Towards clinical application of perioperative telemonitoring

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DOI:
10.33612/diss.244295830

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Document Version
Publisher's PDF, also known as Version of record

Publication date:
2022

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):

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General discussion and future perspectives towards clinical application
GENERAL DISCUSSION

Telemonitoring has potential benefits for patients undergoing major surgery, for example by postoperative monitoring of vital signs using wearable sensors or symptoms by mobile applications.1 To address the first steps needed towards clinical application of (cost-)effective perioperative telemonitoring, the objective of this thesis was to evaluate: (1) the quality of monitoring technology, (2) its feasibility in surgical patients, and (3) monitoring strategies for clinical application. Results of this thesis showed that the quality of the investigated monitoring technology varied between different wearable sensors, and data availability and accuracy of vital signs measured by these wearable sensors decreased during physical activity in volunteers. Moreover, only HR measured by a wearable sensor had moderate validity compared to nurse measurements in surgical patients at the surgical ward. Our feasibility assessment showed high patient satisfaction and compliance with wearing a sensor and answering daily questions in an app in a diverse surgical patient population. However, surgery-related mental burden and recurrent technical issues were main barriers for patient participation. Evaluation of monitoring strategies in this thesis indicated that a reliable measurement period for preoperative baseline values of HR and daily steps at home comprised of at least three consecutive measurement days. The results in this thesis emphasize that evaluation of these three steps is indeed needed before effective clinical application of telemonitoring technology. Main results from each part are discussed in light of the surgical and non-surgical treatment of patients with peripheral arterial disease (PAD). This expert opinion was published as part of a literature review (early 2019) to evaluate the applications.1

PART III        MONITORING STRATEGIES FOR CLINICAL APPLICATION

So far, main challenges of technology for telemonitoring are: (1) improvement of the diagnostic accuracy of wearable sensors, and therefore, the monitoring of patients anywhere; (2) comparison of every vital sign measured by the sensor with hospital-grade patients monitors; (3) ‘field-testing’, for example 5 days at home, to assess the quality and usability of the implemented technology; and (4) privacy and storage of data. Electronic applications enable remote consultation between patients and healthcare professionals2 and can be used to monitor patients wellbeing through wound monitoring or experience sampling (measuring experiences of daily life, such as pain and fear); inform patients about their treatment; and provide feedback and coaching.3

Chapter 3 showed that accuracy of all wearable sensors (Everon, VitalPatch, and Fitbit Charge) for vital signs monitoring decreased during physical activity in volunteers. Chapter 4 showed that HR measurements from Everon worn by surgical patients had a moderate relationship with nurse measurements, where RR >16 breaths/min was overestimated, and SpO 2 and temperature were underestimated. Although this provided a first evaluation of the quality of these sensors, this is only part of the technology evaluation towards clinical implementation according to the expert opinion section.

Regarding the needed hardware, the quality of the used sensors in this thesis was lower than anticipated, with the exception of VitalPatch. To bring a sensor to the market, manufacturers only have to demonstrate the ability of a sensor to measure the intended parameters without any quality or validity requirements. Validity is often at most evaluated in a small number of healthy volunteers in a controlled environment for few of the available parameters, as was the case for Everon for HR.5 It could be helpful if manufacturers provide information about accuracy of all measured parameters and settings within their intended use; transparency in changes in software updates (and ideally enable manual updates6); access to (raw) data; insight in used (variables for) algorithms7; and clear instructions for use in-hospital and at home.

Before use of a new wearable sensor in clinical practice, researchers may evaluate its performance as well for a specific clinical application. Brelent et al.1 proposed a test protocol that existed of four phases: (1) routine electrical safety and bench tests by the hospital medical physics department; (2) comparison of every vital sign measured by the sensor with hospital-grade patients monitors; (3) ‘field-testing’, for example 5 days at home, to assess the quality of data and the usability from patient experiences; and (4) subsequent a clinical validation study in high-risk patients to evaluate sensor performance in abnormal physiological ranges.

