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Haveman, Marjolein E; Jonker, Leonie T; Hermens, Hermie J; Tabak, Monique; de Vries, Jean-Paul Pm

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Effectiveness of current perioperative telemonitoring on postoperative outcome in patients undergoing major abdominal surgery: a systematic review of controlled trials.

Marjolein E. Haveman[1], Leonie T. Jonker[1], Hermie J. Hermens[2,3], Monique Tabak[2,3], Jean-Paul P.M. de Vries[1]

[1] Department of Surgery, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands
[2] Department of Biomedical Signals and Systems, University of Twente, Enschede, The Netherlands
[3] eHealth group, Roessingh Research and Development. Enschede, The Netherlands

Correspondence:
Marjolein E. Haveman
Postal address: House postal code BA60, Hanzeplein 1, 9713 GZ Groningen, The Netherlands
E-mail address: m.e.haveman@umcg.nl

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Abstract

Background: Perioperative telemonitoring of patients undergoing major surgery might lead to improved postoperative outcomes. The aim of this systematic review is to evaluate the effectiveness of current perioperative telemonitoring interventions on postoperative clinical, patient-reported, and financial outcome measures in patients undergoing major surgery.

Methods: For this systematic review, PubMed, CINAHL, and Embase databases were searched for eligible articles published between January 1, 2009 and March 15, 2021. Studies were eligible as they described: (P) patients aged 18 years or older who underwent major abdominal surgery, (I) perioperative telemonitoring as intervention, (C) a control group receiving usual care, (O) any type of postoperative clinical, patient-reported, or financial outcome measures, and (S) an interventional study design.

Results: The search identified 2958 articles of which ten were eligible for analysis, describing nine controlled trials of 2438 patients. Perioperative telemonitoring comprised wearable biosensors (n=3), websites (n=3), e-mail (n=1), and mobile applications (n=2). Outcome measures were clinical (n=8), patient-reported (n=5) and financial (n=2). Results show significant improvement of recovery time, stoma self-efficacy and pain in the early postoperative phase in patients receiving telemonitoring. Other outcome measures were not significantly different between the groups.

Conclusion: Evidence for the effectiveness of perioperative telemonitoring in major surgery is scarce. There is a need for good quality studies with sufficient patients while ensuring that the quality and usability of the technology and the adoption in care processes are optimal.

Keywords: telemonitoring; eHealth; perioperative; major surgery; postoperative outcome

Introduction

Elective major abdominal surgery is associated with substantial morbidity and risk of complications [1-3]. Minimal invasive surgical techniques and protocols for enhanced recovery after surgery (ERAS) aim to decrease length of hospital stay (LOS), complication rates, readmission rates and mortality [4,5]. However, complication rates still range from 33%-43%, depending on the type of surgery [1,6,7]. Patient outcomes and experiences could be further improved by better monitoring in-hospital and at home. Telemonitoring is hypothesized to play a role in this, for example by early detection of postoperative deterioration and by facilitating migration of care towards home.

Telemonitoring shows great diversity in goals and applications. Web- or mobile applications are available to monitor physical and mental parameters. Besides, technological development enables wireless measurement of vital parameters and activity with wearable sensors with improving quality [8,9]. Such insight in patients' perioperative wellbeing might enable earlier or better management of health changes [10-13]. In this way, telemonitoring also contributes to controlling healthcare costs [14].

Most perioperative telemonitoring interventions target patients undergoing cardiac or orthopedic surgery [15]. With increasing interest, studies focus on perioperative telemonitoring in patients before or, mainly, after abdominal surgery as well [12,16,25,17-24]. Although initiatives are frequently assessed in

terms of feasibility, there is a need to get insight in current evidence of effectiveness of perioperative telemonitoring interventions around major surgery and guidance in how to implement this in healthcare practice.

The aim of this systematic review is to evaluate the effectiveness of current perioperative telemonitoring on postoperative outcome in patients undergoing major abdominal surgery in controlled trials.

Methods

This systematic review was written according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [26]. The review protocol was prospectively registered in the PROSPERO database (ID: CRD4202016898).

Eligibility criteria were formulated using PICOS (patient, intervention, comparator, outcome, study design). Studies were eligible if they: included patients aged ≥18 years undergoing major abdominal surgery (P), used perioperative telemonitoring (I), included a control group receiving usual care (C), reported any type of postoperative clinical, patient-reported or financial outcome measures (O) in interventional studies (S). Feasibility outcome measures were not included. Perioperative telemonitoring comprises the wireless monitoring of patients either in-hospital or at home in addition to or as replacement of regular care and used to act upon (by patient and/or healthcare professional) during the perioperative period, defined as the period of waiting time before surgery until 30-days after hospital discharge. Telephone follow-up was outside the scope of this review as was telemonitoring during surgery or admission at the intensive care unit (ICU).

Exclusion criteria were: i) no telemonitoring, ii) only minor, ambulatory, or day surgery, iii) telemonitoring not perioperative, during surgery or ICU/Post Anesthesia Care Unit admission, iv) no controlled interventional study, v) no postoperative patient-related or financial outcome measures, vi) age patients <18 years, vii) or no full text available. Articles were excluded in case of unavailable full text articles after our medical library could not gain access and the author was contacted. No restrictions were made for language or sample size.

PubMed, CINAHL (via EBSCO), and Embase databases were searched for eligible articles published between January 2009 and March 15, 2021. Search terms existed of telemonitoring, perioperative, and outcome terms, both free-text and controlled terms (Medical Subject Headings in PubMed, Subject Headings in CINAHL, and Emtree in Embase). Terms for children and study types (study protocol and case study) were used to limit the search. The full search strategy can be found as Supplementary.

Two authors (MH, LJ) independently screened the unique titles and abstracts of the identified studies for relevance and made a final selection of eligible articles after full text reading of the remaining relevant studies. Data were extracted from the eligible articles by two reviewers (MH, LJ). In case of

discrepancies between the two reviewers in study selection or data extraction, a third reviewer (JV) was consulted.

Extracted data consisted of year of publication, study design, study period, study inclusion criteria, age of included patients, sample size, description of control group, type of surgery, type and moment of telemonitoring intervention, and study outcomes including assessment method and moment of follow-up. Postoperative outcomes were either clinical (i.e. LOS), patient-reported (i.e. pain), or financial (i.e. cost-effectiveness) reported by intention-to-treat.

The risk of bias of the studies per type of outcome measure was assessed using the Cochrane Risk of Bias 2 tool (RoB 2) for the randomized controlled trials (RCTs) [27] and the ROBINS-I tool for the non-randomized intervention studies [28], and the assessment was performed by two reviewers independently (MH, LJ).

Due to the methodological and clinical heterogeneity of patient groups, data pooling and meta-analysis were not performed. Results were descriptively presented by type of outcome measures (clinical, patient-reported and financial) and related to the type of telemonitoring. The risk of bias assessment was considered in the interpretation of study outcomes.

