and efficient means of delivering care to children in the perioperative setting [17-24]. However, the objective data obtained during an in-person encounter remain largely absent—there are no vital signs available to interpret and the physical exam is limited to visual inspection [17]. Consumer-grade wearable devices, such as the Fitbit, have been shown to supplant this absent objectivity by delivering measures of post-operative recovery including measures of heart rate, physical activity and sleep [7, 8].

Consumer wearable devices are unique in that they allow continuous capture and real-time transmission of health care measures which enables recovery trends to be examined [17]. When our survey participants were asked, 80-96% of clinicians reported they would reach out to the patient in

response to concerning wearable data while only 24-30% would do so in response to reassuring wearable data. This demonstrates heart rate and step count data derived from wearables can be accurately analyzed and interpreted with ease by clinicians and can be integrated as a monitoring tool if wearable data are presented in real-time. The integration of wearable data from Apple Health and Fitbit into the electronic health system has begun at several institutions [25]. Therefore, the practicality of wearables for post-discharge monitoring must be determined. This includes how data should be presented to optimize efficiency and how it will be incorporated into clinical workflow. Prior work has shown that clinicians favor data metrics familiar to them, such as heart rate, over those unique to wearable devices, such as step count [10]. Advances in wearable technology have continued to expand the range of measures available with newest models including measures routinely used in practice, such as respiratory rate and oxygen saturation, which would further enhance clinician comfort and desirability of use.

Limitations

This study has a number of limitations. First, the clinicians were responding to simulated patient scenarios. Although they were derived from actual patients, one set of wearable data was constructed for each scenario to create a pair of concerning and reassuring data. Second, clinicians were responding to these questions in a simulation environment and survey format, which is low stakes and low stress in comparison to the high-demand workflow experienced by clinicians in daily practice. Prospective studies using actual patients are necessary to determine how wearable data change clinical decision-making in practice and their impact on post-operative outcomes and health care utilization. In addition, the Likert scales employed for the survey were developed for the purposes of this study and have not been externally validated limiting the generalizability of our findings beyond this setting. Moreover, the sites included in the study were all high volume, academic children’s hospitals and the study participants may not be representative of all clinicians

caring for post-appendedctomy children throughout the US. Lastly, the majority of respondents were attending surgeons. Although use in practice requires further elucidation, system patterns suggest it is more likely nurse clinicians, advanced practice providers and surgeons-in-training who will field an initial post-operative telephone call. This further suggests the need to define the platform upon which wearable data will be implemented.

CONCLUSION

Wearable data enhance the communication between caregiver, patient and the health care team. The addition of objective measures of recovery to simulations of post-operative telephone scenarios impact the recommendations made by pediatric surgery clinicians from diverse practice settings and improves clinician confidence when making remote patient assessments. Augmenting remote patient assessment offers the potential for improved triage of pediatric patients and could serve to reduce avoidable health care utilization. Furthermore, wearable devices, such as the Fitbit, have the capability of providing real-time measures of recovery, which can be employed as a post-operative monitoring tool to avoid delays in care for pediatric patients with post-operative complications.

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CONFLICTS OF INTEREST

None declared.

ABBREVIATIONS

ED – emergency department

IQR – interquartile range

US – United States

REFERENCES

FIGURE LEGEND

Figure 1: Recommendation for emergency department presentation provided by pediatric surgery clinicians at five institutions when presented with three simulated telephone scenarios: 1) without wearable data, 2) with concerning wearable data, and 3) with reassuring wearable data. Likelihood of emergency department referral reported on a 10 point Likert Scale with 1 representing “Not at all likely” and 10 representing “Definitely”. *Significant change by Wilcoxon Rank Sum.

Figure 2: How the likelihood of emergency department referral changed at each institution with the addition of reassuring and concerning wearable data to scenario one.

Figure 3: How the likelihood of emergency department referral changed at each institution with the addition of reassuring and concerning wearable data to scenario two.

Figure 4: How the likelihood of emergency department referral changed at each institution with the addition of reassuring and concerning wearable data to scenario three.