For the assessment of technological quality, uniformity in measurement methods is currently lacking.14 The following methods were used in Chapter 3 and 4 of this thesis, and could be useful for future evaluation of the monitoring quality of wearable sensors. In clinical validation studies, Bland-Altman analyses adjusted for repeated measurements15 are commonly used to calculate the mean difference and 95% limits of agreement to assess reliability of vital signs measured by wearable sensors.16,17 Besides, intra-class correlation coefficients with

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95% confidence intervals could be used in future studies to assess concurrent validity. The median absolute percentage error (MAPE) or root-mean square error (RMSE) may be used to measure the average amplitude of the error of continuous measurements compared to reference values. MAPE is easier to understand and less vulnerable for changes in sample size, whereas RMSE gives a higher weight to large errors. For all analyses, it is still unknown what performance is acceptable for clinical use of wearable sensors. Acceptable mean differences reported by other studies were ±5 beats/minute or ±10% for HR, ±2 to ±3 breaths/minute or ±10% for RR, ±2% for SpO₂, ±0.5°C for skin temperature, ±5 mmHg for blood pressure, and ±1 for Modified Early Warning Score (MEWS) compared to reference values. These limits are considered relevant, since they affect the level of surveillance based on MEWS. The consequences on treatment decisions could be further investigated using Clarke’s Error Grid Analysis in which areas are defined in the plot of sensor measurements compared to reference measurements to define the percentage of data points leading to inadequate or adequate treatment decisions. Besides evaluation of absolute differences between a sensor and its reference, a sensor’s trending ability may be even more relevant. The trending ability could be assessed by calculation of the concordance rate using four-quadrant plots representing differences between consecutive sensor measurements at the y-axis and corresponding the differences between consecutive reference measurements at the x-axis.

Software or algorithms are needed to assist in deriving, handling and interpreting data from patients by telemonitoring, but are still under development. One the one hand, current algorithms for deriving parameters from the PPG signal could be improved, especially during physical activity. Since deviant patterns were shown during rapid physiological changes in Chapter 3, On the other hand, new devices and algorithms are being developed to derive a wide range of parameters from PPG and/or ECG signals, such as non-invasive blood pressure using pulse wave transit time technique. However, most nurses and doctors are not used to interpret data from continuous monitoring in general, and it is still unknown what suitable alarm criteria are. It is debatable whether continuous monitoring with wearable devices is better compared to real time monitoring of the currently used Early Warning Scores (EWS), as evidenced in several studies. For example, available sensors are not able to measure all relevant parameters in the EWS at this moment, such as blood pressure and urinary output. Other algorithms are being developed for alarm criteria with the ability to detect adverse events based on continuous vital sign monitoring. Main barriers mentioned are nursing engagement and alarm burden. More patient-specific and relative alarm criteria might improve alarm accuracy. Algorithms should be developed that take into account a sensor’s accuracy and ability to measure changes over time and the influence of confounding factors on vital signs, such as physical activity, the circadian rhythm, and age.

With the right hardware and software, a network infrastructure should be able to process data from telemonitoring devices into the patients electronic health record (EHR). For that purpose, it is useful that manufacturers facilitate interoperability with the EHR, and optimize data transmission to minimize data loss, for example by development of 4G/5G-based devices. In that case, a sensor’s connectivity does not depend on Bluetooth and Wi-Fi connection at a patient’s own environment, and technical failure and network costs do not have to be a burden for the patient. Regardless of the used network infrastructure, data availability is also important in evaluation of the quality of monitoring technology, and should be taken into account in future work.

Feasibility in surgical patients

“Telemedicine can potentially benefit patients with PAD. There are, however, some practical issues that need to be overcome before this can successfully be implemented in daily clinical practice. Patients feel satisfied and in control at the beginning of a telemedicine intervention, but at a certain point, the intervention becomes routine and motivation decreases. Game-based interventions could possibly have a positive influence on exercise attitudes in vascular patients. Patient input in the development of personalized telemedicine from focus groups and pilot studies might also benefit patient engagement towards such programs. Furthermore, Gunter et al. mentioned concerns about program sustainability because of extra work load for nurses due to the in-hospital explanation of the intervention and processing of app information during their normal work activities. Sustainability depends on integration within the health care system and incorporation into daily routine. The latter is highly dependent on the type of devices used. For example, the ease of use of telemedicine tools (tablets, smartphone, applications, measurement instruments), the presence of feedback and level of control will probably influence patients’ adherence toward telemedicine programs.”