Results

After screening 2958 titles and abstracts after duplicate removal, 50 articles were assessed for eligibility of which ten were included in the review [29-38]. Figure 1 shows the PRISMA flow diagram.

[insert Figure 1]

The ten included articles describe nine controlled trials of 2438 patients in total (mean 271 patients per trial, range 59-854) of which 1219 patients received telemonitoring (mean 135, range 26-396) and 1219 patients received usual care (mean 135, range 33-458). Telemonitoring comprised wearable biosensors (n=3 studies) [29,36], websites (n=3) [30,32,39], e-mail (n=1) [33,40,41], and mobile applications (n=2) [34,35]. Study characteristics are shown in Table 1. Of these ten articles, eight described clinical outcomes, five patient-reported outcome measures (PROMs) and two financial outcomes. Figure 2 shows the results per component of the risk of bias assessment for each outcome measure.

[insert Table 1]
[insert Figure 2]

Clinical outcomes

Reported clinical outcomes were LOS (n=4), recovery time (n=3), readmissions (n=5), postoperative complications (n=4), and consultations (n=2). Study results for clinical outcomes with overall risk of bias are shown in Table 2 and summarized below.

[insert Table 2]

Skraastad et al. [36] aimed to improve quality of care at the surgical ward during the first 24 hours postoperative using the Efficacy Safety Score (ESS) integrated with continuous monitoring compared to usual interval monitoring using Early Warning Scores (EWS). Continuous monitoring comprised measurement of heart rate, ECG, ventilation rate, axillar skin temperature, blood pressure and finger pulse oximetry with wireless sensors. Mean time to mobilization was significantly (4 hours) shorter in patients in the intervention group (n=56) compared to the control group (n=58), p=0.008. Mean LOS was not significantly shorter in the intervention group (n=96) compared to the control group (n=99). No significant difference in postoperative complications was demonstrated (5% in the intervention group vs. 2% in the control group). The clinical outcomes of this study had high risk of bias, because measurement of time to mobilization and complication rates were not clearly stated and almost half of the included patients were excluded from analysis.

Downey et al. [29] aimed to evaluate the practicability and acceptability of remote vital signs monitoring at the surgical ward. Patients were randomized to a ward with continuous remote monitoring (n=140) or intermittent monitoring as usual (n=86). A wearable patch on the chest monitored heart rate, respiratory rate, and temperature of the intervention group continuously. Data were transferred to a central monitoring station or nurses' mobile device every two minutes. In case of deviation from preset physiological norms based on the (for this study adjusted) 2001 international sepsis definitions conference [42], the patient's nurse was alerted. In 34 of 36 septic events, data about the average time from first evidence of sepsis to first administration of antibiotics was available, and the average time was approximately 400 minutes shorter in the intervention group than in the control group. The LOS was 1.3 days shorter and the 30-day readmission rate 9.5% lower in the continuous monitoring group. Significance levels were not reported. There were some concerns in risk of bias regarding the randomization process.

A more recent study of Downey et al. [37] evaluated the same monitoring intervention and clinical outcomes in patients after elective major surgery on the surgical ward using a wearable patch (n=60) compared to standard intermittent monitoring with National EWS (NEWS) (n=65). Non-significantly less complications occurred in the intervention group compared to the control group. Of the 17 patients with major complications, 4 patients were included in the intervention group. The mean LOS was 4.6 days shorter in the group with continuous monitoring, but 95% confidence intervals were overlapping. The mean time to antibiotics in to treat sepsis, and 30-day readmission rate were comparable between the groups. There were some concerns in risk of bias due to missing outcome data.

Heuser et al. [38] assessed the impact of a mobile app for education and symptom monitoring during postoperative recovery in patients undergoing bariatric surgery (n=396) compared to usual care (n=458). Telemonitoring comprised a daily health check survey regarding postoperative symptoms (anxiety, mood, pain, nausea, bowel movement, wound infection), and self-care (mediation and

vitamin supplements, protein and fluid intake). They found no association between use of the app and prolonged LOS, emergency department (ED) visits, and readmission until 30-days postoperative. However, patients reported that the app helped them to avoid at least one phone call to the hospital (48.5% of patients), or hospital visit (12.9%). There was moderate risk of bias due to baseline confounding and deviation from the intended intervention because of low adherence.

Bouwsma et al. [30] and Vonk Noordergraaf et al. [32] investigated the effectiveness of a perioperative eHealth intervention after gynecological surgery on return to work (RTW) in a multi-center RCT. In both studies, the intervention group (n=227 and n=110 respectively) received personalized pre- and postoperative recovery advice and an interactive self-assessment tool on a web portal, to monitor recovery postoperatively. The control group (n=206 and n=105 respectively) received standard care without access to a web portal [30] or with access to a control website [32]. Table 2 shows median (IQR) days to full return to work in both studies. On top of that, they performed additional Cox regression analyses. Bouwsma et al. showed that patients in the intervention group returned to work 2.66 times earlier than the control group within the first 85 days after surgery, HR (95% CI) of 2.66 (1.88-3.77), p<0.001. Vonk Noordergraaf et al. demonstrated that patients in the intervention group returned to work 1.43 times earlier than patients in the control group, HR (95% CI) of 1.43 (1.00-2.04), p=0.048. There was low risk of bias in outcome from Vonk Noordergraaf et al. and some concerns in that of Bouwsma et al. due to significant differences in baseline characteristics between the groups.

Zand et al. [33] evaluated the effectiveness of remote home monitoring of patients during four weeks after surgery for inflammatory bowel disease (IBD) on 30-day hospital readmission rates and hospital visits (n=64) with a matched control group (n=64). Telemonitoring consisted of daily to weekly questionnaires about symptoms and wound healing, and photo upload of patients' surgical wound, both by e-mail. Abnormalities were identified based on 'red flags' for fever, pain, ileostomy output and bowel movement. Readmission rates were similar for both groups (21.9%), and the telemonitoring group had 5% more ED visits and 11% more gastroenterologist visits, both not statistically significant. There was serious risk of bias of these postoperative outcomes, because patients in the intervention group were at higher risk of complications than their matched controls.

Wang et al. [35] investigated the effectiveness of a home care mobile app on postoperative stoma-related complications after hospital discharge (n=103) compared to patients who received usual care after discharge (n=100). The mobile app was used for completion of personal and medical information, upload stoma photographs for diagnosis, and for appointments, contact and face-to-face contact with their enterostomal therapy nurse (every week in the first month). The intervention group had a non-significant lower incidence of stoma complications at 1, 3, and 6 months after discharge. There was low risk of bias.

Patient-reported outcome measures

Evaluated PROMs were physical and mental wellbeing (n=3), pain (n=4), recovery (n=2) and self-efficacy (n=2). Study results for PROMs with risk of bias are shown in Table 3 and described below.

