Functional Recovery in the Elderly After Major Surgery: Assessment of Mobility Recovery Using Wireless Technology

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Purpose. Hospitalization and surgery in older patients often leads to a loss of strength, mobility, and functional capacity. We tested the hypothesis that wireless accelerometry could be used to measure mobility during hospital recovery after cardiac surgery.

Description. We used an off-the-shelf fitness monitor to measure daily mobility in patients after surgery. Data were transmitted wirelessly, aggregated, and configured onto a provider-viewable dashboard.

Evaluation. Wireless monitoring of mobility after major surgery was easy and practical. There was a significant relationship between the number of steps taken in the early recovery period, length of stay, and dismissal disposition.

Conclusions. Wireless monitoring of mobility after major surgery creates an opportunity for early identification and intervention in individual patients and could serve as a tool to evaluate and improve the process of care and to affect postdischarge outcomes.


The aging population introduces challenges in surgical care delivery. Although cardiac surgical risk in the elderly has been defined, there are compelling reasons to expand the outcomes reported. In addition to traditional surgical outcomes, reporting of discharge disposition, functional status on discharge, and their predictors has broad implications for health care delivery [1, 2]. This is now receiving greater attention [3, 4].

Hospitalization in the elderly can be associated with a loss of mobility, and in surgical patients one of the primary determinants of discharge disposition is functional status at discharge [1, 5]. Although management of strength and mobility has traditionally been a focus of nursing care, these functional outcome measures are increasingly important to hospitals and payers [2, 6]. There are multiple barriers to acquiring and reporting functional assessments during hospitalization: reliable measures, consistent reporting, the ability to locate the data, and the fact that these recovery measures typically reside outside of surgical workflow. New technologies create an opportunity to address these barriers, acquire new types of information, and better manage assessment, and support, of functional status during surgical recovery.

We tested the hypothesis that wireless accelerometry could be used to measure mobility during recovery from cardiac surgery.

Technology and Technique

After institutional review board approval and written informed consent, and as part of a larger trial to test an information system designed to support recovery management, we outfitted a postoperative cardiac surgical population with Fitbit (Fitbit, Inc, San Francisco, CA) wireless accelerometers (Fig 1). The devices were placed on patients’ ankles after transition from the intensive care unit (ICU). Day of placement was identified as recovery day 1.

The patients were having elective surgery, were older than 50 years, and expected to have a hospital length of stay (LOS) of 5 to 7 days. Participants were able to read, were English-speaking, lived at home, and were able to ambulate before hospitalization. After surgery, patients who had an ICU stay longer than 72 hours, had a stroke, confusion, or agitation, or chose not to participate were withdrawn from the trial.

Patient rooms were outfitted with an antenna interfaced with the in-room computer. The accelerometer transmitted data by means of the antenna and in-room computer to the Fitbit website. From there, the data were pulled onto a cloud-based data system and configured onto dashboards viewable by providers.
Other clinical data acquired were demographic information, type of surgery, comorbid conditions, LOS, and discharge disposition (home, home with home health care [HHC] support, or discharge to skilled-nursing facility [SNF]). For the purpose of this investigation, LOS was determined from time of operating room entry to time of hospital discharge. Medicare criteria were used for determination of use of SNF or HHC services at discharge.

Data Analysis
To assess mobility we completed a descriptive analysis comparing the total steps during each hospital recovery day. First, we described the mean, median, and interquartile range for mobility in patients with discrete categories of LOS from surgery: less than 5 days, 5 to 6 days, and at least 6 days. Second, we described the mean, median, and the interquartile range for mobility by day in patients who were discharged to home versus those needing increased postdischarge support, either HHC or an SNF. Because mobility data were not normally distributed, the Kruskal-Wallis and Mann-Whitney tests were used for statistical comparisons among groups. The Society of Thoracic Surgeons (STS) risk index was determined, when possible, for each patient using the STS online tool. A two-sample Student’s $t$ test was used to compare demographic variables in patients discharged independently to home versus those discharged to HHC or SNF. A probability value of less than 0.05 was considered significant.

Clinical Experience
The average age of our population was $68 \pm 9$ years (range, 52 to 90 years). Comorbid conditions were typical of this patient age group (Table 1). The surgical procedures primarily consisted of coronary artery bypass grafting, valve repair or replacement, or coronary artery bypass grafting combined with valve surgery. Ascending aortic aneurysm descriptions were placed in a separate category even if coronary artery bypass grafting or valve surgery also occurred. An STS risk index could be determined for 104 patients; for those, the STS risk for morbidity or mortality was $12\% \pm 1\%$.