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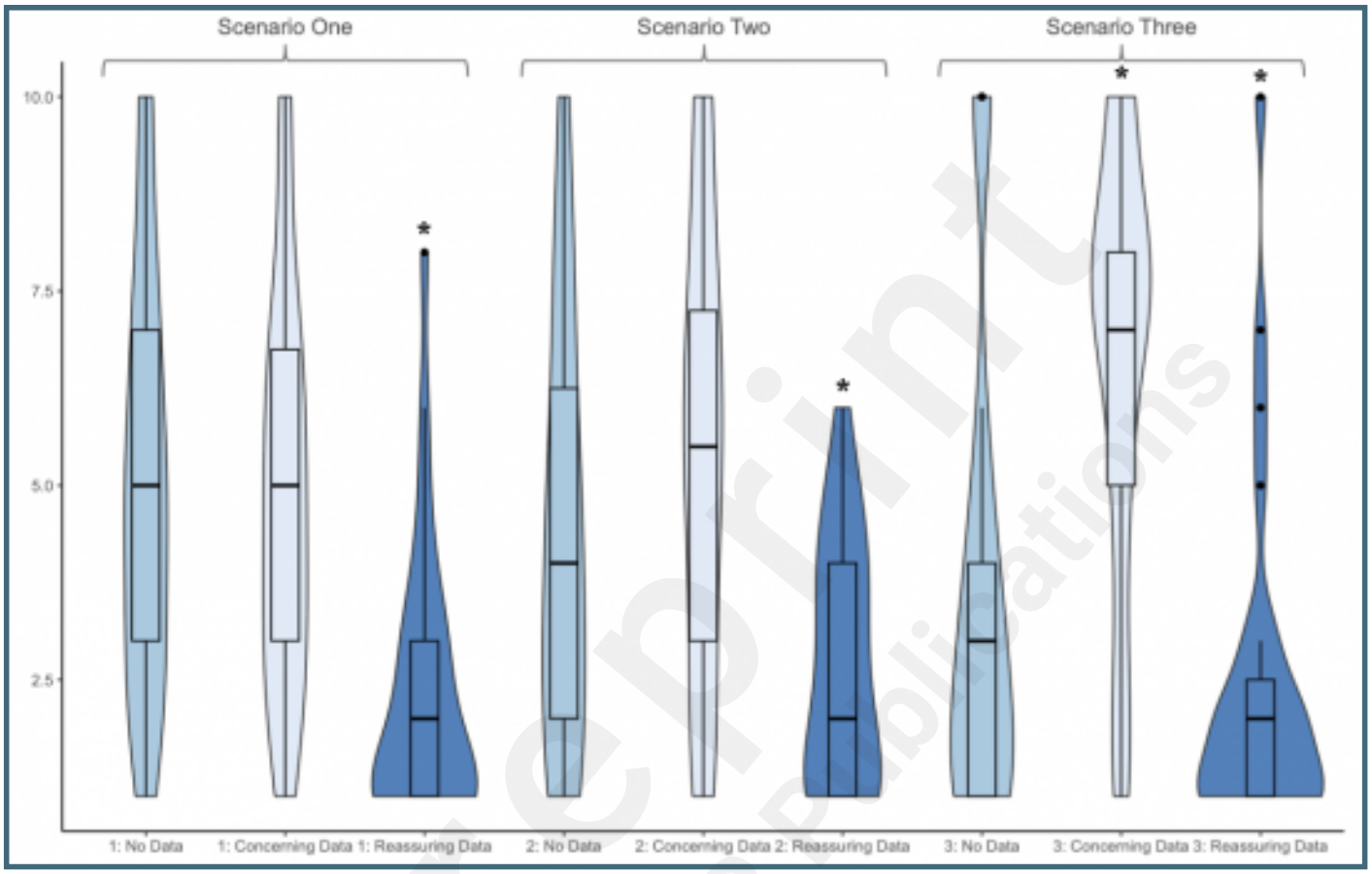
Recommendation for emergency department presentation provided by pediatric surgery clinicians at five institutions when presented with three simulated telephone scenarios: 1) without wearable data, 2) with concerning wearable data, and 3) with reassuring wearable data. Likelihood of emergency department referral reported on a 10 point Likert Scale with 1 representing “Not at all likely” and 10 representing “Definitely”. *Significant change by Wilcoxon Rank Sum.



