A Systematic Review of Smartphone Applications that Address Patient Care in the Peri-Operative Period

Hadal El-Hadi, Brandon Lok-Hang Chan, Brian Wai-Hei Siu, Ivan Ching-Ho Ko, David Ka-Wai Leung, Jeremy Yuen-Chun Teoh, Peter Ka-Fung Chiu, Chi-Fai Ng, Hannah Elizabeth, Alex Qinyang Liu

Submitted to: JMIR mHealth and uHealth
on: October 29, 2024

Table of Contents

A Systematic Review of Smartphone Applications that Address Patient Care in the Peri-Operative Period

Hadal El-Hadi[1] MSc; Brandon Lok-Hang Chan[2] MBChB; Brian Wai-Hei Siu[2] MBChB; Ivan Ching-Ho Ko[2] MBChB; David Ka-Wai Leung[2] MBChB; Jeremy Yuen-Chun Teoh[2, 3] MBBS; Peter Ka-Fung Chiu[2] MBChB, PhD; Chi-Fai Ng[2] MBChB, MD; Hannah Elizabeth[1]; Alex Qinyang Liu[2, 1] MBBS, MSc

[1]London School of Hygiene and Tropical Medicine London GB
[2]The Chinese University of Hong Kong Hong Kong HK
[3]Medical University of Vienna Vienna AT

Corresponding Author:
Alex Qinyang Liu MBBS, MSc
The Chinese University of Hong Kong
Surgery Office, 4/F, LCW Clinical Sciences Building, Prince of Wales Hospital, Hong Kong
Hong Kong
HK

Abstract

Background: The use of smartphone applications by patients can be utilized to transform peri-operative care. With the ever-evolving landscape, updated systematic review is needed in this field.

Objective: This study aims at summarising the smartphone-based applications used by patients as discussed in academic literature in the setting of peri-operative patient care.

Methods: Seven databases were searched to identify articles discussing the use of smartphone applications by patients peri-operatively. Articles were included if they examined the use of smartphone-based applications in the setting of the perioperative period and examined the application's usability and effectiveness. Each paper was appraised using CASP checklists and analysed by the thematic synthesis method.

Results: Eighteen articles were selected for this study from 8,204 articles initially obtained. Themes that emerged from the analysis include the benefits of smartphone applications in peri-operative patient care: (1) patient education and instruction, (2) clear communication, (3) decreasing complications and use of healthcare resources, (4) postoperative monitoring and pain control, (5) improved patient support, satisfaction and safety. Other themes also emerged such as requirements of a practical smartphone application, what to include in smartphone application assessments, limitations of smartphone application studies and future directions of smartphone applications regarding patient peri-operative care.

Conclusions: The landscape of mobile applications is exponentially growing and their use in the peri-operative period is imminent for the future. Their use can improve communication between surgical care professionals, enhance patient care in the perioperative period, and strengthen medical education. Further studies, validation tools and improvements will be required to implement their use and demonstrate outcomes that can guide recommendations surrounding their use. Clinical Trial: Not applicable

(JMIR Preprints 29/10/2024:68121)
DOI: https://doi.org/10.2196/preprints.68121

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Title: A Systematic Review of Smartphone Applications that Address Patient Care in the Peri-Operative Period

Authorship:

Hadal El-Hadi [1], Brandon Lok-Hang Chan [2], Brian Wai-Hei Siu [2], Ivan Ching-Ho Ko [2], David Ka-Wai Leung [2], Jeremy Yuen-Chun Teoh [2 3], Peter Ka-Fung Chiu [2], Chi-Fai Ng [2], Hannah Elizabeth [1], Alex Qinyang Liu [1 2]

Affiliations

1. London School of Hygiene and Tropical Medicine, London, The United Kingdoms

2. S.H. Ho Urology Centre, Department of Surgery, The Chinese University of Hong Kong, Hong Kong

3. Department of Urology, Medical University of Vienna, Vienna, Austria

Corresponding author

Alex Qinyang Liu, MBBS, MRCSEd, MCSHK

Position: Resident

E-mail: alexliu@surgery.cuhk.edu.hk

Phone: +852 97582233

Mailing Address: Department of Surgery, 4/F, Lui Che Woo Clinical Sciences Building, Prince of Wales Hospital, Shatin, Hong Kong SAR, 999077