Overall, the LOS from surgery was $5.3 \pm 1.4$ days. Two study participants died and are excluded from analysis. Twenty-one patients (14%) were discharged with HHC or to an SNF; they were older (76 versus 67 years) and had a higher STS risk index (17% versus 10%) than those discharged to home independently ($p < 0.01$ for both variables by two-sample Student’s $t$ test).

Figure 2 shows the relationship between mobility by recovery day and discharge disposition. No patient walked on the day of surgery, so all data begin with recovery day 1. On the second recovery day, significant differences in mobility were identifiable between those bound for home independently and those discharged to SNF or HHC ($p < 0.001$ by Kruskal-Wallis test). On recovery day 2, the median steps measured in the home-independent group were 675 versus 108 steps in the SNF-HHC group. This between-group difference was also evident on the third and fourth recovery days (Fig 2).

Table 1. Demographics and Surgical Procedures of Trial Population

<table>
<thead>
<tr>
<th>Variable</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients (n)</td>
<td>149</td>
</tr>
<tr>
<td>Age (y)</td>
<td>$67.8 \pm 9$</td>
</tr>
<tr>
<td>Males</td>
<td>66%</td>
</tr>
<tr>
<td>Diabetes</td>
<td>17%</td>
</tr>
<tr>
<td>Hypertension</td>
<td>65%</td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
<td>4%</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>21%</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>15%</td>
</tr>
<tr>
<td>Sleep apnea</td>
<td>16%</td>
</tr>
<tr>
<td>Anticoagulation</td>
<td>14%</td>
</tr>
<tr>
<td>Renal insufficiency</td>
<td>5%</td>
</tr>
<tr>
<td>Society of Thoracic Surgeons risk index</td>
<td>$12% \pm 1%$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surgery</th>
<th></th>
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<tbody>
<tr>
<td>Valve</td>
<td>43%</td>
</tr>
<tr>
<td>CABG</td>
<td>32%</td>
</tr>
<tr>
<td>Valve and CABG</td>
<td>14%</td>
</tr>
<tr>
<td>Ascending aortic aneurysm</td>
<td>4%</td>
</tr>
<tr>
<td>Septal myectomy</td>
<td>5%</td>
</tr>
<tr>
<td>Other</td>
<td>1%</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass grafting.
The patient population was also divided into three groups by LOS. Patients with the short and intermediate LOS walked more on the first \( (p < 0.05) \) and second \( (p < 0.05) \) recovery days relative to the longer-stay group (Fig 3). By the end of the second recovery day, patients with the shortest LOS reached a median of 818 steps versus 514 and 223 steps in intermediate and longer stay groups, respectively \( (p = 0.001) \). The median ICU LOS and interquartile range for the three groups were as follows: short (21.8, 4.8 hours), intermediate (22.8, 6.3 hours), and longer-stay (23, 6.2 hours); they did not differ \( (p = 0.125) \).

Figures 2 and 3 show a decrease in steps measured in the higher mobility groups on either recovery day 4 or 5. The short in-hospital time on the day of discharge accounts for the reduced steps measured rather than a decrease in functional status. Finally, one device was lost in approximately 750 patient-days of monitoring.

Fig 2. Steps by recovery day and discharge disposition, either independent to home \( (n = 128) \) or discharge to skilled-nursing facility (SNF) or to home with health care (HHC; combined \( n = 21) \). Day 1 is the first day after intensive care unit discharge. Inset shows median and interquartile (IQ) range. ***\( p < 0.001 \) between groups by Kruskal-Wallis test.

Fig 3. Steps by recovery day and length of stay (LOS): <5 days, 5 to 6 days, or >6 days. Day 1 is the first day after intensive care unit discharge. Inset shows median and interquartile (IQ) range. *\( p < 0.05 \) between two shorter and the longest LOS group by Mann-Whitney test.
Comment

This is the first U.S. description, to our knowledge, of using wireless accelerometry to monitor daily mobility recovery during hospitalization after major surgery. The study intent was to determine whether postoperative mobility could be measured wirelessly in a hospitalized elderly population, and secondarily to examine the relationship between mobility and LOS. Although it is obvious that patients who recover mobility sooner are likely to have better outcomes, it is critical in the face of changing demographics and financial rules that we measure functional measures of recovery for individuals and populations. Functional status and variables such as mobility will impact discharge disposition, patient satisfaction, social support required, falls, hospital readmission \[7\], and ultimately health care costs. Assessment and management of mobility in hospitalized, older patients must be assumed to be a component in mitigating what has been termed posthospital syndrome \([2]\).