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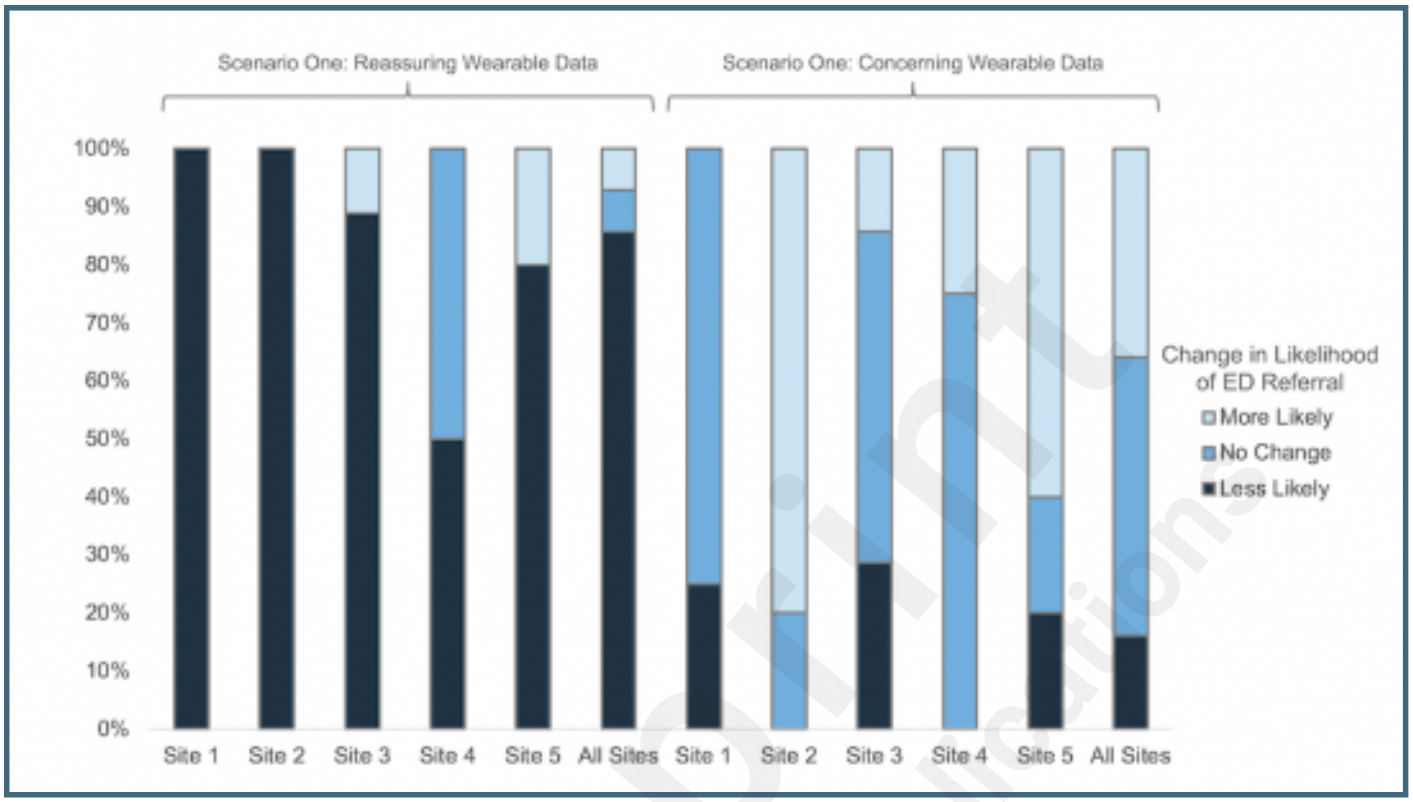
How the likelihood of emergency department referral changed at each institution with the addition of reassuring and concerning wearable data to scenario one.