[insert Table 3]

Patient-reported outcomes of the internet-based perioperative care program of Bouwsma et al. [30] were functional health status, recovery, self-efficacy, coping, and pain. At two weeks after gynecological surgery, patients in the intervention group (n=227) scored significantly better on recovery, pain intensity and pain disability than the control group (n=206) (respectively p=0.046, p=0.014 and p=0.000), however, at longer follow-up, these differences disappeared. No differences were found between the groups in health status, coping or self-efficacy. There were some concerns in risk of bias due to differences in baseline characteristics between the groups.

Vonk Noordergraaf et al. [32] found that physical and mental quality of life (QoL) of gynecological surgery patients improved significantly more in the intervention group (n=110) compared to the control group [(n=105), p=0.028 and p=0.044 respectively]. The recovery index did not differ between the groups, but women in the intervention group were more likely to be in a significant lower pain intensity category than those in the control group (cumulative Odds ratio 1.84 after 26 weeks, p=0.035). These outcomes had low risk of bias.

Gustavell et al. [34] evaluated the impact of an interactive mobile app on health-related quality of life after pancreaticoduodenectomy due to cancer in the intervention group (n=26) compared to a historic control group that received usual care (n=33). The app enabled daily self-reporting of symptoms after discharge with risk assessment models for alerts and graphs, and self-care advice. Symptoms with alerts comprised fever, pain, nausea, vomiting, fatigue, dizziness, eating difficulties, stool, depression, and daily activities.[43] At six weeks after surgery, the intervention group had significantly higher emotional functioning scores (p=0.001) and lower pain and pancreatic pain scores (p=0.047 and p=0.007 respectively). Physical functioning scores were also higher in the intervention group, although not statistically significant (p=0.057). At six months after surgery, the differences between both groups on these scores became non-significant. No information about missing data caused a moderate risk of bias.

Skraastad et al. [36] demonstrated a significant decrease in pain intensity on a verbal numeric rating scale from 0-10 in patients at the surgical ward monitored with ESS and a wearable patch (n=96) compared with a control group (n=99) (2.1 vs. 3.3, $p < 0.001$). There was a high risk of bias because of different (frequency of) pain measurements between both groups, missing data and selection of reported result.

Wang et al. [35] reported an improvement in ostomy psychosocial adjustment scores and stoma self-efficacy scale scores over time in both the intervention group (n=103) and control group (n=100). Nevertheless, patients who used the home care mobile app had higher scores at 1, 3, and 6 months after discharge compared to the control group ($p<0.001$). There was low risk of bias.

Financial outcome measures

Bouwsma et al. [31] evaluated the cost-effectiveness of their perioperative internet-based care program based on the primary outcome duration until full RTW, and patient-reported outcomes. Although societal costs were lower in the intervention group (n=227) compared to the control group (n=206), differences in costs or quality-adjusted life years (QALYs) gained over 12-months were not statistically significant between the groups (Table 2). There were some concerns in risk of bias because of baseline differences between both groups.

Downey et al. [37] evaluated the incremental cost-effectiveness ratio (ICER, e.g. cost per QALY gained) when patients are monitored during a 6-weeks period with a wearable patch (n=60) compared to NEWS monitoring as usual (n=65) after elective major surgery. The cost-utility analysis (Table 2) indicated that the probability of telemonitoring being cost-saving was 69.9%, whereas 58% for being beneficial to QoL as compared to usual care. There were some concerns in risk of bias due to missing outcome data and selection of reported results.

Discussion

This review aimed to evaluate the effectiveness of current perioperative telemonitoring on postoperative clinical, patient-reported, and financial outcome measures in patients undergoing major abdominal surgery compared to a control group receiving usual care. Only ten eligible articles have been found in this review and few of them show significant results for (long-term) outcomes. Recovery time (time to full mobilization [36] and RTW [30,32]) was significantly lower in the telemonitoring groups. All patient-reported pain scores at two or six weeks after surgery that were found in this review were significantly lower in the telemonitoring group, however, these differences between pain scores in both groups became non-significant during follow-up [30,34,36]. The two articles evaluating financial outcomes show that mainly societal costs are lower in patients that receive perioperative telemonitoring [31]. Although these results are promising, the overall lack of evidence for effectiveness of perioperative telemonitoring might question both the interventions as the methodology used in these studies.

As for the interventions, closing the monitoring gaps at the surgical ward while allowing early mobilization is considered one of the main applications of telemonitoring [44,45]. Other research regarding traditional continuous versus intermittent monitoring on general or surgical wards did show earlier detection of clinical deterioration [46], decrease of cardiac arrest and mortality [47] and benefits in critical care use and LOS [48]. However, evidence for continuous monitoring with wearable devices is lacking [49] and this may be a reason why it is still not implemented. Main barriers mentioned are nursing engagement and alarm burden [29,44,50,51]. Downey et al. [29] and Skraastad et al. [36] documented non-significantly more (minor) complications in the intervention group. They discussed that endpoints common to all patients such as LOS should be preferred over rare endpoints such as complications [29], and that the sample size should at least be large enough for the detection of complications [36]. Furthermore, the quality of technology is often not sufficient (at low technology readiness levels) or

does not fit with these evaluation levels, for example because the embedding in clinical practices is not complete.

As for methodology, although RCTs are seen as gold standard in evaluation of healthcare innovations, they might not be well-fit for the evaluation of eHealth interventions due to rapidly evolving technologies and dependence on end-user acceptability and integration in healthcare practice [52]. Besides, a double-blind study is almost impossible to perform [53]. Cohort multiple randomized controlled trials enable patient centered informed consent and to perform multiple randomized controlled trials within the same cohort, for example when technology for telemonitoring develops over time [54].

The wide range of telemonitoring strategies described in this review emphasize its potential for patients undergoing major surgery. However, it also highlights that perioperative telemonitoring should not be used as a goal itself, but a support for personalized care. Perioperative monitoring of vital signs and wellbeing for early detection of postoperative deterioration and self-monitoring for early recovery and self-efficacy have the ability to do so. After major surgery, performance status, nausea, fatigue, pain, dyspnea, fever, and wound complications are the most distressing symptoms [55] and development of chronic pain after surgery may vary between 15-60% [56-58]. Preoperative expectancies have been related to postoperative pain and fatigue in breast cancer surgery [59] and one week of pain education with telemonitoring leads to lower pain in patients with outpatient care of patients with solid tumors [60]. Not only are pain and other PROMs relevant measures for the evaluation of a telemonitoring intervention, they could also be used to monitor postoperative recovery and be part of alarm criteria [33,40,41]. Other relevant features of telemonitoring to support personalized care that are underexposed in the results of this review are wound photographs as triage for wound infection [24], video visits, and behavior support tools to enhance objectively measured mobilization [61], and need to be subject to future research as well. Video visits alone were not considered in this review, but have great potential in postoperative follow-up to reduce hospital visits with high patient satisfaction and without decrease in clinical outcomes [62-66].