Although the results are not unexpected, they are unique: (1) this is the first demonstration that remote monitoring of mobility is effective to assess hospital surgical recovery, and (2) such data have implications for resource utilization and outcomes. Patients with the highest early mobility had the shortest LOS and were less likely to be discharged to SNF or HHC. Although our investigation was not designed to determine the mobility threshold predictive of early discharge or discharge to home, the data suggest mobility achieved on recovery day 2 may lead to both outcomes. Such data may have powerful predictive value for discharge planning and resource utilization and are additive to conventional predictors. Our use of the technology to monitor daily in-hospital mobility recovery is unique, but is likely to find broad application as it augments our ability to evaluate, triage, and intervene in regard to dismissal disposition.

This type of technology and the data it makes available have tremendous potential. The ability to describe population norms for mobility recovery has implications for individual patients and care process improvement. Once we know the expected mobility by day for a 70-year-old female coronary artery bypass grafting, total hip arthroplasty, or colectomy patient, we can early identify pending recovery failure and triggers for intervention(s). Similarly, the care of populations can be impacted. If we change a plan of care (postoperative pain management), acquiring mobility data for populations of patients allows us to determine whether the population norms for recovery are altered. Such technology also increases the ease with which data are acquired.

Specific patient mobility data are typically found in nursing notes and are not usually part of the workflow of the surgical team. Such data may not be obtained in all patients and are intermittent (two or three times a day). With wireless technology, data are objective, acquired, and displayed nearly continuously. This means of acquiring information can greatly simplify information transfer in the hospital and demonstrates the power of remote monitoring. It has the potential to increase efficiency, reduce data loss, and reduce the cost of care \([8]\). In fact, such technology can be configured to enable determination of time out of bed and patient activity levels throughout the day and can be integrated into surgical or nonsurgical recovery pathways. Although beyond the scope of this investigation, the implications for health care, both in hospital and at home, are profound. New technologies, especially consumer technologies, make this easy to do in a cost-effective way. The device chosen is approximately $100 and reusable.

Limitations

Designating the first day post-ICU as recovery day 1 might be considered problematic given that LOS included ICU time. However, ICU LOS did not differ among LOS groups. Furthermore, we chose this design because (1) ambulation in the ICU is unusual in our trial population, (2) accelerometers were first placed after ICU discharge, and (3) we assumed that patients would be at similar functional status (having met ICU discharge criteria), so measuring mobility recovery from ICU discharge point offered a uniform starting point.

A few technical points also bear elaboration. First, the accelerometer has a recommended placement on the waist or upper arm. This placement did not work for shuffling patients using walkers. As such we configured the device to the shortest possible stride length, and placed the accelerometer in a disposable ankle strap. These provided sufficient sensitivity to measure mobility in the lowest-mobility patients. Second, data acquisition required that each device be linked to each patient, antenna, and a computer workstation. Devices must be tracked, cleaned, and reconfigured before reuse. Third, data on the web-based dashboards were not integrated into our electronic medical record, so each surgical service was provided with an iPad (Apple, Inc, Cupertino, CA) with a hyperlink to the dashboard where patient mobility data were displayed. Fourth, patient confidentiality was achieved by password protection and only the data from patients on the specific surgical service were viewable by that surgical service.

Conclusions

With changing reimbursement models, expansion of accountable-care organizations, and bundled payments, increasing attention to functional measures of recovery are inevitable. The establishment of mobility after surgery is a key recovery outcome in surgery. Here we offer the first report of the use of wireless accelerometry to monitor mobility through major surgical recovery.

Wireless monitoring of mobility after major surgery was easy and practical. There was a significant relationship between the number of steps taken in the early recovery period, LOS, and dismissal disposition in an older cardiac surgery population. This opens the door for changing recovery models and improving outcomes in surgical practice.
Disclosures and Freedom of Investigation

Mayo Clinic and Foundation provided all funds for the investigation, the software, and supporting technologies. Technologies and software were purchased or contacted by the investigators for study conduct using Mayo funds. Additionally, the authors had full control of the design of the study, methods used, outcome parameters, analysis of data, and production of the written report.

References


INVITED COMMENTARY

The ability to predict the course of recovery after a cardiac operation is important because skilled care and rehabilitation needs and wants, and the ability to participate in therapy and life contexts [4]. The application of wireless accelerometry to quantify physical activity has the potential to extend the capabilities of the physical therapy team, measure the effectiveness of rehabilitation regimens, quantify progress, and improve the ability to predict operative risk. It can help identify early ambulators so that physical therapists can allocate their time appropriately.

It will be interesting to also test if accelerometry can be used to help identify hospitalized patients at risk for other complications such as venous thromboembolism, pneumonia, skin breakdown, or malnutrition. The investigators have shown that creative application of sophisticated but affordable miniature electronic devices has the potential to advance the care of hospitalized patients.

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