The most important facilitators reported in Chapter 5 and Chapter 6 were a feeling of empowerment because of the ability or expectation of self-monitoring, and the ease to wear a sensor. Main barriers were technical problems, such as connectivity issues, and the time-consuming aspect for patients (Chapter 5) and healthcare personnel (Chapter 6). Since quality of technology influences the feasibility and usability of a telemonitoring service, the latter should be evaluated once the quality of technology is sufficient. A general limitation is that the feasibility study of Chapter 6 using the Everion biosensor was performed during the same period as its validation in Chapter 3 and 4. In contrast, technical issues such as connectivity problems or limited battery performance are less likely to occur during short-term validation studies in controlled environments (i.e. the lab from Chapter 3 or in-hospital from Chapter 4) than at home, and will be part of the evaluation of feasibility of telemonitoring as well.
The expert opinion section highlighted concerns about patient engagement (intention to or actual use) towards telemonitoring programs. According to the Technology Acceptance Model, actual use of technology depends on perceived usefulness and perceived ease of use. The Unified Theory of Acceptance and Use of Technology showed that usage prediction also involves performance and effort expectancies, facilitating conditions and social influences, and is moderated by gender, age, voluntariness, and experience. Compliance (as measure of actual use) with a telemonitoring service has been associated with clinical benefit. However, usage fatigue has been reported as a general limitation for SMS (short message service) or mobile application interventions in surgical patients.

In addition, selection bias is a common limitation for the generalizability of telemonitoring studies and may overestimate compliance and satisfaction in the entire patient population. On the one hand, Chapter 5 and 6 showed that patients may already feel too overwhelmed by the planned surgery to be willing to participate in a telemonitoring study. Unfortunately, patients not willing to participate in technology-based intervention studies are likely to benefit the most from it. On the other hand, 32% of participants mentioned contributing to improvement of care as a positive experience of study participation in Chapter 6, as is well known in clinical research in general. A first pilot study to evaluate feasibility provides valuable information and recommendations for future studies or use. Nevertheless, the potential relationship between selection bias and feasibility outcomes (i.e. compliance and satisfaction) in telemonitoring research should be taken into account in the translation to clinical practice.

For application in clinical practice, feasibility and usability may be improved with early phase engagement of end-users including nurses and patient focus groups in development. This is probably especially the case for (software) applications or questionnaires, since these require a more active user role compared to wearable devices. In line with this, for surgical patients who had to actively perform and report measurements in an app, compliance decreased in case of postoperative complications. Engagement with using such an app may be further increased by: (1) optimal embedding of the service in care processes; (2) using persuasive strategies; such as personalization of content and moment of notifications and the provision of self-monitoring; and (3) by a more sociotechnical approach involving e.g. patients’ relatives.

Monitoring strategies for clinical application

“1. Telemonitoring could already be of additional value in the pre-operative phase by providing information for preoperative screening, decision making, and optimizing patients before surgery. The latter is known as prehabilitation, which is currently increasing interest and is based on the “better in, better out” principle. In PAD patients, telemedicine could assist in prehabilitation by activity monitoring and coaching, for example, in patients who receive supervised exercise therapy from a physical therapist. Furthermore, mobile applications that consist of information and questionnaires can play an important role in (preoperative) secondary risk prevention by lifestyle management coaching in this fragile population.

During the complete care trajectory of PAD patients (hospitalized or not), implementation of continuous monitoring with wearable devices could not only be used for earlier detection of deterioration but might also reduce the workload for nurses and contribute to patients’ comfort and satisfaction. However, what the optimal frequency is for monitoring and in which phase of care is unclear: continuously, hourly, daily, weekly? A pilot study in which patients are monitored in the complete perioperative trajectory to answer these questions would be beneficial. Subsequently, the effects of implementation of telemedicine interventions in PAD patients should be further explored in larger randomized controlled trials.”