A limitation of this review might be that the perioperative period was represented in the search by general operative and surgery terms only, which might have excluded articles that only used terms for specific surgery types. Besides, outcome measures for feasibility and acceptability were outside the scope of this review. In 2015, Van der Meij et al. [15] reviewed studies evaluating the effect of any type of eHealth intervention in the perioperative trajectory of patients undergoing any type of surgery on postoperative outcome measures. However, only one of their 26 included studies comprised telemonitoring in abdominal surgery [32]. Therefore, in this rapidly growing area of medicine, our review provides a needed overview of the available evidence of telemonitoring in patients undergoing major abdominal surgery.

In our opinion the following steps are recommended to increase the effectiveness and therefore use of perioperative telemonitoring. First, high quality technology in terms of accuracy, validity and stability

is needed. Second, feasibility and usability studies are prerequisite to ensure adoption by end-users and workflow. Third, an investment is required in money and time to develop strategies for implementation and scalability of telemonitoring. Fourth, effectiveness should be evaluated in appropriate clinical trials, for example as proposed by Kosterink [54]. Important is the awareness of bias and generalizability as faced in the included studies of this review. Telemonitoring studies tend easily toward selection bias toward higher educated patients, causing reduced external validity and generalizability [30,32]. Besides, when both the intervention and control group are treated in the same hospital, contamination between both arms might occur [32]. It is also highly recommended that outcome measures of clinical trials are standardized to enable future comparison. Examples of relevant outcome measures common to all patients are LOS, recovery in terms of time to full mobilization and return to work, number of outpatient and ED visits, and well-being parameters such as pain. Relevant outcome measures that are less common and require studies with larger groups of patients are ICU admission, complications and hospital readmissions. Although guidelines can probably not be facilitated for every eHealth application, practical guidelines for telemonitoring need to become available as the American Telemedicine Associated already promised a few years ago [53], including the choice of outcome measures to assess.

Conclusion

In conclusion, the interest in perioperative telemonitoring has only increased in recent years. However, evidence for the effectiveness of perioperative telemonitoring in major surgery is scarce and perioperative telemonitoring is still rarely used in current clinical practice nowadays. Future challenges to support personalized care with perioperative telemonitoring include: validation of technology, choice of (standard) outcome measures, development of alarm criteria, the value of PROMs and activity monitoring both pre- and postoperatively, and importantly, last but not least altering existing surgical care protocols for optimal use of promising telemonitoring strategies.

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554 # Tables

555 Table 1. Study characteristics clustered by type of telemonitoring intervention.

Study			Patients			Telemonitoring intervention			Control group
First author (year of publication)	Period	Design	Inclusion criteria	N (I/C)	Age (I/C)	Description	Start	End	Description
Wearable patch									
Downey (2020)[37]	2017-2018	Single-center pilot randomized controlled trial	Patients undergoing major abdominal surgery admitted at surgical ward	60/65	mean 65range 36-85/ mean 62 range 22-87	Continuous monitoring of vital parameters at surgical ward with wearable patch (SensiumVitals)	Postoperative at surgical ward	Discharge from surgical ward	Usual care
Skraastad (2020)[36]	2018	Single-center randomized controlled trial	Patients undergoing acute or elective surgery expected to be hospitalized >24h postoperatively	96/99	mean 61 SD 12.5/ mean 62 SD 13.3	ESS combined with wireless monitoring of vital parameters (Isansys Lifecare Ltd.)	Postoperative at surgical ward	24h postoperatively	Usual care
Downey (2018)[29]	2017	Cluster-randomized, prospective, parallel-group, controlled single-center pilot study	Patients admitted to elective general surgical ward in tertiary center	140/86	mean 65.2 range 24-94/ mean 63.7 range 21-92	Continuous monitoring of vital parameters at surgical ward with wearable patch (SensiumVitals)	Admission at surgical ward	Discharge from surgical ward	Usual care
Mobile application									
Heuser (2021)[38]	2017-2019	Retrospective controlled cohort study	Patients undergoing Roux-en-Y gastric bypass or sleeve gastrectomy	396/458	mean 44.9 SD 9.9/ mean 47.6 SD 10.8	Mobile app (Home to Stay) for pre- and postoperative education an self-follow-up on symptoms	3 weeks before surgery	30 days after surgery	Usual care
Gustavell (2019)[34]	2012-2017	Historically-controlled, single center design	Patients scheduled to undergo pancreaticoduodenectomy due to a suspected malignancy	26/33	mean 67 SD 8.7/ mean 66 SD 8.8	Interactive app (Interaktor) with self-reported symptom assessment, alerts and insight, self-care advice and information.	Day 1 after discharge	6 months after discharge	Usual care
Wang (2018)[35]	2016	Single-blind, randomized controlled trial	Aged >18 years with primary CRC or other digestive and urinary tumors with permanent stoma after surgery	100/103	mean 56.95 SD 14.88/ mean 59.18 SD 14.14	Home care mobile app for information/communication with ET nurses, making appointments, and photograph diagnosis	After discharge	6 months after discharge	Usual care

E-mail									
Zand (2019)[33]	2013-2015	Retrospective cohort study with matched control group	Aged >18 years with IBD-related intestinal surgery	64/64	mean 37.9/ mean 38.3	4-week program monitoring recovery after surgery with questionnaires and abdominal wound photo upload through e-mail	Day 1 after discharge	4 weeks after discharge	Historic controls
Website or portal									
Bouwsma (2018a)[30] (2018b)[39]	2011-2014	Stepped-wedge cluster-randomized trial	Employed women aged 18-65 years scheduled for a hysterectomy and/or laparoscopic adnexal surgery	227/206	mean 46.1 SD 7.3/ mean 45.6 SD 6.7	Webportal prior to surgery with recommendations for self-management and monitoring postoperatively	Several weeks before surgery	5 weeks after surgery	Usual care
Vonk Noordegraaf (2014)[32]	2010-2011	Randomized single-blinded controlled trial	Aged 18-65 who had hysterectomy and/or laparoscopic adnexal surgery for a benign indication	110/105	mean 43.5 SD 7.8/ mean 43.2 SD 8.5	eHealth instructions to improve self-empowerment, communication and identify recovery problems using a website	4 weeks before surgery	7 weeks after surgery	Usual care with placebo website with telephone numbers and general info leaflets

N = number, I = intervention group, C = control group, SD = standard deviation, ESS = Efficacy Safety Score, IBD = inflammatory bowel disease, IVR = interactive voice response, NR = not reported, IQR = interquartile range, CRC = colorectal cancer, ET = enterostomal therapy

Table 2. Study results for clinical and cost-related outcome measures for the intervention group and control group during the follow-up period with risk of bias.

