Feasibility and patient’s experiences of perioperative telemonitoring in major abdominal surgery: an observational pilot study

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ABSTRACT

Background
Telemonitoring during the perioperative trajectory may improve patient outcomes and self-management. The aim of this study is to assess the feasibility of and patient's experiences with telemonitoring before and after major abdominal surgery to inform future study design.

Methods
Patients planned for elective major abdominal surgery wore a sensor and answered well-being questions on a tablet daily at least two weeks preoperatively up to 30-days postoperatively. Feasibility was assessed by participation and completion rate, compliance per day, weekly satisfaction scores, reasons for non-scheduled contact.

Results
Twenty-three patients were included (participation rate of 54.5%) with a completion rate of 69.6%. Median compliance with the wearable sensor and well-being questions was respectively: 94.7% and 83.3% preoperatively at home; 100% and 66.7% postoperatively in-hospital; and 95.4% and 85.8% postoperatively at home. Median weekly satisfaction scores for both wearing the sensor and well-being questions were 5 (IQR, 4-5). Contact moments were related to absence of sensor data and technological issues (76.0%) or patient discomfort and insecurity (24.0%).

Conclusion
In this study, telemonitoring showed high satisfaction and compliance during the perioperative trajectory. Future trial design regarding effectiveness of telemonitoring requires embedding in clinical practice and support for patients, relatives and healthcare personnel.

INTRODUCTION
In recent years, interest in telemonitoring before or, mainly, after major abdominal surgery has increased with the aim to improve postoperative outcomes or support self-management of patients. For these purposes, several wearable sensors and (mobile) applications are available to monitor physical and mental parameters at home or in-hospital. Despite this, perioperative telemonitoring is currently still rarely used in clinical practice. Evidence for the effectiveness of perioperative telemonitoring in major abdominal surgery is scarce, probably due to limitations of the used technology or methodology in these studies.

In development and evaluation of telemedicine services, it is important that the evaluation method chosen matches the state of the technology development. Most studies on perioperative telemonitoring are still in the feasibility phase: telemonitoring is hereby used as a standalone service and endpoints focus on its feasibility and usability. To work towards consequent study designs for effectiveness, not only the technology development is of importance, but also how the telemonitoring will be implemented and used by its stakeholders. For example, compliance of patients to treatment is related to clinical outcomes in chronic diseases. However, actual use and patient's experiences are hardly evaluated for perioperative telemonitoring services but only by future intention-to-use of patients, which does not match actual usage behavior. Additionally, evaluation afterwards causes non-response due to patient drop-out or recall bias for patients.

Therefore, the aim of this study is to assess the feasibility of and patient's experiences with telemonitoring during the perioperative trajectory of patients undergoing major abdominal surgery. Patients wore a wearable sensor and answered questions using a mobile app daily at least two weeks before surgery up to 30-days after surgery both at home and in-hospital. This study addresses benefits and barriers and intends to provide recommendations on trial design of studies that may also focus on clinical- and cost-effectiveness of perioperative telemonitoring.

PATIENTS AND METHODS
Design
A single-center prospective observational cohort pilot study was performed at the University Medical Centre Groningen (UMCG) between January 2020 and January 2021. The protocol was approved by the Ethical Committee of the UMCG (PROMISE-study, research register number #201900432), and this study was executed in accordance with the STROBE guidelines and the Declaration of Helsinki. The aim was to include 20 patients, and this number was supplemented if patients dropped out before surgery. Clinical data from study measurements are reported separately (not published yet).
Participants
Patients of 18 years or older were included if they were planned for elective open abdominal surgery; were expected to be at least two weeks on the waiting list; and had access to WiFi at home. Patients were excluded if they were mentally incapable of participation; could not mobilize without aids; or were unable to wear wearable sensors. Patients were informed about this study after they were planned for open abdominal surgery at the outpatient clinic and were asked informed consent one week later.

Outcome measures
Outcome measures for feasibility were participation rate, completion rate, compliance, weekly satisfaction, and number of and reasons for contact moments between researcher and patient or representative.