Declaration of conflicting interest: there is no conflicting interest to be declared
Funding statement: this study was not funded
Ethical approval: This study was approved by LSHTM's ethics committee (reference number: 27003) on May 5th, 2022. As this project is a systematic/literature review only, it was assessed by the Research Governance and Integrity Office as not requiring ethical approval from the ethics committee.
Data availability statement: data will be available upon reasonable request to the corresponding author

Title: A Systematic Review of Smartphone Applications that Address Patient Care in the Peri-Operative Period

Abstract

Background: The use of smartphone applications by patients can be utilized to transform peri-operative care. With the ever-evolving landscape, updated systematic review is needed in this field.

Objective: This study aims at summarising the smartphone-based applications used by patients as discussed in academic literature in the setting of peri-operative patient care.

Methods: Seven databases were searched to identify articles discussing the use of smartphone applications by patients peri-operatively. Articles were included if they examined the use of smartphone-based applications in the setting of the perioperative period and examined the application's usability and effectiveness. Each paper was appraised using CASP checklists and analysed by the thematic synthesis method.

Results: Eighteen articles were selected for this study from 8,204 articles initially obtained. Themes that emerged from the analysis include the benefits of smartphone applications in peri-operative patient care: (1) patient education and instruction, (2) clear communication, (3) decreasing complications and use of healthcare resources, (4) postoperative monitoring and pain control, (5) improved patient support, satisfaction and safety. Other themes also emerged such as requirements of a practical smartphone application, what to include in smartphone application assessments, limitations of smartphone application studies and future directions of smartphone applications regarding patient peri-operative care.

Conclusions: The landscape of mobile applications is exponentially growing and their use in the peri-operative period is imminent for the future. Their use can improve communication between surgical care professionals, enhance patient care in the perioperative period, and strengthen medical education. Further studies, validation tools and improvements will be required to implement their use and demonstrate outcomes that can guide recommendations surrounding their use.

Introduction

The perioperative surgical patient experience can be a complex series of clinical and administrative events that begins with the surgical referral and ends with the postoperative recovery process (1). Surgical patient care can be implemented in an operating room, outpatient clinic, inpatient ward, emergency department, intensive care unit, or home (2-5). Smartphone and mobile health (mHealth) technologies are becoming integral to the evolution of telemedicine and digital health technology, as recent years have seen increased adoption of smartphones by surgical care professionals and patients (6-8). They also have the potential to optimize the quality and access to healthcare, reduce healthcare costs, support personal health management by encouraging healthy behaviour, improve adherence and self-management and overall, change the face of surgery, patient care and medical education (7-12).

The increased adoption of smartphones by surgical care professionals and patients across a wide age range makes it a logical tool that can improve communication and access to information systems and clinical tools at the point of care (1, 8). New advances in smartphone applications (apps) provide opportunities for innovative patient care, real-time data delivery, and patient-provider engagement from anywhere at any time (7, 8). Standardizing patient care by utilizing smartphone apps can address key components in access to care, patient safety, and healthcare quality by eliminating variations in patient education, recovery monitoring, treatment compliance, counselling, and accessibility to providers (1, 13).

There is an emerging interest in smartphone apps by surgical care providers with an increased focus on patient-centred care. Numerous apps are available that can assist in the peri-operative period (8). Patient education plays an important role in the treatment process, aiming to develop self-management skills to facilitate recovery and ensure long-term success (14). Apps can help patients enhance their involvement in their management, for example, by providing an opportunity to enter their own data and symptoms on their smartphone that can be relayed in real-time to the care team, who can then act on abnormal trends in symptoms (6, 8, 14). Apps can be used not only as a technology adjunct for point-of-care and as a diagnostic tool but also to send medication and appointment reminders (6, 8, 15). Apps must

address best practices and regulatory standards with regards to privacy, security and patient confidentiality (6).