Outcome measure			Study results				
Type	Specification	Follow-up	Intervention group	Control group	p-value	First author (year of publication)	Overall risk of bias*
LOS	Prolonged LOS of > 2 days % (N/total)	NA	7.3% (29/396)	9.8% (45/458)	0.18	Heuser (2021)[38]	Moderate
	Days in-hospital Mean (95% CI)	NA	11.6 (9.5-13.7)	16.2 (11.3-21.2)	NR	Downey (2020)[37]	Some concerns
	Hours in-hospital Mean (95% CI)	NA	70.9 (63.1-78.7)	76.6 (61.0-92.3)	0.580	Skraastad (2019)[36]	High
	Days in-hospital Mean (95% CI)	NA	13.3 (11.3-15.3)	14.6 (11.5-17.7)	NR	Downey (2018)[29]	Some concerns
Recovery time	Hours to full mobilization† Mean (95% CI)	Within 24 hours after surgery	10.1 (8.1-12.2)	14.2 (12.0-16.3)	0.008‡	Skraastad (2019)[36]	High
	Days to full RTW Median (IQR)	Within 12 months after surgery	49 (27-76)	62 (42-85)	0.153§	Bouwsma (2018a)[30]	Some concerns

	Days to full RTW Median (IQR)	Within 6 months after surgery	39 (20-67)	48 (21-69)	NR¶	Vonk Noordegraaf (2014)[32]	Low
Readmissions	Hospital readmissions % (N/total)	Within 30 days after surgery	2.8% (11/396)	2.6% (12/458)	0.97	Heuser (2021)[38]	Moderate
	Hospital readmissions % (N/total)	Within 30 days after discharge	10% (6/60)	7.7% (5/65)	NR	Downey (2020)[37]	Some concerns
	Unplanned admissions to HDU or ICU % (N/total)	During admission at surgical ward	1.7% (1/60)	7.7% (5/65)	NR	Downey (2020)[37]	Some concerns
	Hospital readmissions % (N/total)	Within 30 days after discharge	21.9% (14/64)	21.9% (14/64)	1.000	Zand (2019)[33]	Serious
	Hospital readmissions % (N/total)	Within 30 days after discharge	11.4% (16/140)	20.9% (18/86)	NR	Downey (2018)[29]	Some concerns
Postoperative complications	Complications % (N/total)	Within 24 hours after surgery	4.8% (5/96)	2.0% (2/99)	NR	Skraastad (2019)[36]	High
	Complications % (N/total)	Within 30 days after discharge	72.9% (102/140)	66.3% (57/86)	NR	Downey (2018)[29]	Some concerns
	Major complications % (N/total)	Within 30 days after discharge	6.7% (4/60)	20% (13/65)	NR	Downey (2020)[37]	Some concerns
	Major complications % (N/total)	Within 24 hours after surgery	0.0% (0/96)	2.0% (2/99)	NR	Skraastad (2019)[36]	High
	Major complications % (N/total)	Within 30 days after discharge	5.7% (8/140)	5.8% (5/86)	NR	Downey (2018)[29]	Some concerns
	Sepsis events % (N/total)	During hospital admission	20% (12/60)	13.8% (9/65)	NR	Downey (2020)[37]	Some concerns
	Sepsis events % (N/total)	During hospital admission	17.1% (24/140)	14.0% (12/86)	NR	Downey (2018)[29]	Some concerns
	Minutes to antibiotics in sepsis Mean (95% CI)	NA	551 (296-805)	527 (199-856)	NR	Downey (2020)[37]	Some concerns
	Minutes to antibiotics in sepsis Mean (95% CI)	NA	626.0 (431.7-820.3)	1012.8 (425.0-1600.6)	NR	Downey (2018)[29]	Some concerns
	Mortality % (N/total)	During hospital admission	1.7% (1/60)	0.0% (0/65)	NR	Downey (2020)[37]	Some concerns
	Mortality % (N/total)	During hospital admission	0.7% (1/140)	0.0% (0/86)	NR	Downey (2018)[29]	Some concerns
	Stoma related complications % (N/total)	6 months	23.00% (23/100)	28.16% (29/103)	0.400	Wang (2018)[35]	Low
Consultations	ED visits without subsequent readmission % (N/total)	Within 30 days after surgery	7.6% (30/396)	6.1% (28/458)	0.65	Heuser (2021)[38]	Moderate

	ED visits % (N/total)	Within 30 days after discharge	25.0% (16/64)	20.3% (13/64)	0.677	Zand (2019)[33]	Serious
	Gastrointestinal office visits % (N/total)	Within 30 days after discharge	57.8% (37/64)	46.9% (30/64)	0.265	Zand (2019)[33]	Serious
Costs	ICER £ (95% CI)	Within 6 weeks after discharge	£1460 (-£6780-£9701)	-	NA	Downey (2020)[37]	Some concerns
	Societal costs Mean € (SEM)	Within 12 months after surgery	€12 266 (€596)	€13 795 (€602)	NA	Bouwsma (2018b)[39]	Some concerns
	QALYs gained Mean (SEM)	Within 12 months after surgery	0.96 (0.008)	0.96 (0.007)	NA	Bouwsma (2018b)[39]	Some concerns

CI = confidence interval, ED = emergency department, LOS = length of hospital stay, NA = not applicable, NR = not reported, SEM = standard error of the mean, IQR = interquartile range, RTW = return to work, N = number, QALY = quality-adjusted life year.
* Risk of bias for RCTs based on Cochrane RoB 2.0 (low, some concerns or high) and for non-randomized controlled trials with Cochrane ROBINS-I (low, moderate, serious, critical).
† Significant difference between the results of the intervention group and control group p<0.05.
‡ Full mobilization is defined as being able to walk more than one step with or without support.
§ A Hazard ratio (95% CI) of 1.43 (1.003-2.040), p=0.048, was found in favor of the eHealth intervention for RTW and was constant over time.
¶ Within the first 85 days after surgery, duration to RTW effectively reduced with a Hazard ratio (95% CI) of 2.66 (1.88-3.77), p<0.001.

Table 3. Study results for patient-reported outcome measures for the intervention group and control group at follow-up moment with risk of bias.