Patient’s experiences comprised overall satisfaction, intention-to-use and intention-to-recommend-to-others, and positive and negative experiences and future expectations of perioperative telemonitoring.

Study protocol
Figure 1 illustrates the study protocol in relation to the perioperative trajectory. After a patient gave informed consent, the researcher visited the patient at home with the telemonitoring devices and instructions. From this moment patients received telemonitoring until 30 days after surgery or earlier if a patient decided to or needed to stop (e.g. due to severe postoperative complications). Telemonitoring consisted of wearable sensor measurements and daily questions about well-being (“experience sampling”), as explained below.

Patients wore the Everion® biosensor (Biovotion AG, Zürich, Switzerland), a CE class IIa-certified wearable sensor for monitoring vital signs and physical activity, on their upper arm, as depicted in Figure 1A. Patients were instructed to wear the sensor during the day and charge it during the night, and nurses also received these instructions at the surgical ward. The Healthy Chronos app and platform (Healthy Chronos, Alphen a/d Rijn, Netherlands) were used to transfer data from the wearable sensor to a tablet (Samsung Galaxy Tab A 10.1 2019) through Bluetooth, and to the database using WiFi. Without an active WiFi connection, measured data were saved locally at the sensor for up to five days. Patients and researchers (MH, RM) checked whether data was transmitted to the Healthy Chronos app and platform on a daily basis. If data from the wearable sensor was not transmitted to the platform for two days or more, the researcher contacted the patients to solve potential technical problems.

Experience sampling was performed through a mobile app (Activity Coach) on the same tablet, running on the RRD-eHealth platform (Roessingh Research and Development, Enschede, The Netherlands). Twice a day, at one random moment between 9:00 AM and 1:00 PM and at 8:00 PM, patients received a notification to answer short questions about well-being (pain, fear, nausea and fatigue) on a 0-10 Visual Analogue Scale (VAS), as illustrated in Figure 1B. Patients could also choose to receive notifications via SMS and answer the questions via the internet browser on their smartphone. Researchers did not check data transmission for experience sampling during the study period, and did not remind patients to respond nor were nurses at the surgical ward instructed to do so.

Patients were asked to answer the Customer Satisfaction Score on a 5-point Likert scale (very unsatisfied to very satisfied) for wearing the sensor and experience sampling in the app weekly. Researchers contacted the patient as part of the study protocol before hospital admission to remind the patient to bring the devices to the hospital, and at 30 days after surgery to confirm study completion and to make an appointment to return the devices. At return of the devices, one of the researchers conducted a structured final evaluation questionnaire on paper or
digitally including both closed and open questions regarding patient’s experiences with the telemonitoring. The final evaluation questionnaire consisted of the following questions: (1) overall satisfaction (scale 0 to 10); (2) intention-to-use and intention-to-recommend-to-others according to the System Usability Scale (strongly agree to strongly disagree); and (3) open questions to describe at least one positive and one negative experience, important factors for use, and expectations of telemonitoring.

Patients could contact the researchers by telephone during office hours in case of study-related questions or difficulties. The surgical procedure, clinical diagnostics or treatment were not affected by this study, and were performed in accordance with standard of care. Patients and healthcare personnel did not have insight into the study data, and did not receive feedback based on the monitoring.

Data collection
Telemonitoring data was retrospectively retracted from the Healthy Chronos platform and RRD-eHealth database. Data was processed and analyzed in Matlab R2021b (Mathworks, Inc., Natick, MA, USA). Days within the protocol included the day after delivery of devices (start telemonitoring) until 30 days after surgery or earlier patient drop-out (end of telemonitoring). The day of surgery and days of admittance at the intensive care unit during the study period were outside protocol. Specific periods were documented as outside protocol if the sensor was worn by one of the researchers for testing, or if the study was paused, i.e. due to significantly delayed surgery or prolonged technical problems.

Patient and surgery characteristics, contact moments between researcher and patient or representative, and answers to the final evaluation questionnaire were stored in REDCap version 10.0.23 (Vanderbilt University, Nashville, TN, USA). Contact moments that were part of the study protocol (e.g. contact before hospital admission or at 30 days after surgery) were excluded from data analysis.