In this review, the peri-operative period is defined as the time between the beginning of the pre-operative period (the period between the decision for operation till the operation) and the end of the postoperative period (the period where a patient is being followed up for his/her post-operative recovery). The current mobile health landscape for surgical patients is heterogeneous, and many different efforts have been made to incorporate the technology with perioperative care. However, there has been a gap in the literature to summarise the evidence supporting their use by patients. There have been small-scale randomized control trials (RCTs) to assess the use of apps, with outcomes such as patient-rated satisfaction, anxiety, patient awareness, behavioural change, and complication detection. However, no literature review currently summarises the findings, specifically in the peri-operative setting. As there is an emerging interest in apps by surgical care providers, and as more apps are developed to help patients in the peri-operative period, completing this study will be of interest and relevance to all surgical care providers and patients who currently are interested in the use or development of patient-care peri-operative smartphone apps.

Aims and Objectives

This project describes recent clinically tested apps in scientific literature and how they were integrated into peri-operative patient care. It aims to describe the current scope of app use within the peri-operative period for patients, classify and summarize how they are used according to their functionalities and benefits, and finally, review the outcomes of their use. Apps found in recent scientific literature were classified into areas of benefits that were deduced from the analysis of the included studies. Limitations of these studies, as well as future directions of smartphone apps, were also examined. Therefore, this review aims to fill in the gap in the literature by meeting the following objectives:

1) To describe the current attempts in smartphone apps to aid in the peri-operative care of patients by identifying and classifying published information in the literature on their benefits and perceived outcomes.
2) To identify and summarize effective smartphone app features, assess the usability and effectiveness of the apps to help guide future studies, identify the limitations of the studies included in the project, identify gaps in the literature, and identify areas of interest for further clinical studies.

Methodogy

Research Question

The research question was created by defining and developing a specific searchable question from a research topic. The research question was developed according to the Sample, Phenomenon of Interest, Design, Evaluation, Research type (SPIDER) tool derived from the Population, Intervention, Comparator, Outcome (PICO) tool. For the research question “how are smartphone apps utilized in the peri-operative period by surgical patients, what mobile applications have been described in the published literature and what are their benefits, utility, features, limitations and future directions in peri-operative patient care?” the SPIDER framework utilized was:

(S)ample: Surgical patients
(P)henomenon of (I)nterest: Use of smartphone applications in the peri-operative period that involve patient care
(D)esign: Structured literature review using thematic synthesis
(E)valuation: Smartphone application benefits, utility, features, limitations and future directions
(R)esearch type: Qualitative

Search Strategy

The research question was then used to create searchable concepts. In June 2022, seven appropriate databases (MEDLINE/Pubmed, Embase, Academic Search Complete, BASE, Cochrane Library, International HTA database and Open Grey) were searched to identify articles that discussed the use of smartphone applications by surgical patients in the perioperative period. Relevant search terms were identified and chosen to be included in a search strategy, including free text terms (keywords) and subject headings. Prior to a complete search, a discussion with a senior librarian from the London School of Hygiene and Tropical Medicine (LSHTM) helped guide the process through advice regarding search terms and databases. Search term concepts that discuss the design, development, evaluation, or use of smartphone applications to be used by surgical patients around patient care helped inform the MeSH vocabulary and included the following: “mobile application”, “peri-operative”, and “patient care”, with each term further incorporating relevant synonyms and alternative terms. An effective search strategy was constructed by compiling and connecting the words and phrases together, making appropriate use of common search techniques such as Boolean operators and truncation. Filters were used to exclude non-English papers, and no limit was selected regarding year of publication or status. An example of the search strategy is provided in Figure 1.

Inclusion Criteria

- Full-text
- English language
- Primary research
- Used by patients who underwent any type of surgery
- Interventions aiming to improve postoperative care
- Interventions using mHealth
- Patient-care oriented
- Focused on the design, development, evaluation or use of smartphone-based app
- Discussed phone apps that had the ability to function independently without need for medical device
- Discussed features and utility of the app

Exclusion Criteria

- Did not meet the inclusion criteria listed above
- Studies not in English
- Unavailable full-text articles
- Studies that were research protocols, conference presentations, reviews, editorials, case reports and case series
- Smartphone technology used for health intervention as opposed to patient-care were excluded
- Smartphone apps whose target audience were surgical care providers as opposed to patients
- Did not discuss features and utility of the app