Outcome measure			Study results				
Type	Instrument	Follow-up	Intervention group	Control group	p-value	First author (year of publication)	Overall risk of bias*
Physical wellbeing	EORTC QLQ-C30 physical functioning score† Mean (SD)	6 weeks	73.2 (16.9)	63.3 (20.5)	0.057	Gustavell (2019)[34]	Moderate
		6 months	82.9 (18.0)	80.9 (15.0)	0.650		
	SF-36 physical score‡ Mean	12 weeks	53.26	52.25	0.111	Bouwsma (2018a)[30]	Some concerns
		6 months	55.52	56.41	0.169		
		12 months	56.16	57.06	0.159		
	Rand-36 physical score§ Mean (SE)	6 months	345 (9)	330 (10)	0.028¶	Vonk Noordegraaf (2014)[32]	Low
Mental wellbeing	EORTC QLQ-C30 emotional functioning score† Mean (SD)	6 weeks	83.3 (19.2)	64.7 (20.5)	0.001¶	Gustavell (2019)[34]	Moderate
		6 months	86.7 (19.2)	76.9 (18.5)	0.062		
	SF-36 mental score‡ Mean	12 weeks	50.12	51.31	0.146	Bouwsma (2018a)[30]	Some concerns
		6 months	50.89	52.02	0.179		
		12 months	50.69	51.48	0.339		
	Rand-36 mental score§ Mean (SE)	6 months	317 (10)	301 (11)	0.044¶	Vonk Noordegraaf (2014)[32]	Low

Pain	VNRS‖ Mean (95% CI)	Within 24 hours after surgery	2.1 (1.8-2.9)	3.3 (2.9-3.7)	<0.001¶	Skraastad (2019)[36]	High
	EORTC QLQ-C30 pain score[4] Mean (SD)	6 weeks	20.7 (26.5)	35.9 (29.4)	0.047¶	Gustavell (2019)[34]	Moderate
		6 months	16.0 (22.3)	16.7 (20.5)	0.91		
	EORTC QLQ-PAN26 panreatic pain score† Mean (SD)	6 weeks	21.0 (15.6)	35.7 (22.1)	0.007¶	Gustavell (2019)[34]	Moderate
		6 months	12.0 (11.3)	18.6 (17.5)	0.11		
	Von Korff pain intensity score** Mean	2 weeks	9.20	10.55	0.014¶	Bouwsma (2018a)[30]	Some concerns
		6 months	2.27	1.87	0.483		
		12 months	2.14	1.79	0.531		
	Von Korff pain disability score** Mean	2 weeks	11.83	14.23	0.000¶	Bouwsma (2018a)[30]	Some concerns
		6 months	0.93	1.05	0.851		
		12 months	1.39	0.61	0.235		
	VAS†† Mean (SE)	6 months	1.92 (0.41)	3.52 (0.58)	NR‡‡	Vonk Noordegraaf (2014)[32]	Low
Recovery	RI-10[10] Mean	2 weeks	30.07	28.61	0.046¶	Bouwsma (2018a)[30]	Some concerns
		6 months	42.97	42.86	0.889		
		12 months	43.33	44.16	0.267		
	RI-10‖‖ Mean (SE)	6 months	40.8 (1.1)	39.3 (1.2)	0.091	Vonk Noordegraaf (2014)[32]	Low
Self-efficacy	General Self-Efficacy Scale*** Mean	2 weeks	32.42	32.54	0.811	Bouwsma (2018a)[30]	Some concerns
		6 months	34.07	33.89	0.717		
		12 months	34.54	34.34	0.687		
	Pearlin Mastery Scale††† Mean	2 weeks	26.88	27.38	0.243	Bouwsma (2018a)[30]	Some concerns
		12 months	27.76	28.85	0.015¶		
	SSES‡‡‡ Mean (SD)	1 month	66.08 (12.53)	60.21 (16.94)	0.01¶	Wang (2018)[35]	Low
		6 months	92.10 (7.78)	75.50 (13.38)	<0.001¶		
	Ostomy adjustment score§§§ Mean (SD)	1 month	51.32 (8.43)	41.23 (11.43)	<0.001¶	Wang (2018)[35]	Low
		6 months	70.80 (4.64)	54.54 (10.48)	<0.001¶		

571 SE = standard error, SD = standard deviation, IQR = interquartile range, N = number

* Risk of bias for RCTs based on Cochrane RoB 2.0 (low, some concerns or high) and for non-randomized controlled trials with Cochrane ROBINS-I (low, moderate, serious, critical).
† EORTC QLQ range 0 – 100 where a high score reflects a high level of functioning, a high score for symptoms scales reflects more symptoms.
‡ Short Form Health Survey (SF)-36 scale 0 – 100, higher indicates better health status.
§ Rand-36 scale 0 – 800, higher is better health status.
¶ Significant difference between the results of the intervention group and control group $p<0.05$.
|| Visual Numeric Rating Scale (VNRS) range 0 – 10 with higher score indicates more pain.
** Von Korff scale 0 – 100, higher is more pain (intensity/disability).
†† Visual Analogue Scale (VAS) range 0 – 10 with higher score indicates more pain.
‡‡ The cumulative odds ratio from an adjusted generalized mixed ordered regression analysis was 1.84 in favor of the intervention group after 26 weeks, $p=0.035$.
§§ Hospital Anxiety and Depression Scale range 0 – 10 with higher score indicates more anxiety/despression.
¶¶ Symptom interference score was the mean of the six M.D. Anderson Symptom Inventory (MDASI) interference items, range of 0 – 10, and assessed in a linear mixed model over time between the groups, adjusted for age and sex.
|||| Recovery Index (RI)-10 range 10 – 50, with a score of 50 indicating perfect recovery.
*** General Self-Efficacy Scale, range 10 – 40, with higher scores indicating higher perceived self-efficacy.
††† Pearlin Mastery Scale, range 7 – 28, with higher scores indicating greater levels of mastery.
‡‡‡ Stoma Self Efficacy Scale (SSES) 22 – 110, higher scores refer to higher levels of self-efficacy.
§§§ Ostomy Adjustment Inventory-23 (OAI-23) The revised Chinese version of the scale consisted of 20 items with the scores varying from 0 – 80. Higher scores indicated better adjustment.