Data analysis
Participation rate was calculated as the percentage of patients included in the study of all patients who received the information letter. Completion rate was the percentage of patients who received telemonitoring until 30 days after surgery of all included patients.

Compliance with wearing the sensor and experience sampling was calculated as the percentage of days with data of all days within the protocol per perioperative phase: preoperative at home; postoperative in-hospital; and postoperative at home. No minimum was set for the number of measured data points or hours per day with data to calculate compliance. The median number of days within the protocol with interquartile ranges (IQR) and the median number and IQR of measured data points or hours per day with data for all patients were also shown. For experience sampling, the median number postoperative in-hospital; and postoperative at home. No minimum was set for the number of days with data of all days within the protocol per perioperative phase: preoperative at home; postoperative in-hospital; and postoperative at home. No minimum was set for the number of measured data points or hours per day with data to calculate compliance. The median number of days within the protocol with interquartile ranges (IQR) and the median number and IQR of measured data points or hours per day with data for all patients were also shown. For experience sampling, the median number of responses in both the morning and at 8.00 PM and IQR were calculated as well. Weekly satisfaction scores for wearing the wearable sensor and experience sampling in the app scores were calculated and shown in boxplots with median values, IQR, ranges and outliers per week before and after surgery for all patients. Mean weekly scores were added to this figure to emphasize extreme values. Median weekly satisfaction scores and IQR were also computed for the total preoperative and postoperative period.

Contact moments were described per perioperative phase and in total. This included the total number of contact moments, number of patients with extra contact moments, and median number of contact moments with IQR per patient. Besides, type of contact (i.e. outgoing or ingoing, call or visit), and reasons for contact were described.

As for patient’s experiences, median overall satisfaction with IQR were calculated for both wearing the sensor and experience sampling. Intention-to-use and intention-to-recommend-to-others were presented as percentages per score (strongly agree to strongly disagree). Positive and negative experiences and future expectations were described in order of how often it has been mentioned.

RESULTS
Study participation
Twenty-three patients planned for elective open abdominal surgery were included in this study; all were monitored preoperatively at home, 19/23 postoperatively in-hospital (82.6%) and 16/23 postoperatively at home (69.6%). The study flow diagram is shown in Figure 2 and patient characteristics are shown in Table 1. The participation rate of patients that received the information letter was 54.5%. Reasons not being included in the study are shown in Figure 1. Reasons for 10/43 patients (23.3%; two reasons in two patients) not willing to participate were: expected extra mental burden (n=8), insecurity about technology use (n=1), and not willing to wear a sensor on the arm during this period (n=3).

Nineteen patients underwent surgery. For these patients, the median number of days from inclusion to surgery was 21.6 with an IQR of 13.8-41.2 days, and median length of hospital stay was 10.2 days (IQR 6.2-13.0 days). In total, 16 patients received telemonitoring until 30 days after surgery, resulting in a completion rate of 69.6%. Reasons for study drop-out were cancelation of surgery (n=3), complicated postoperative course (n=2), and study withdrawal (n=2). Withdrawal was related to recurrent technical problems (i.e. no data transfer) in combination with surgery-related mental burden, because either surgery was repeatedly postponed due to COVID-19 (n=1), or being at home after hospital discharge was experienced as difficult (n=1).
Figure 2. Study inclusions.

Compliance

Compliance with wearing the wearable sensor and experience sampling per perioperative phase is shown in Table 2. Of the three perioperative phases, compliance with wearing the sensor was highest at the surgical ward with a median of 100% of days. At home, compliance during the preoperative and postoperative phase was similarly high with median compliance around 90%. Experience sampling at home was performed in 83.3% and 87.5% of preoperative and postoperative days respectively. Compliance with experience sampling was lowest at the surgical ward (median 72.7% of days with data). The median number of responses were slightly higher in the morning compared to 8:00 PM postoperatively.

Weekly satisfaction

Figure 3 shows boxplots and means of the weekly satisfaction scores for wearing the sensor and experience sampling in the app. On average, patients were very satisfied about wearing the sensor (median 5 [IQR 4-5] on a 5-point Likert scale) and answering questions in the app (median 5 [IQR 4-5]), both preoperatively and postoperatively.