Study Screening, Selection, Analysis and Quality Appraisal

For assessing the methodological quality of the included studies, four major areas were assessed, including the design, features, benefits, and analysis of the studies. For the selection process, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for systematic reviews were adhered to (16). The information created was carefully managed during the search process. Selected articles were exported using Endnote referencing manager and results of all database searches were imported to Mendeley and manually de-duplicated. Titles were screened for relevance, and those that fell within the scope of the project were screened by abstract to identify relevant papers. The titles and abstracts screened had to satisfy the inclusion criteria described above, and those that did not were excluded. Full texts of articles located during the literature search were accessed. The full text of these papers was then examined to determine eligibility for the final studies. An in-depth review was then conducted, and qualitative data was extracted. The reference lists of

included articles were also searched systematically and assessed for eligibility in a snowballing process. Quantitative studies were assessed by the STrengthening the Reporting of OBservational Studies in Epidemiology (STROBE) guidelines (17) and qualitative studies were assessed by the Qualitative Research Review Guidelines (RATS) guidelines (18). While extracting data from the included studies, several themes began to emerge, including 1) patient education and instruction, 2) clear communication, 3) decreasing complications and use of healthcare resources, 4) postoperative monitoring and pain control, and 5) improved patient support, satisfaction and safety. Other themes also emerged, such as requirements for an effective smartphone application, what to include in smartphone application assessments, limitations of smartphone application studies, and future directions for smartphone applications in regard to patient peri-operative care. The data was narratively summarized in a concise fashion using thematic synthesis.

Ethics Approval

This study was approved by LSHTM's ethics committee (reference number: 27003) on May 5th, 2022. As this project is a systematic/literature review only, it was assessed by the Research Governance and Integrity Office as not requiring ethical approval
from the ethics committee. This study was also conducted according to universal ethical principle

Main Report – Results

Search Results

The literature search resulted in 8204 articles from 7 databases. Duplicate articles, of which there were 733, were removed, and the inclusion and exclusion criteria described above were applied, resulting in the exclusion of 7286 articles. The remaining 185 articles were initially screened based on the titles and abstracts. These 185 were reviewed in full text, and an additional 162 were excluded as they did not describe the perceived outcome of the phone application regarding patient care. Twenty-three studies were selected for an in-depth review as they met the inclusion criteria. A flowchart of eligible articles for this project is shown in Figure 2.

General Description of the Included Studies

Twenty-three articles that described the current scope of mobile application use within the perioperative period for surgical care providers and their patients were analyzed. Table 1 describes the paper, the application, its utility and the perceived outcomes.

Thematic Synthesis

Themes that emerged from the analysis include the benefits of smartphone applications in peri-operative patient care: 1) patient education and instruction, 2) Clear communication, 3) complication monitoring, 4) pain monitoring and control, 5) improved patient support, satisfaction and safety. Other themes also emerged such as requirements of an effective smartphone application, what to include in smartphone application assessments, limitations of smartphone application studies and future directions of smartphone applications regarding patient peri-operative care.

Discussion

Patient Education and Instruction

Well-structured and effective patient education and instruction has been linked directly to improved satisfaction (by understanding their physical situation better and empowering them to actively participate in their recovery), decreased anxiety, lower rates of complications, decreased utilization of the emergency department for surgery-related concerns, decreased readmission rates, and decreased overall health costs (1, 15, 35-39). A general strength and important motivator for app users is the accessibility of specific information that could increase knowledge about their condition (40, 41). Improvement in surgical education and instruction throughout the pre-operative and post-operative timeframes can be accomplished by using patient's smartphones and the data favours acceptance of the use of mobile technology for peri-operative education (1). Same-day admissions in modern hospital practices and reduced length of hospital stay do not leave much time for patients to adjust to their situation (42). Applications can also serve as an important tool for patient engagement in education about their condition and procedure, and pre-operative education appears to positively affect the patients' postoperative coping abilities (43). An important concern regarding trustworthiness is that this information is not always up-to-date and valid (40). Accurate and relevant information within applications provided with direct input from surgical care providers, such as peri-operative nurses and surgeons, ensure that the information provided to patients complements the in-person counselling during pre-operative appointments (1). This information can also directly impact improving the overall surgical experience and clarify the information provided during counselling without contradicting the information between the surgical care providers and the application (1).