Figures

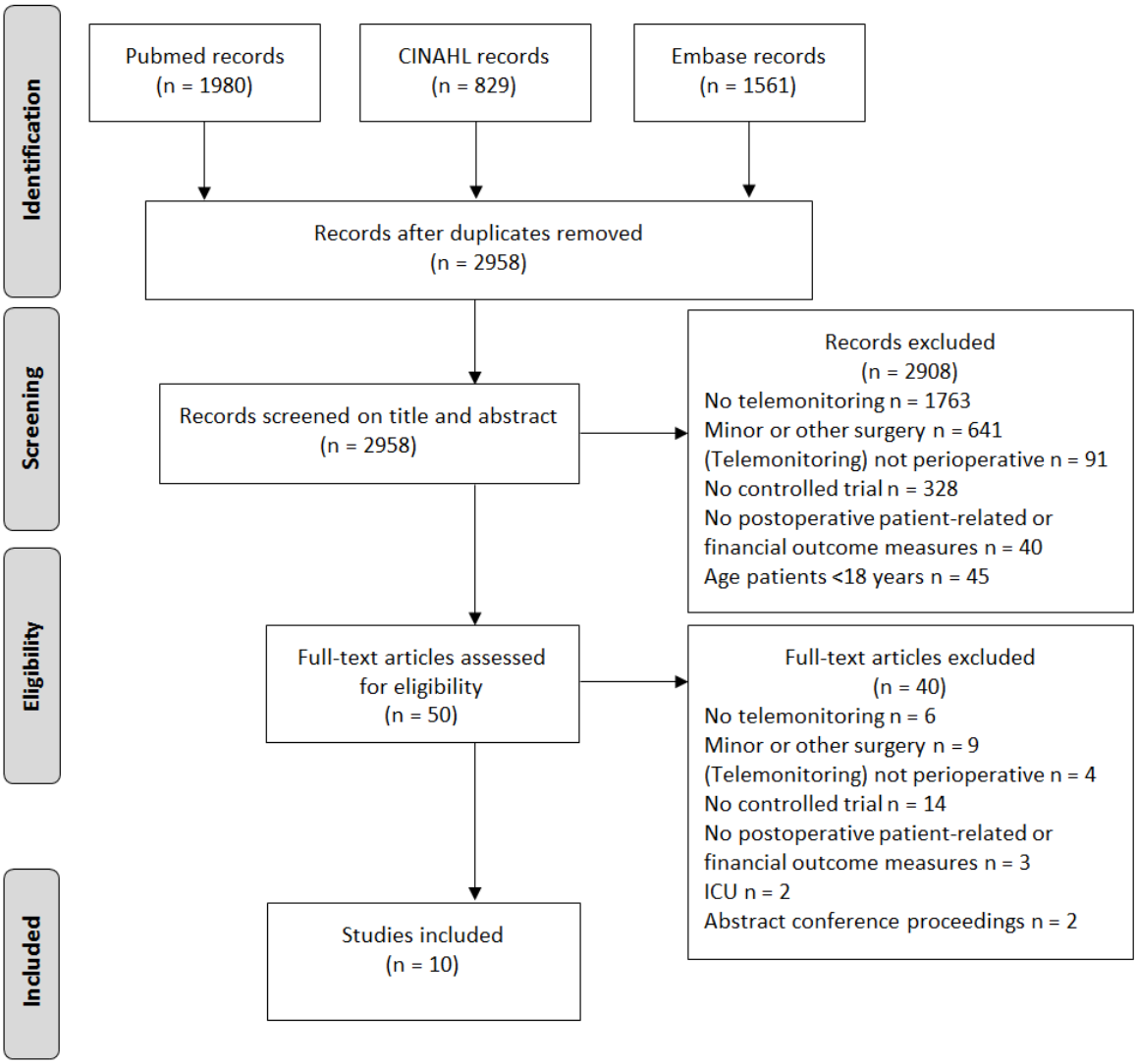
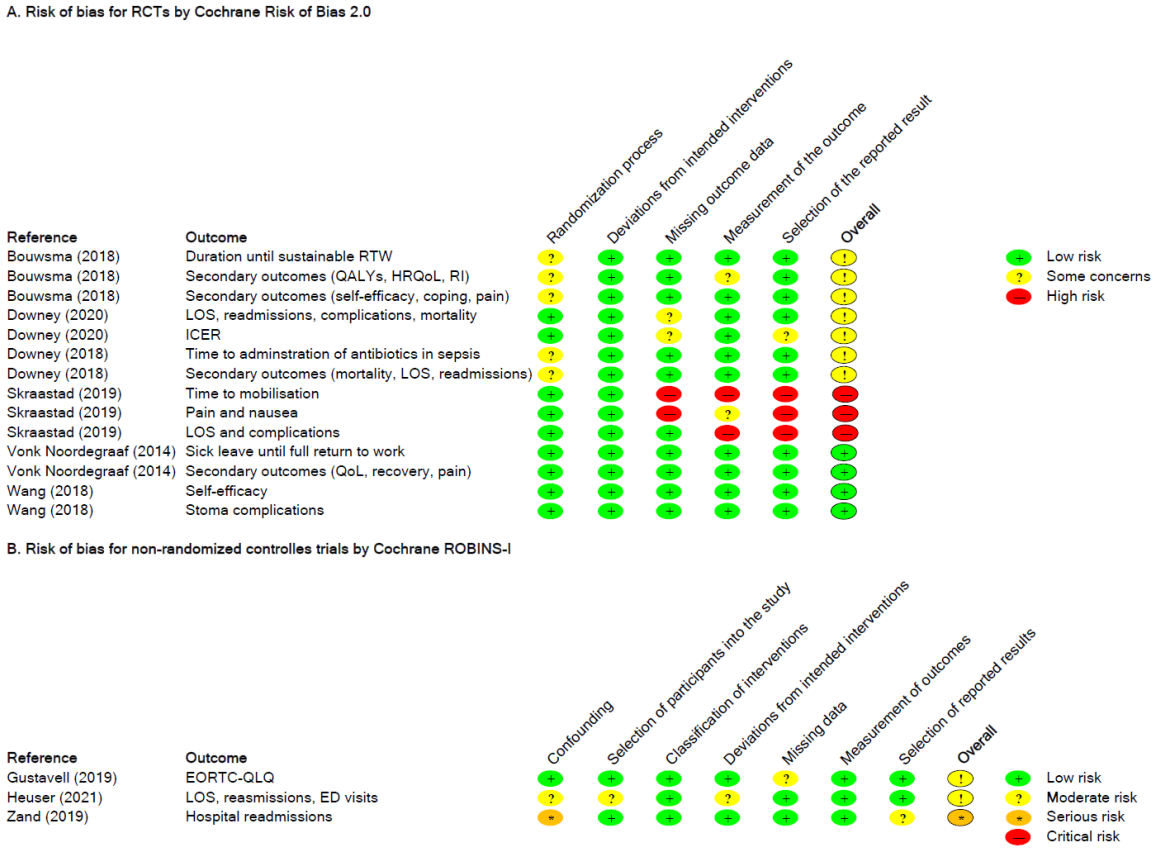


Figure 1. PRISMA flow diagram.

595



596

597 Figure 2. Risk of bias assessment per outcome measure for: (A) randomized controlled trials by
598 Cochrane risk of Bias 2.0 and; (B) non-randomized controlled trials by Cochrane ROBINS-I.