Chapter 7 showed that patients awaiting major open abdominal surgery should be monitored for at least three days at home to get reliable individual baseline values for heart rate daily step count, and PROMs could be reliably measured at any preoperative day. Despite this, it is still unknown whether and how preoperative telemonitoring at home can be used to improve postoperative patient outcomes, for example in preoperative risk assessment, prehabilitation, or as individual baseline for monitoring postoperative recovery.

Closing the monitoring gaps between intensive care unit, surgical ward and at home for early warning of postoperative deterioration, while allowing early mobilization, is considered one of the main applications of telemonitoring. Postoperative telemonitoring has been associated with early administration of antibiotics in sepsis, shorter length of hospital stay (LOS), and lower risk for readmission within 30-days after discharge. In-hospital, the measurement frequency for continuous monitoring has been set at one minute with a moving median filter of 15 minutes epochs. At home, the most common frequency of data collection is daily during follow-up of 1 to 3 months after surgery. The optimal frequency and filtering settings of postoperative telemonitoring depend on the clinical question and should be subject of future research. Besides, standardization of clinical outcome measures are not only relevant for reporting outcomes, but also for detection of deterioration.

Combining information from telemonitoring devices and the EHR enables advanced analyses of a patient’s health status and potentially even prediction of progress, for example by using artificial intelligence (AI). AI tools are already involved in detection of abdominal emergencies with imaging and laboratory data. Besides continuous monitoring of vital signs, acquisition of wound images, nutrition monitoring, sleep monitoring, symptom monitoring (for example
postoperative pain management by SMS, or activity monitoring may improve recovery assessment after surgery. Activity trackers are relatively cheap and may be useful in objective monitoring of physical activity for optimizing prehabilitation and rehabilitation, prevention of postoperative complications, predicting LOS, detection of falls and tracking body position to support prophylactic measures and pressure sores. A new and interesting approach for remote patient monitoring is the use of ‘light detection and ranging’ or ‘laser imaging, detection, and ranging’ called LIDAR. With 3D scanning of an environment (for example a patients’ hospital room or home environment), fall risk factors can be identified or physical activity can be monitored by calculating range of motion after surgery.

In summary, the possibilities for application of perioperative telemonitoring are countless. However, it is not likely that telemonitoring alone accomplishes measurable clinical improvement after surgery. Telemonitoring should be complemented with other services for optimal use and effectiveness, such as patient education, prehabilitation programs and video consulting. Video consulting has urgently been adopted as a safer means of providing medical care during the COVID-19 pandemic. Based on patient preferences, video consultations might be equivalent to face-to-face consultations in terms of patient satisfaction and perceived quality of care. Reported benefits for video-consults could be reduced costs and time investment for patients. A recent review reported that multiple studies proved video visits to be safe and effective for both preoperative assessments and postoperative monitoring or follow-up, also in high-risk surgical patients. Nevertheless, its applicability to different surgical sub-specialties should be investigated in future work.

**Evaluation of (cost-)effectiveness**

It is remarkable that such an important outcome as cost-effectiveness of telemonitoring (in PAD or other patient groups) is still an underexplored area. The following factors are to be considered in future cost-effectiveness assessments. First, economic evaluation of telemonitoring interventions requires proper implementation in healthcare. Second, the definition of a cost or effect in evaluation of telemedicine interventions compared to usual care relies on the policy level of interest: whether it comprises cost-effectiveness at the level of government, hospital or patient. Third, although economic evaluation of telemedicine interventions will influence its availability in future healthcare, the success of such implementations probably also depends on hardly measurable subjective perceptions of both caregivers and patients, such as workload and feeling of security respectively.

Standardization in reporting on outcomes of the use of telemedicine is important and further development of telemedicine guidelines is necessary. One of the important initiatives is from the American Telemedicine Association which made progress to prioritize such guidelines and development of telemedicine standards. Physicians all over the world implementing telemedicine and studying the effects of telemedicine in healthcare should be encouraged to work according these standards. Moreover, finetuning of global telemedicine guidelines and standardization in reporting on outcomes should be on the agenda in the world-leading telemedicine conferences.