Table 1. Characteristics of included patients (n=23).

<table>
<thead>
<tr>
<th>Descriptive</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years, median (IQR)</td>
<td>68 (61-72)</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>16 (95.6)</td>
</tr>
<tr>
<td>Female</td>
<td>1 (5.4)</td>
</tr>
<tr>
<td>BMI, kg/m², median (IQR)</td>
<td>26.0 (23.5-28.0)</td>
</tr>
<tr>
<td>Highest education, n (%)</td>
<td></td>
</tr>
<tr>
<td>University education</td>
<td>3 (13.0)</td>
</tr>
<tr>
<td>Higher professional education</td>
<td>5 (21.7)</td>
</tr>
<tr>
<td>Secondary vocational education</td>
<td>7 (30.4)</td>
</tr>
<tr>
<td>Pre-vocational secondary education</td>
<td>6 (26.1)</td>
</tr>
<tr>
<td>Elementary school</td>
<td>2 (8.7)</td>
</tr>
<tr>
<td>Experience with technology, n (%)</td>
<td></td>
</tr>
<tr>
<td>Smartphone</td>
<td>21 (91.3)</td>
</tr>
<tr>
<td>Computer</td>
<td>18 (78.3)</td>
</tr>
<tr>
<td>Tablet</td>
<td>15 (65.2)</td>
</tr>
<tr>
<td>Planned surgery type, n (%)</td>
<td></td>
</tr>
<tr>
<td>Abdominal aortic aneurysm open repair</td>
<td>9 (39.1)</td>
</tr>
<tr>
<td>Hepato-pancreato-biliary surgery</td>
<td>9 (39.1)</td>
</tr>
<tr>
<td>Lower gastrointestinal surgery</td>
<td>5 (21.7)</td>
</tr>
</tbody>
</table>

Table 2. Compliance with wearing the wearable sensor and experience sampling in the three phases of the perioperative trajectory (in median and interquartile ranges, IQR).

<table>
<thead>
<tr>
<th></th>
<th>Preoperative at home (n=23)</th>
<th>Postoperative in-hospital (n=19)</th>
<th>Postoperative at home (n=16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearable sensor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days with data within protocol, median (IQR)</td>
<td>22.0 (11.0-38.3)</td>
<td>7.0 (5.0-10.5)</td>
<td>19.0 (13.5-22.5)</td>
</tr>
<tr>
<td>Percentage days with data within protocol, median (IQR)</td>
<td>93.3% (75.1-100.0%)</td>
<td>100% (90.0-100%)</td>
<td>90.0% (71.1-100%)</td>
</tr>
<tr>
<td>Hours per day with data, median (IQR)</td>
<td>14.0 (12.6-15.8)</td>
<td>13.0 (12.0-13.8)</td>
<td>14.0 (12.3-15.0)</td>
</tr>
<tr>
<td>Experience sampling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage days within protocol, median (IQR)</td>
<td>83.3% (64.4-91.1%)</td>
<td>72.7% (57.5-79.1%)</td>
<td>87.5% (44.7-96.0%)</td>
</tr>
<tr>
<td>Responses in the morning, median (IQR)</td>
<td>19.0 (8.5-20.0)</td>
<td>4.0 (2.0-5.0)</td>
<td>19.0 (8.5-24.0)</td>
</tr>
<tr>
<td>Responses at 8:00 PM, median (IQR)</td>
<td>18.0 (8.0-33.3)</td>
<td>4.0 (2.0-6.0)</td>
<td>14.5 (7.0-21.5)</td>
</tr>
</tbody>
</table>
Contact moments