Supplementary files

Search strategy in PubMed (March 15th, 2021)

Filter: from 2009

Search	Query	Results
#5	#1 AND #2 AND #3 NOT #4	1980
#4	("Child"[Mesh] NOT "Adult"[Mesh]) OR protocol for a randomized[tiab] OR protocol for a pilot[tiab] OR trial protocol[tiab] OR study protocol [tiab] OR case study[tiab]	487070
#3	"Patient Readmission"[Mesh] OR "Postoperative Complications"[Mesh] OR "Length of Stay"[Mesh] OR clinical outcome*[tiab] OR readmission*[tiab] OR mortality[tiab] OR morbidity[tiab] OR complication*[tiab] OR infection*[tiab] OR hospital stay[tiab] OR ICU stay*[tiab] OR length of stay[tiab] OR duration of stay[tiab] OR intensive care stay*[tiab] OR visit*[tiab] OR adverse event*[tiab] OR pain[tiab] OR return to work[tiab] OR quality of life[tiab] OR anxiety[tiab] OR satisfaction[tiab] OR physical[tiab] OR symptom*[tiab] OR function*[tiab] OR patient outcome*[tiab] OR patient reported outcome*[tiab] OR "Costs and Cost Analysis"[Mesh] OR cost[tiab] OR costs[tiab] OR cost-effective*[tiab] OR economic[tiab] OR financ*[tiab] OR pric*[tiab] OR expens*[tiab]	5245229
#2	"Perioperative Care"[Mesh] OR "Perioperative Period"[Mesh] OR "Preoperative Care"[Mesh] OR perioperati*[tiab] OR peri-operati*[tiab] OR preoperati*[tiab] OR pre-operati*[tiab] OR presurg*[tiab] OR before surg*[tiab] OR postoperati*[tiab] OR post-operati*[tiab] OR postsurg*[tiab] OR after surg*[tiab] OR following surg*[tiab] OR surgery[tiab]	916003
#1	"Telemedicine"[Mesh] OR "Wearable Electronic Devices"[Mesh] OR "Computers, Handheld"[Mesh] OR eHealth*[tiab] OR e-health*[tiab] OR mobile health*[tiab] OR mHealth*[tiab] OR mobile app*[tiab] OR telehealth*[tiab] OR telemedic*[tiab] OR telemonitor*[tiab] OR tele-monitor*[tiab] OR wearable*[tiab] OR wireless monitor*[tiab] OR activity monitor*[tiab] OR ambulatory monitor*[tiab] OR real-time-monitor*[tiab] OR realtime-monitor*[tiab] OR fitbit[tiab] OR smartwatch*[tiab] OR patch sensor*[tiab]	75194

Search strategy in CINAHL (March 15th, 2021)

Limit to: from 2009

Search	Query	Results
#5	#1 AND #2 AND #3 NOT #4	829
#4	(MH “Child+” NOT MH “Adult”) OR "study protocol" OR "pilot protocol" OR “case study”	390552
#3	MH “Readmission” OR MH “Postoperative Complications” OR MH “Length of Stay” OR “clinical outcome*” OR “readmission*” OR “mortality” OR “morbidity” OR “complication*” OR “infection*” OR “hospital stay*” OR “ICU stay*” OR “length of stay” OR “duration of stay” OR “intensive care stay*” OR “visit*” OR “adverse event*” OR “pain” OR “return to work” OR “quality of life” OR “anxiety” OR	1993995

	"satisfaction" OR "physical" OR "symptom*" OR "function*" OR "patient outcome*" OR "patient reported outcome*" OR MH "Costs and Cost Analysis+" OR "cost*" OR "cost-effective*" OR "economic" OR "finance*" OR "pric*" OR "expens*"	
#2	MH "Perioperative Care" OR MH "Postoperative Care+" OR "perioperati*" OR "peri-operati*" OR "preoperati*" OR "pre-operati*" OR "presurg*" OR "before surg*" OR "postoperati*" OR "post-operati*" OR "after surg*" OR "postsurg*" OR "following surg*" OR "surgery"	483838
#1	MH "Telehealth+" OR MH "Wearable Sensors" OR MH "Computers, Hand-Held" OR "eHealth*" OR "e-health" OR "telehealth*" OR "telemedic*" OR "mobile app*" OR "mobile health intervention*" OR "mobile health*" OR "mhealth*" OR "telemonitor*" OR "tele-monitor*" OR "wearable*" OR "wireless monitor*" OR "real-time-monitor*" OR "realtime-monitor*" OR "fitbit" OR "smartwatch" OR "patch sensor*"	43920

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607 **Search strategy in Embase (March 15th, 2021)**

608 Filter: from 2009

609 Publication type: Article

Search	Query	Results
#5	#1 AND #2 AND #3 NOT #4	1561
#4	('child'/exp NOT 'adult'/exp) OR 'study protocol':ti,ab OR 'pilot protocol':ti,ab OR 'case study':ti,ab	620502
#3	'hospital readmission'/exp OR 'postoperative complication'/exp OR 'length of stay'/exp OR 'clinical outcome*':ab,ti OR 'readmission*':ab,ti OR 'mortality':ab,ti OR 'morbidity':ab,ti OR 'complication*':ab,ti OR 'infection*':ab,ti OR 'hospital stay':ab,ti OR 'ICU stay*':ab,ti OR 'length of stay':ab,ti OR 'duration of stay':ab,ti OR 'intensive care stay*':ab,ti OR 'visit*':ab,ti OR 'adverse event*':ab,ti OR 'pain':ab,ti OR 'return to work':ab,ti OR 'quality of life':ab,ti OR 'anxiety':ab,ti OR 'satisfaction':ab,ti OR 'physical':ab,ti OR 'symptom*':ab,ti OR 'function*':ab,ti OR 'patient outcome*':ab,ti OR 'patient reported outcome*':ab,ti OR 'economic evaluation'/exp OR 'cost*' OR 'cost-effective*':ab,ti OR 'economic':ab,ti OR 'financ*':ab,ti OR 'pric*':ab,ti OR 'expens*':ab,ti	4508582
#2	'preoperative period'/exp OR 'postoperative period'/exp OR 'perioperative period'/exp OR 'perioperati*':ab,ti OR 'peri-operati*':ab,ti OR 'preoperati*':ab,ti OR 'pre-operati*':ab,ti OR 'presurg*':ab,ti OR 'before surg*':ab,ti OR 'postoperati*':ab,ti OR 'post-operati*':ab,ti OR 'postsurg*':ab,ti OR 'after surg*':ab,ti OR 'following surg*':ab,ti OR 'surgery':ab,ti	873941
#1	'telehealth'/de OR 'telemedicine'/de OR 'telemonitoring'/exp OR 'ehealth*':ab,ti OR 'e-health':ab,ti OR 'mhealth*':ab,ti OR 'mobile health*':ab,ti OR 'telehealth*':ab,ti OR 'telemedic*':ab,ti OR 'telemonitor*':ab,ti OR 'tele-monitor*':ab,ti OR 'wearable*':ab,ti OR 'wireless monitor*':ab,ti OR 'activity monitor*':ab,ti OR 'ambulatory monitor*':ab,ti OR 'real-time-monitor*':ab,ti OR 'realtime-monitor*':ab,ti OR 'fitbit':ab,ti OR 'smartwatch':ab,ti OR 'patch sensor*':ab,ti	50743

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