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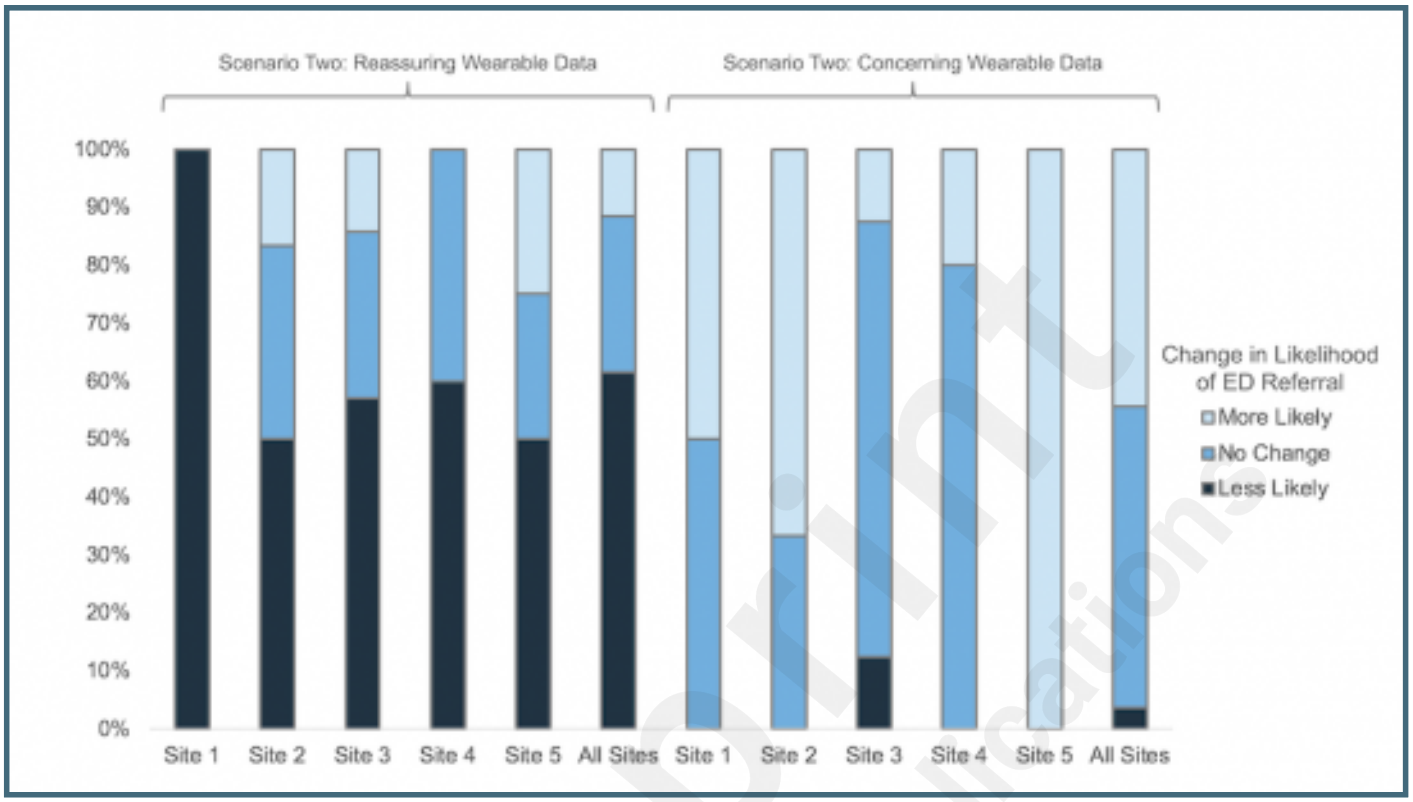
How the likelihood of emergency department referral changed at each institution with the addition of reassuring and concerning wearable data to scenario two.