Clear Communication

The peri-operative period can be very complicated and complex to navigate for surgical patients. Clear and accurate communication is critical in delivering quality surgical care, and information regarding surgery can frequently be lost, misinterpreted, or even influenced by outside sources such as the internet and others' experience (1). Information from the internet is not surgeon or hospital-specific and can potentially lead to decreased care and morbidity (1). The post-operative care of the surgical patient usually depends on the pre-operative visit

with the surgeon. Still, it is often limited by time constraints and previous studies of the patient's ability to recall information immediately after counselling after their pre-operative visit demonstrated poor recall of procedural risks, as explained in the informed consent process (1). Managing surgical patients' expectations is important for better physical function post-surgery and satisfaction with outcomes (44, 45). mHealth can have additional value because only a limited amount of medical information can correctly be remembered after a consultation, and this can enhance information recall and adherence to health instructions at any time and at any place (46-50). Moreover, mHealth apps can reduce inconsistencies in the information given by healthcare providers (51).

Decreasing Complications and Use of Healthcare Resources

The first 30 days after an operation is critical, given that most complications occur (2, 3). Efforts to improve patient education and peri-operative experiences have decreased readmission rates and emergency department visits, enhancing cost-effectiveness and increasing healthcare service efficiency (1, 9, 51, 52). Non-optimal post-operative care can lead to preventable complications such as long-term disability such as chronic pain, organ rejection and death (53). Smartphone applications can inform patients about possible complications and potential warning signs contributing to preventable morbidity and mortality (11). Smartphone applications can also remotely monitor patient recovery, improve completion of post-operative follow-up appointments, monitor non-severe complications and provide surveillance of wound infections, which decreases unscheduled visits (54-60).

Postoperative Monitoring and Pain Control

In surgical care, remote monitoring may allow improved transition care and greater insight regarding the development of postoperative complications and readmissions (6).

For example, an application can provide a pop-up notification for a self-monitoring questionnaire regarding symptoms of potential concern: pain affecting function, headache, weakness and/or numbness, nausea and/or vomiting, and others, and if any of the symptoms were clicked, the patient could be directed to education topics on the symptom(s) (19). The self-monitoring questionnaire submissions may allow surgical care providers to target patients who need close follow-up (19). For example, if continuous bleeding was noted as a symptom of concern, especially for multiple days, a surgical care provider could proactively

further evaluate the patient. Also, the application could be useful in the follow-up of patients at high risk of complications (19). The frequency of symptoms from daily self-check questionnaires can highlight opportunities for two-way communication between the surgical care provider and the patient to address common complications at key time points in the recovery process (19). Research shows that the usage of interactive systems, chat interactions, videoconferencing sessions, and phone counselling improves physical function, disability, and pain compared to conventional methods of information delivery (61). Pain disability, in particular, is largely influenced by how patients interpret and adapt to their pain (62). Recent studies have shown that mHealth apps are promising tools in the guidance of pain control and opiate use and are effective in reducing pain medication intake (1). Instructions regarding postoperative pain medication use can decrease opioid requirements related to surgery, and implementing pain measurements and content on how to reduce pain medication could reinforce a positive attitude of users toward the application (1). Through smartphone applications, patients can initiate contact for concerns such as pain and wound issues (63).

Improved Patient Support, Satisfaction and Safety

The overall experience of the surgical patient is not only related to their operative experience, but also the pre-operative consultation and appointments as well as their post-operative recovery (1). While much of this may be subjective, many factors, in addition to the technical success of the surgery, are amenable to provider and institutional improvement efforts (1). Patient education and communication are two particular areas of interest as they improve patient satisfaction and impact overall patient safety (1). Smartphone applications have reported advantages for a patient's sense of being looked after, enhancement of patient-centred care and can also increase feelings of managing health-related behaviour by making users feel more reassured and empowering patients (64, 65). Patients who are highly engaged in self-management can experience using mHealth apps as more beneficial than others (65). Furthermore, peer support can enhance patient socialization by providing social support, and facilitating 2-way communication with clinicians could increase patient engagement (65, 66).

Requirements of an Effective Smartphone Application

For high yield benefit and impact for a smartphone application, several critical features

should be included (1). These features are important when considering the wide age-range of patients and the diverse range of technological literacy among patients (1). To increase the relevance of app use, it is preferable that mHealth apps include diverse functions that enable patients to personalize and tailor them to meet their needs (41, 65). The pre-requisites of an ideal smartphone application are summarised in Table 2.