Concerning the contact moments outside the protocol, the number, type, and reason are shown per perioperative phase in Table 3. Of all 96 contact moments, 61.5% occurred during the preoperative phase of which 33.9% during the first week of inclusion. Preoperative contact moments occurred in 16/23 patients (69.6%), whereas 6/16 patients (37.5%) still needed extra contact moments postoperative at home. Most contact moments were outgoing calls from the researchers (45.8%) when data was not transferred to the database (53.1%). Other main reasons for contact in any phase were: technical problems (in total 22.9%), such as empty batteries or connectivity problems; discomfort of the patient (12.5%), such as wrong size of the bracelet; and insecurity of the patient (11.5%), such as removal of an app from the tablet by accident. The latter mainly occurred during the preoperative period. Of first contact moments due to no data transfer or technical problems, 59.1% were solved or did not require further action. A subsequent call or visit at home or in combination with another appointment in-hospital was needed in 13.6% and 12.1% of contact moments respectively, and 7.6% led to a (temporary) protocol stop. Possible solutions were reset of the HealthyChronos app or charging the sensor. Contact because of no data transfer or technical problems occurred for 59.1% in the first 9 patients who initially used an earlier version of the app. Of all contact moments, 75.8% comprised contact with the patient, 14.7% with a family member, and 9.5% with nurses.

Table 3. Number of contact moments outside the protocol, type of contact, and reason of contact per perioperative phase and in total. Percentages are calculated with respect to the total number of contact moments per phase.

<table>
<thead>
<tr>
<th>Reason of contact</th>
<th>Preoperative at home (n=23)</th>
<th>Postoperative in-hospital (n=19)</th>
<th>Postoperative at home (n=16)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No data transfer, first contact / follow-up, n (%)</td>
<td>26 (44.1) / 3 (6.8)</td>
<td>13 (68.4) / -</td>
<td>9 (56.3) / -</td>
<td>51 (53.1)</td>
</tr>
<tr>
<td>Technical problems, first contact / follow-up, n (%)</td>
<td>10 (18.2) / 2 (3.4)</td>
<td>5 (26.3) / 14.3</td>
<td>3 (18.8) / 17.5</td>
<td>22 (22.9)</td>
</tr>
<tr>
<td>Discomfort patient, first contact / follow-up, n (%)</td>
<td>6 (10.2) / 3 (5.1)</td>
<td>2 (10.5) / -</td>
<td>1 (7.1) / -</td>
<td>12 (12.5)</td>
</tr>
<tr>
<td>Insecurity patient, first contact / follow-up, n (%)</td>
<td>7 (12.1) / 2 (3.4)</td>
<td>2 (10.5) / -</td>
<td>-</td>
<td>11 (11.5)</td>
</tr>
</tbody>
</table>

Patient experiences

Seventeen patients (73.9%) completed the final evaluation questionnaire, as illustrated in Figure 2. Median overall satisfaction was 9.0 (IQR, 8.0 - 10.0) for both wearing the sensor and experience sampling. As for the intention-to-use, 16 patients (94.1%) would definitely use telemonitoring, and one patient (5.9%) would probably use it. Fifteen patients (88.2%) would also definitely recommend it to others, one (5.9%) probably, and one (5.9%) probably not.

Positive experiences mentioned by 16 patients included the low effort (n=11), contributing to the improvement of care (n=5), not noticing wearing the sensor (n=3), and receiving messages (n=1). Negative experiences of 12 patients comprised questions being short and monotonous (n=5), skin irritation of wearable sensor (n=3), no possibility to explain answers (n=3), connectivity problems (n=3), easy to forget to take the sensor from the charger in the morning (n=2), being too restricted (n=1), too much burden (n=1), and having no insight in data (n=1).

Patients considered the following factors important for telemonitoring being used in future perioperative care: being monitored (n=9), self-monitoring (n=8), monitoring blood pressure (n=3), sleep (n=1) and eating pattern (n=1), monitoring and feedback on physical activity to...
improve condition after surgery (n=2), involvement nurses (n=2), being able to choose time for experience sampling or wear sensor (n=2), and receiving a reminder to wear the sensor (n=1).

Expectations about future use comprised feeling of security at home (n=5), integrating personal measurements (n=2), decreasing workload nurses (n=1), less hospital visits (n=1), easier contact with healthcare personnel (n=1), monitoring with a chip (n=1), and more patient-centered monitoring (n=1).