After evaluation of the steps towards clinical application as presented in this thesis, it is less remarkable that (cost-)effectiveness is hardly evaluated and evidence is scarce. The results of this thesis emphasize the importance to follow these steps before evaluation of a telemonitoring service in a randomized controlled trial (RCT). In Chapter 1, the methodology of controlled trials was discussed, since RCTs may not be optimal for the evaluation of effectiveness of telemonitoring interventions. This is in contrast with the earlier statement in the expert opinion section. Nevertheless, evaluation of (cost-)effectiveness is important before a telemonitoring service can be embedded in clinical practice. As an alternative for the RCT, Relton et al. introduced the cohort multiple randomized controlled trial (cmRCT) that starts with recruitment of a large observational cohort with regular outcome measurements and random selection of patients from this cohort to receive an intervention. This enables multiple randomized controlled trials from the same cohort, which is more suitable when technology develops over time.

Objective data on costs, both in- and outside the hospital is not readily available and assessment of cost-effectiveness requires a well-integrated process. Modeling cost-effectiveness might be an alternative for prospective RCTs to evaluate perioperative telemonitoring interventions and assist in policy making about financing. Javanbakht et al. presented such a model showing that the total costs of intermittent monitoring with wireless vital sign monitoring in patients at the surgical ward were lower compared to intermittent monitoring alone over a 30-day period. Reasons for this were lower numbers of hospital readmissions and shorter LOS, which were besides ICU admissions, the only outcome measures included in the model. A drawback of these models is that clear assumptions need to be made about: (1) the effects of telemonitoring, preferably in a specific patient population; (2) the policy level of interest as mentioned in the expert opinion section; and (3) the relevant outcome measures to take into account and how to value measures as satisfaction or feeling of security.
FUTURE PERSPECTIVES TOWARDS CLINICAL APPLICATION

Current lack of (successful) application of telemonitoring services might be related to its complexity and consequences for scalability in clinical practice. The NASSS framework was developed to evaluate non-adoption, abandonment and challenges for scale-up, spread and sustainability of technology adoption and innovations in healthcare organizations.68 This framework could be used for guidance on seven domains with subquestions that can be classified by different levels of complexity: (1) the condition; (2) the technology; (3) the value proposition; (4) the adopter system (staff, patient, caregivers); (5) the organization; (6) the wider system; and (7) embedding and adaptation over time. Relevant insights from this thesis as future perspectives for clinical application of perioperative telemonitoring will be addressed per domain.

1. The condition
The first domain of the framework comprises the clinical context, comorbidities and sociocultural aspects of patients for which telemonitoring will be used.68

Patients undergoing major abdominal surgery are at high-risk, since postoperative complication rates up to 44% have been reported.56 About 60% of the complications after major abdominal surgery, such as respiratory failure, pulmonary embolus, myocardial infarction and congestive heart failure, occur within three postoperative days.70 Throughout the 30-days postoperative period patients are also at risk of pneumonia, sepsis, surgical site infections, arrhythmia, bleeding or falls.54,70 A mortality rate of 4% within 30 days after abdominal surgery has been reported,70 of which 75% after the first postoperative week, mainly due to cardiac events (30%), sepsis, hemorrhage, respiratory failure or other causes.70

Only a fraction of patients has been considered suitable to use a new technology by their clinicians, for example due to their clinically high-risk condition, comorbidities or sociocultural factors, such as cognitive considerations or health illiteracy.68 In Chapter 5 we learned that age alone should not be a problem for the feasibility of telemonitoring interventions in surgical patients. However, involving patients relatives is important for participation and use of telemonitoring (Chapter 6), especially in patients with technology illiteracy or cognitive considerations. Complexity on this domain may be reduced by scaling back on the conditions for which telemonitoring might be useful.68 Most importantly, future work regarding telemonitoring services needs to focus on accessible patient education to involve as many patients as possible.

