Consumer wearables data impact pediatric surgery clinicians’ remote management

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Research Article

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Abstract

Purpose

Integration of consumer wearables data has the potential to inform clinicians’ remote assessment of postoperative patients. This multi-institutional study evaluated the impact of adding objective recovery data from consumer wearables to postoperative telephone encounters on clinicians’ management.

Methods

Three 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 postoperative complication. Clinicians rated likelihood of ED referral and confidence in decision-making.

Results

Thirty-four clinicians participated. Compared to the scenario alone, the addition of reassuring wearable data resulted in decrease in likelihood of ED referral for all three scenarios (p < 0.01). When presented with concerning wearable data, there was significant increase in the likelihood of ED referral for two of three scenarios (p = 0.72, p = 0.02, p < 0.001). 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 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.

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 their 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 including heart rate, step count and sleep assessment. 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 evaluation and triage of post-operative patients after discharge [7–10].

Within our institution, we previously demonstrated that the addition of wearable data to unplanned post-operative episodes of health care utilization impacted pediatric surgery clinicians’ decision-making, including 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 objective data derived from a consumer grade wearable device to simulated post-operative telephone scenarios impacted the decision-making of a diverse cohort of pediatric surgery clinicians.

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 common clinical scenarios which could have been clarified with the addition of wearable data. 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 documented telephone encounters between caregiver and pediatric surgery clinicians, were utilized to generate the simulated 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 either concerning or reassuring wearable 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 when the patient’s actual wearable data were reassuring. The source of the wearable data and the classification as concerning or reassuring was not shared with the clinicians who participated in the study.

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. 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.

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). Furthermore, Wilcoxon Rank Sum test was performed comparing the clinician’s recommendation for ED presentation without wearable data to their recommendation with both concerning and reassuring wearable data. Statistical significance was defined as p < 0.05.

RESULTS

Thirty-four clinicians voluntarily participated in the study (Table 1). 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 question. Survey results are broken down by scenario and question and are displayed in Table 2 and Fig. 1.

When scenario 1 was presented without wearable data, 61% of respondents recommended outpatient follow-up while 36% recommended they seek care immediately and 4% recommended reassurance without need for follow-up. When asked to rank the likelihood of recommending ED presentation, median recommendation was 5 (IQR 3–7). When presented with reassuring vitals, median recommendation for ED presentation was 2 (IQR 1–3) with a median

<table>
<thead>
<tr>
<th>Table 2</th>
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</thead>
<tbody>
<tr>
<td>Management recommendations from pediatric surgery clinicians at five institutions in response to three telephone scenarios presented 1) without wearable data, 2) with reassuring wearable data, and 3) with concerning wearable data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-year-old female POD 7 s/p complicated appendectomy, 2 days of abdominal pain, loose stools &amp; incisional drainage</td>
<td>10-year-old female POD 3 s/p uncomplicated appendectomy, 2 days of fevers, abdominal pain, periumbilical erythema</td>
<td>9-year-old male POD 10 s/p complicated appendectomy, 2 days of purulent drainage from port site</td>
</tr>
<tr>
<td><strong>No Wearable Data</strong></td>
<td><strong>Reassuring Wearable Data</strong></td>
<td><strong>Concerning Wearable Data</strong></td>
</tr>
<tr>
<td><strong>No Wearable Data</strong></td>
<td><strong>Reassuring Wearable Data</strong></td>
<td><strong>Concerning Wearable Data</strong></td>
</tr>
<tr>
<td><strong>Initial recommendation, n (%)</strong></td>
<td>10 (36%)</td>
<td>7 (25%)</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>7 (25%)</td>
</tr>
<tr>
<td><strong>Seek care immediately</strong></td>
<td>17 (61%)</td>
<td>14 (50%)</td>
</tr>
<tr>
<td></td>
<td>1 (4%)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Rx &amp; outpatient follow-up</strong></td>
<td><strong>Out-patient follow-up</strong></td>
<td><strong>Reassurance &amp; no follow-up</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>How likely to recommend presentation to ED, median (IQR)</strong></td>
<td>5 (3–7)</td>
<td>2 (1–3)</td>
</tr>
<tr>
<td></td>
<td>4 (2–6.75)</td>
<td>2 (1–4)</td>
</tr>
<tr>
<td></td>
<td>22 (85%)</td>
<td>23 (85%)</td>
</tr>
<tr>
<td><strong>Change with vitals, median (IQR)</strong></td>
<td><strong>p-value</strong></td>
<td><strong>Increased confidence, n (%)</strong></td>
</tr>
<tr>
<td></td>
<td>0 (0–2)</td>
<td><strong>p &lt; 0.001</strong></td>
</tr>
<tr>
<td></td>
<td>p = 0.72</td>
<td><strong>p &lt; 0.001</strong></td>
</tr>
<tr>
<td>0 (0–2)</td>
<td><strong>p = 0.02</strong></td>
<td>19 (76%)</td>
</tr>
<tr>
<td></td>
<td><strong>p &lt; 0.001</strong></td>
<td>23 (85%)</td>
</tr>
<tr>
<td></td>
<td><strong>p = 0.002</strong></td>
<td>23 (85%)</td>
</tr>
<tr>
<td></td>
<td><strong>p &lt; 0.001</strong></td>
<td>23 (85%)</td>
</tr>
</tbody>
</table>