DISCUSSION
Main findings
This study assessed the feasibility and patient’s experiences of telemonitoring at home and in-hospital before and after major abdominal surgery. Overall, telemonitoring as used in this pilot study showed to be feasible from patient’s perspective. Patients had high compliance with wearing the sensor and experience sampling throughout the complete perioperative phase. Weekly and overall satisfaction, intention-to-use and intention-to-recommend-to-others were high.

Compliance with wearing the sensor was highest in-hospital compared to the pre- and postoperative phase at home. Other studies at the surgical ward merely used wearable patches, for which compliance is less relevant.26 One potential barrier for postoperative telemonitoring could be that patients have increased physical and mental burden after surgery. For example, Jonker et al.20 observed that patients are less compliant with telemonitoring at home when they experienced postoperative complications. High in-hospital compliance with the sensor may be due to additional nurse involvement, easier on-site support by researchers, or possibly better WiFi connectivity in-hospital. In a recent study, the feasibility of the Everion biosensor was investigated in 20 pediatric patients undergoing chemotherapy for cancer.21 Participants were instructed to wear the Everion as often as possible during 14 days. They showed that no (heart rate) data was available for 35% of hours. Reasons for this were forgetting to wear the sensor and demotivating technical problems,21 which were also apparent in our results. Their compliance may be lower than ours due to differences in patient population and used methods to compute compliance. To increase compliance with wearing the sensor at home, it is advisable to remind patients to wear the sensor, or to notify when the sensor needs to be charged or is fully charged. The use of a sensor with prolonged battery life may also limit moments in which patients forgot to wear the sensor in the morning.

Our results show that experience sampling had slightly lower compliance compared to wearing the sensor, especially in-hospital. To our best knowledge, literature about monitoring patients’ well-being with a mobile app in-hospital is lacking. Other published studies regarding symptom monitoring in patients after major abdominal surgery started inclusions after discharge.23-26 where a median daily adherence of 95% (range 32-100%) has been reported.24 Apps for preoperative use in patients undergoing major surgery have been hardly described yet. Recently, Van der Velde et al.26 evaluated the usability of an app to improve preoperative health and risk behavior before major elective surgery. Although they reported that 73% of patients activated the app, they did not describe actual use. Experience sampling took more effort for patients, because they needed to actively respond. At home, patients were called if sensor data were not transferred for two consecutive days, while experience sampling responses were not monitored during the study period. Patients might have forgotten to answer the questions when they were not at home or preoccupied at that moment. At the surgical ward, patients were even more likely to forget or did not want to wear the sensor and answer daily questions, potentially because of their postsurgical state-of-mind. Nurses were only instructed to place the sensor on the upper arm of the patient in the morning and were not asked to stimulate experience sampling to limit bias in compliance. Nurse involvement may also have a positive effect on compliance with experience sampling in-hospital. Moreover, experience sampling might be well suitable for in-hospital telemonitoring when combined with well-being assessments by nurses in usual care. Integration of telemonitoring in clinical practice is important for compliance and should be taken into account in future trial design.

Weekly and overall satisfaction for both wearing the sensor and experience sampling, intention-to-use and intention-to-recommend-to-others were high. Huis in ’t Veld et al.27 showed no relationship between satisfaction and compliance in their study regarding a telerehabilitation app for chronic pain, although they found a trend between compliance and clinical benefit. However, according to the Technology Acceptance Model, the intention to accept technology is based on ease of use and perceived usefulness.27,28 Patients also mentioned that telemonitoring will be most useful during the postoperative period at home to improve monitoring and increase their feeling of security. They also found self-monitoring important in this respect. In a recent study on a general ward, 67% of abdominal surgery patients (n=27) felt safer when monitored with a wearable patch and 89% would like to keep wearing the patch at home after surgery.29 The high satisfaction we found might be related to the fact that patients experienced the telemonitoring as low effort, although we did not evaluate this. Future studies investigating feasibility of telemonitoring services should also focus on perceived usefulness in patients to increase their acceptance of telemonitoring, and therefore potentially increase compliance and clinical benefit.