What to Include in Smartphone Application Assessments

Before an effectiveness study can be performed, the user-friendliness of the app needs to be assessed (9). When assessing an application, usability based on a standardized scoring system such as the System Usability Scale (SUS) developed by John Brooke in 1986 can be utilized (1). It was first used in usability engineering of electronic office systems but is now applied to various technologies as a valid and reliable measure of effectiveness, efficiency, and satisfaction (67). The SUS is a reliable and robust 10-item questionnaire and scores on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) (13, 68). The total SUS score (0 to 100) can be interpreted as not acceptable (0-64), acceptable (65 to 84), or excellent (85 to 100) (69, 70).

When assessing an application, specific attitudes of eHealth users toward the application can also be applied (9). The attitude of eHealth users can be measured with part 2 of the eHealth impact questionnaire (eHIQ), which includes 3 subscales: (1) Confidence and identification (9 items), (2) Information and presentation (8 items), and (3) Understanding and motivation (9 items) (71). The eHIQ uses a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) (9). Confidence and Identification measures to what extent using the app has affected the confidence of app users in discussing and managing their health with others and whether individuals could identify with others who use the app (71). Information and Presentation measures the ease of use from the user's perspective (71). Understanding and Motivation measures whether respondents felt reassured, understood their condition, and felt motivated to manage their health (71).

User outcomes should also be measured by user attitude-based questionnaires that can include numeric rating scale, 5-point Likert scale, multiple choice questions and open-ended questions that allow for descriptive statistical analyses and inductive thematic content

analyses. Nominal, ordinal, and discrete data can be presented as medians and interquartile ranges, while continuous data can be analysed using means and standard deviation. Table 3 summarises the data metrics that should be included in the user questionnaires.

Once an application's usability has been determined, the next step would be to determine the effectiveness and characterize patient engagement in terms of uptake and usage during real-time implementation: do patients use it, and if so, how often and when? (19). Monitoring questionnaires completed and the number of total visits to the mobile application per participant within 30 postoperative days is critical in evaluating the application's usability (19). Multiple user uptake and behavioural characteristics that are of interest for further development and implementation include, the time of the day participants visited, the time of the day participants filled out the questionnaire, the number of visits on each postoperative day, duration of interaction within 30 postoperative days, the number of information topics viewed, ranking of the most-viewed topics, ranking of the most-completed questionnaire by number of postoperative days, and incidence of self-check symptoms entered by the participant (19). Demographic data such as age, gender, race, education level, household income, relationship status and other metrics should also be collected.

Limitations of Smartphone Applications Studies

The articles included were all in English, and smartphone application usage may differ globally between English-speaking countries and other geographical details. Furthermore, the exclusion criteria of most of the studies excluded several patient demographics that are different from the reality of the diverse patient population that surgical care providers regularly encounter, such as patients with cognitive impairments, mental illnesses, or limited language skills. Most of the articles studied smartphone applications that were developed and provided in English, and language limitations would have biased the studies. The studies were also completed in urban tertiary academic centres. Though many of the apps were specifically developed to meet the needs of their target group, patient technology literacy cannot be entirely eliminated, thereby, as a further limitation, negatively affecting patient adaptation and compliance to smartphone application utilization (15).

Most of the articles studied applications only available on the iOS App Store and iOS

platforms, which meant that participants had to own an iOS smartphone with internet access lending to a significant selection bias. Some apps were also available on Android platforms, but that was less common. Most of the studies excluded patients with any self-reported condition that impaired their ability to use mobile applications, answer questionnaires and surveys, and/or provide insights representative of the general population, such as blindness or active influence of recreational drugs or alcohol. A major limitation of most of the studies includes platform engagement being more likely in participants who signed up for a study (19).

The majority of the articles included in this study used surveys to extract data regarding the perceived outcome of the smartphone application being discussed. Surveys commonly have low response rates with small sample sizes, and most papers were only able to collect de-identified data. Due to this, it is difficult to elicit which patients benefited the most from using smartphone applications. There is also a wide variation in how counselling is provided to patients based on surgeon preference. Given this, there may be subtle differences between in-office counselling from specific surgeons and the standardized information sent to patients (1).