2. The technology
The technology domain addresses the features of and measured parameters by telemonitoring devices. Additionally, this domain includes the knowledge needed to use this technology and the extent to which adjustments are still needed within the organization for the use of this technology.68 Acquisition of more data is not always better and demands for critical selection of measured parameters and frequencies, and for proper agreements about responsibilities. Future work should focus on what information is provided by telemonitoring to end-users (nurses and patients) and how they should interpret and use this.

Complexity in the technology domain could be reduced by using less complex technological features and interconnections, such as technological integration within the organization.68 In telemonitoring research, technology is often evaluated as a freestanding service, which influences the actual and perceived usability,68 such as presented in Chapter 6. In the future, a “research integration” with the EHR could be useful to enable visualization in the EHR while data is being saved and algorithms run on a research server.

3. The value proposition
In this domain, it is important to know whether telemonitoring services are worth developing at all, since there is frequently a mismatch between the value for the developer and that for patients or other users.56 For clinical application, it is important to have a clear objective and understanding of the (potential) value of perioperative telemonitoring for the patient, staff, and the organization in advance.

For the patient, the added value of telemonitoring might be a feeling of empowerment or security (Chapter 5) by high-frequency self-monitoring, especially at home. In addition, telemonitoring might save time and money by reducing the number of unnecessary hospital visits. It should be investigated whether all surgical patients would benefit from telemonitoring or whether a selection of patients can be made, for example based on patient characteristics or other risk factors to be defined, to increase the value and (cost-)effectiveness of telemonitoring.

Telemonitoring is expected to support staff, for example to identify patients at high risk of deterioration. Moreover, telemonitoring might be less time consuming than manual monitoring. Future work should also take into account the value for staff to guide changing the work process and increasing usage. For the organization, the potential cost-effectiveness of care by telemonitoring is most relevant, for example if surgical patients return to the hospital early because of risk for deterioration based on telemonitoring. This might prevent unplanned readmissions or reoperations on the one hand, and unnecessary hospital visits on the other hand. An early business case is needed to inform the organizational or division board about needed funding decisions to make telemonitoring part of standard care and to increase its scalability. In line with that, it could also be useful to investigate reimbursement options from health insurers in an early phase. Financial support from health insurers contribute to sustainable use of telemonitoring in cross-organizational care. Although this is still a vision for future healthcare, there are many developments in this field. For example, a health insurer...
and hospital in The Netherlands recently agreed on reimbursement of telemonitoring for chronic heart failure as part of usual care.71

4. The adopter system
This domain is about the engagement and use of telemonitoring by patients and staff, which depends on the usability or ease of use of the technology, acceptance and required work of users, or the behavior of lay caregivers.68

Besides the aspects mentioned in part II of this thesis about patient engagement towards telemonitoring programs, an investment in time and money is required to provide technological support and training for patients, relatives and personnel for optimal adoption. The usability, acceptance and required work of patients and staff depend on the care process re-design as well. In practice, workload often increases first when using new technologies and task allocation might be needed. The Burden of Treatment Theory of May72 proposes that shifting work from clinician to patients creates higher demands on patients, which might be rather disempowering instead of increasing self-empowerment for patients, while the latter is considered a possible advantage of telemonitoring. In general, complexity in this domain could be lowered by reducing demands on staff and patients,69 for example by critical consideration of the tasks that users are asked to perform. A stepwise approach might lower the threshold to use the telemonitoring service, including an important role for project leaders, researchers and involved ambassadors, such as lay caregivers, to optimize adoption for patients and staff. Frequent evaluation of acceptance and required workload is needed so that the willingness to use remains high.

5-7. The organization, the wider system, and embedding and adaptation over time
Although this was outside the scope of this thesis, important factors to scale-up a telemonitoring service are the organizations’ capacity and readiness for the technological innovation and board-level decisions on dedicated budget to support implementation. Aspects of the wider system include health, fiscal, legal and regulatory policies for technology development.68 Since these policies rapidly change, as well as technology itself, it is important that the organization is resilient and flexible.