Eighty-five percent of respondents reported increased confidence in their recommendation with the addition of vital signs. Twenty-four percent of participants 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 symptoms of 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 = 0.72). However, 88% of participants reported increased confidence in their recommendation and 85% reported they would reach out to the patient/caregiver if presented the wearable data alone.

When scenario 2 was presented without wearable data, 50% recommended outpatient follow-up while 25% recommended a prescription and outpatient follow-up and 25% recommended the patient should seek care immediately. Median likelihood of recommending ED presentation was 4 (IQR 2.675). When reassuring objective 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 < 0.001). Eighty-five percent of respondents reported increased confidence in their recommendation. Thirty percent reported they would initiate contact with the patient/caregiver in response to the reassuring wearable data alone. When concerning vitals 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 = 0.02) while 76% reported increased confidence with this recommendation. Eighty percent of clinicians reported they would reach out to the patient/caregiver if presented the wearable data alone.

When scenario 3 was presented without wearable data, 64% recommended outpatient follow-up while 21% recommended the patient seek care immediately, and 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 vitals were added, the median recommendation dropped to 2 (IQR 1–3) representing a median decrease in recommendation of 0 (IQR = 2 – 0, p = 0.002). Eighty-five percent of clinicians reported increased confidence in their recommendation, and 24% reported they would reach out to the patient/caregiver if presented the vitals alone. When presented concerning vitals, the median recommendation for presentation to the ED increased to 7 (IQR 5–8), a median increase of 3 (IQR 0.5–5, p < 0.001). Eighty-eight percent of clinicians reported increased confidence in their recommendation and 96% reported they would initiate contact with the patient/caregiver if presented the wearable data alone.

DISCUSSION

This study investigated the potential impact that post-operative objective measures of recovery collected by a consumer grade wearable device, the Fitbit Inspire, 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. This provides the opportunity to address patient and caregiver concerns in the post-operative post-discharge period in a remote, low-cost and efficient setting 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 it 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 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 scenario 1, 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 strengthened 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 scenarios 2 and 3 were presented with concerning vitals, 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 vitals 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, we propose an enriched form of communication between the health care system, caregiver and patient, and with such a system it is anticipated that unnecessary ED presentation be reduced even further.

Avoidable ED use has become an important focus of quality improvement initiatives to decrease unnecessary health care expenditures and health care saturation [6, 11–13]. 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 [14]. 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 [15–22]. 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 [15]. 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 [15]. 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 [23]. 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, is that 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 survey type 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. Additionally, 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-appendectomy 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 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.

**Abbreviations**

ED – emergency department

IQR – interquartile range

US – United States

**Declarations**

**FUNDING AND CONFLICT OF INTEREST STATEMENT**

There is no funding to declare. All authors have no conflicts of interest to disclose.

**AUTHOR CONTRIBUTIONS**

Study conception and design by Fizan Abdullah, Hassan Ghomrawi, Samuel Linton, Suhail Zeineddin and Christopher De Boer. Acquisition of data performed by Samuel Linton, Suhail Zeineddin, Christopher De Boer, Angie Figueroa, Ankush Gosain, David Lanning, Aaron Lesher, Saleem Islam and Chethan Sathya. Analysis and interpretation of data performed by Samuel Linton, Michela Carter, Suhail Zeineddin and J. Benjamin Pitt. Drafting of manuscript performed by Michela Carter. Critical revision performed by all authors.

**References**

Figures
Fig. 1: Recommendations from pediatric surgery clinicians at five institutions when presented with simulated telephone scenarios: 1) without wearable data, 2) with concerning wearable data, and 3) with reassuring wearable data. Question: “How likely are you to recommend this patient present to the Emergency Department immediately?” Responses reported on a 10 point Likert Scale with 1 anchored as “Not at all likely” and 10 anchored as “Definitely”. *Significant change by Wilcoxon Rank-Sum test

Figure 1

See image above for figure legend