Strengths and limitations
A strength of this study is that we included a diverse patient population with varying age, comorbidities, diagnoses, and surgical interventions. This study provides a comprehensive picture of the feasibility of and patient’s experiences with perioperative telemonitoring in patients undergoing major abdominal surgery. A limitation concerns the relatively small sample size. Another limitation is the observational pilot study design in which patients did not have
any benefit from telemonitoring. On the other hand, this study design enabled us to overcome
connectivity issues and learn from patients' experiences for the first time. Another limitation
is that it is difficult to distinguish compliance and technical problems, because compliance
with wearing the sensor was measured as percentage of days with data available, and data
might have also been unavailable due to technical problems while a patient did wear the
sensor. Regardless of our reports of contact moments in case of technical problems, this
may have led to an underestimation of actual compliance.

Facilitators and barriers: recommendations for future trial design
Our results show that important facilitators were the low effort and ease to wear the sensor.
Another potential facilitator for acceptance and use of telemonitoring services we identified
may be the ability to integrate patient specific preferences and to adjust the telemonitoring
service to a patient’s sleep-rhythm and habits. Patients were notified for experience sampling
twice a day. Compliance with experience sampling might be increased if patients could choose
the moment of notification (time-based monitoring of patient-reported outcome measures),
or receive a reminder. Contrary to our expectations and our aim to minimize the potential
burden of the questionnaires, several patients mentioned that the questions were too short
and monotonous. Besides, patients appreciate the opportunity to explain answers about their
well-being. This should be taken into account in future studies using experience sampling.
Main barriers for participation in and completion of the study were surgery-related mental
burden and recurrent technical issues. Most contact moments occurred preoperatively and
were mostly technology related. An important facilitator for successful implementation of
telemonitoring services in clinical practice will therefore be the technical support (e.g. training,
education and helpdesk or available coordinator) provided to patients and relatives and
healthcare personnel. We provided information about the study preferentially face-to-face
and visited the patients at home to deliver the devices and install WiFi on the tablet. This
requires a substantial time investment of healthcare personnel. Feasibility for healthcare
personnel has not been evaluated in this study, and should be taken into account and
assessed. Implementation of telemonitoring should actually lead to time savings, for example
by fewer hospital visits or length of hospital stay of patients, also for healthcare personnel. In
future trial design for studies evaluating effectiveness of telemonitoring, an optimized care
pathway is needed to maximize its effect instead of only adding telemonitoring to standard
of care.

A general barrier for implementation of telemonitoring is the current readiness of technology.5,30
Recent validation studies with the same sensor showed that data availability decreased during
physical activity and validity for the measured vital signs was poor to moderate.31,32 Koenig et
al.21 also showed problems with data quality assignment, data quality during physical activity,
and connectivity of the Everion biosensor. It is preferable to have continuous connection to
transfer sensor data to the database, for example by using 4G or 5G monitoring instead of
Bluetooth and WiFi. Although we did not evaluate this, WiFi speed at patients’ homes may
also be relevant for optimal connectivity. Currently, most available wearable sensors still
depend on Bluetooth or WiFi for data transfer. Battery performance of wearable sensors
should be improved to limit charging periods and enable continuous monitoring of multiple
parameters, such as vital signs, for at least several days.

Another barrier is that telemonitoring studies often are limited by selection bias.33,34 However,
not all patients included in our study had (extensive) experience with technology or a high
educational level. In that case, the role of family is important for success. For example, a
recent study showed that patients who considered telemonitoring less useful had a lower
educational level and were more frequently living on their own.35 For future studies, we
recommend involving relatives in telemonitoring at an early stage, especially at home.

Conclusions
In this small prospective study, telemonitoring before and after major abdominal surgery
was feasible from a patient’s perspective. Compliance was high with technical support
and nurse involvement during in-hospital stay. Compliance may be further increased with
patients’ input about the preferred moments for notifications and with reminders to wear a
sensor or improved sensor technology. Surgery-related mental burden and technical issues
were main barriers for patient participation. For future trial design regarding effectiveness
of telemonitoring, optimal implementation in clinical practice is required, and training and
support for patients, relatives and healthcare personnel highly recommended.
REFERENCES