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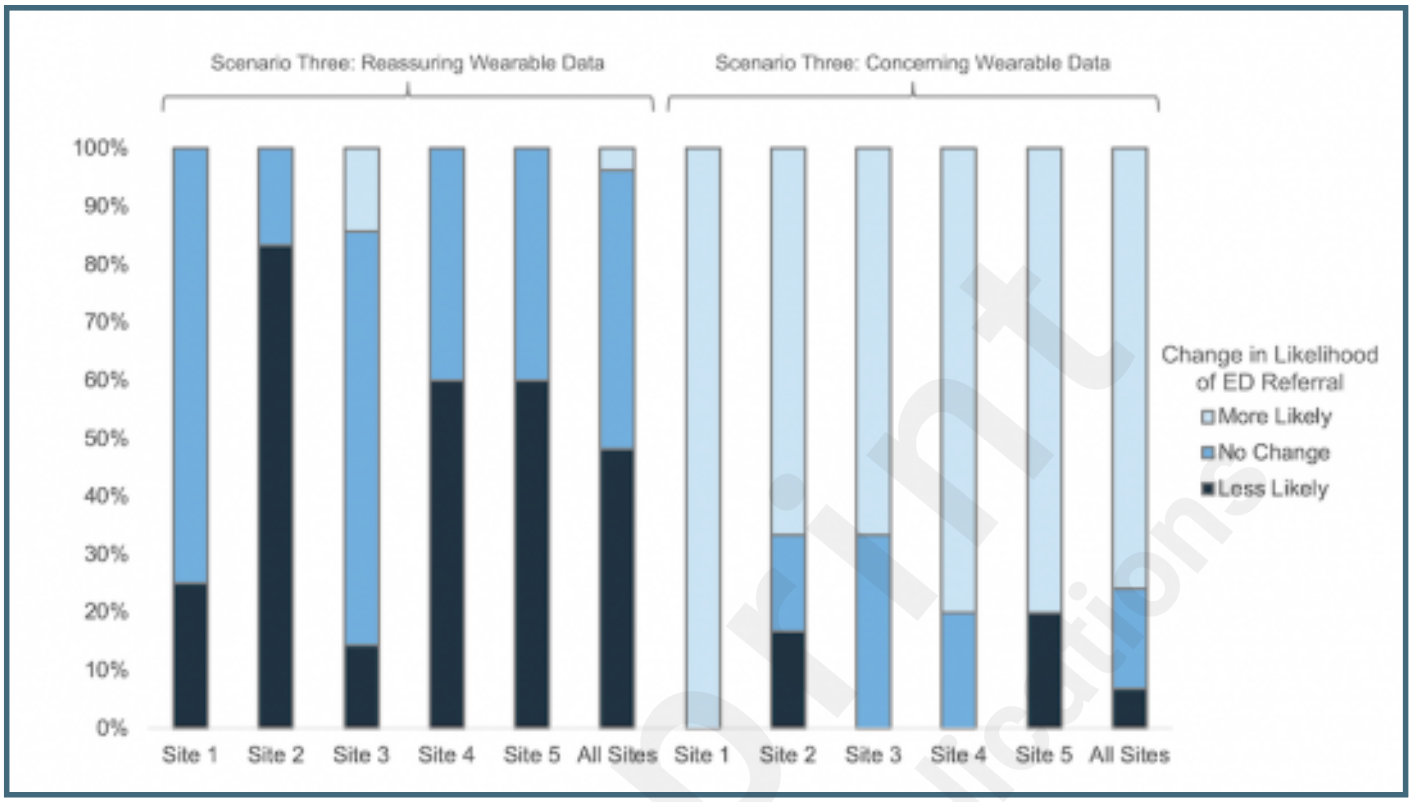
How the likelihood of emergency department referral changed at each institution with the addition of reassuring and concerning wearable data to scenario three.



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