To start with telemonitoring, pilot studies evaluating the feasibility and usability provide valuable information about clinical application in a specific population and medical center. However, usability and effectiveness of telemonitoring can only be properly assessed after full integration into and potential adaptation of the clinical process, when the telemonitoring service is not only an addition to the existing processes. The gap between research and clinical application if often large. A shared vision should be built to create collective guidance on what such technologies can and cannot do in the organizational setting.68 Furthermore, a physical service point in-hospital could be used for the exchange of devices, and service and training for patients and personnel.73

Safety and privacy issues are mentioned as concerns for use of eHealth technology by both patients and healthcare personnel.43,44 It was common for data to be collected only within the hospital, while telemonitoring enables data acquisition outside the hospital as well. Trust in safety and privacy aspects of such technologies might influence its use. Technology has to comply with changing regulation, and knowledge about this is often hard to find within the hospital. It is important for the adoption in the network infrastructure to comply with regulations on who has insight in the measured data69 and on what is the appropriate use of data for both research and development, as established in contracts and informed consents.46 Support within the hospital is needed on (continuously changing) technological, regulatory, legal and privacy issues, ideally without substantial delay of the process.

In line with this, the organization should be resilient for rapid changes in technology development. New technologies should be reevaluated as proposed in part I of this thesis. Subsequently, the value proposition (domain 3) and adoption (domain 4) should be studied again depending on the actual differences in technology, for example when different parameters are monitored or ease of use had potentially changed. It is recommended that the organization is more or less sensor independent in the sense of enabling interoperability and standardized exchange of data with which sensor suppliers need to comply, such as the MedMij criteria.75 Since more and more companies emerge in the field of telemonitoring technology and software, the potential disappearance of these companies from the market must be taken into account for the scalability and sustainability of the service.

In conclusion, this chapter highlights challenges of and recommendations for clinical application of perioperative telemonitoring. To start with, this thesis contributed to the evaluation of monitoring technology quality, feasibility in surgical patients and development of monitoring strategies for clinical application. Ideally in the future, telemonitoring facilitates a patient-centered approach (Figure 1) for monitoring a patient during the complete perioperative trajectory to minimize the monitoring gap between in-hospital and at home. Patient data is continuously communicated to a server from which: (1) relevant data can be stored in the patients’ EHR; (2) a platform can be used to communicate with, inform, and provide feedback to the patient; and (3) algorithms can be used to inform or alarm healthcare personnel about potential deterioration. Preferably, all involved healthcare institutes have access to certain data for both research and development, as established in contracts and informed consents.48 Providers and institutions of care in the hospital, while telemonitoring enables data acquisition outside the hospital as well. Trust in safety and privacy aspects of such technologies might influence its use. Technology has to comply with changing regulation, and knowledge about this is often hard to find within the hospital. It is important for the adoption in the network infrastructure to comply with regulations on who has insight in the measured data and on what is the appropriate use of data for both research and development, as established in contracts and informed consents.46 Support within the hospital is needed on (continuously changing) technological, regulatory, legal and privacy issues, ideally without substantial delay of the process.

In conclusion, this chapter highlights challenges of and recommendations for clinical application of perioperative telemonitoring. To start with, this thesis contributed to the evaluation of monitoring technology quality, feasibility in surgical patients and development of monitoring strategies for clinical application. Ideally in the future, telemonitoring facilitates a patient-centered approach (Figure 1) for monitoring a patient during the complete perioperative trajectory to minimize the monitoring gap between in-hospital and at home. Patient data is continuously communicated to a server from which: (1) relevant data can be stored in the patients’ EHR; (2) a platform can be used to communicate with, inform, and provide feedback to the patient; and (3) algorithms can be used to inform or alarm healthcare personnel about potential deterioration. Preferably, all involved healthcare institutes have access to certain relevant information about the patient. Provider-independent central monitoring facilities, such as Zorgcentrale Noord,26 may play a key role in this. The shared goal is to provide the right care in the right place on the right time, where telemonitoring is not used as a goal, but as a tool to support personalized care. It is not questionable whether telemonitoring will play a role in perioperative care such as illustrated in Figure 1. The question is how we can use...
it as effectively and efficiently as possible to reduce the pressure on our healthcare system while maintaining or even improving the quality of care.

**REFERENCES**


PART III    MONITORING STRATEGIES FOR CLINICAL APPLICATION