All the articles included in this study were based on patients who were over the age of 18. Information was not stratified based on age, and some studies showed that middle-aged and older users pay more attention to their health issues and are more motivated to take action by using mHealth to avoid illness and stay healthy (72). However, other studies have shown that younger, higher-educated and higher-income patients were more likely to use smartphone applications. This variation in how age groups utilize smartphone applications shows a gap in the research as different age groups may have different experiences of app usability and other expectations for how apps should function (72). There are also no studies to provide insight into the use of mHealth amongst younger patients who may be more confident in their post-operative recovery course, less motivated to manage their health, and less focused on specific health management. None of the articles used semi-structured interviews to help to define areas that could be further explored about smartphone application usage and could have given more detailed information about some themes (73).

As discussed, many studies are limited by sample size and methodology, and the impact of

mobile platforms on standardized quality of recovery, health outcomes, and health utilization needs to be further studied. However, optimizing current applications on one platform before further development in multiple platforms can allow for rapid, agile development within the confines of available research funding (19).

Telehealth has taken an ever-important role in patients' access to healthcare (74). In the context of physical distancing and resource limitations during the coronavirus disease (COVID-19) pandemic, smartphone apps can limit unnecessary in-person exposure while efficiently providing care (19). Future directions for smartphone apps would be to address the issues related to their confidentiality, staffing, time requirements, and medical-legal issues that can facilitate effective physician-patient contact through a patient-care app (75). Moreover, using multiple peri-operative mobile applications can confuse patients and clinicians, and interdisciplinary collaboration and institutional support are necessary to amalgamate functionalities and standardize care (19). It is imperative to determine ways to improve content and accessibility for marginalized populations with diverse social determinants of health (19). Barriers to access for socioeconomically and culturally diverse individuals have been a widely acknowledged gap in mobile health applications (76-80). Deployment of mobile applications in postoperative follow-up should remain affordable and not widen existing disparities of access and cost in healthcare (6). Smartphone apps may allow for more resources (e.g., in-person) to be redirected to patients who do not have access to smartphone apps or whose needs cannot easily be addressed with apps (19). mHealth interventions must be adapted to the specific needs of the paediatric population, such as children's shorter attention span and the complex interactions between the patient, the caregivers and the healthcare providers (81).

Smartphone apps and patient-care interventions are multifactorial in nature. Future research can elucidate which component(s) or feature of a smartphone app makes the most difference in outcomes and which are the most cost-effective (19). Future research should also focus on differences in app usability and utility amongst diverse demographics, such as age groups, gender, racial and other minoritized patients and patients with disabilities (19). Future studies should also include the introduction of the app in the early pre-operative period, interdisciplinary collaboration to expand the scope and quality of the app, pilots in larger and more diverse populations, interaction among healthcare workers and patients within the app,

and the integration of quality of recovery scores (81).

Conclusion

In the era of patient-centred care, smartphone apps are being used to improve patient care. Many medical apps for smartphones have been developed in evidence-based medicine. Health professionals and patients widely use them to connect patients and their healthcare teams. Smartphones can also play a very important role in patient education, disease self-management, and remote monitoring of patients. This study focused on peri-operative patient care through the use of smartphone applications. There was a wide range of utilities in the apps included within the articles included in this project. There were significant attempts to standardize readily accessible information to surgical patients to help eliminate variation. Timely information and instructions provided to patients through their smartphones may improve their levels of knowledge and information comprehension, medication or treatment adherence, satisfaction, and clinical outcomes, as well as having a positive effect on healthcare economics. Smartphone apps represent a potential technology to improve communication between the surgical community and patients. Using a mobile application to provide patients with educational material and instruction is feasible, beneficial, and improves patient satisfaction. Insights into patient engagement with smartphone apps could help design more effective and tailored peri-operative apps. This project adds to the evidence that telehealth strategies can help during the peri-operative period, a demanding time in the patients' lives. Smartphone apps are a feasible platform that reaffirms the unique opportunity to harness modern technology for patient benefit.

Included Figures and Tables

Figure 1: Example of search strategy

((((((((((((mobile app*) OR (phone app*)) OR (web app*)) OR (online app*)) OR (iPhone app*)) OR (smartphone app*)) OR (mHealth)) OR (application software*)) OR (software app*)) OR (app software*)) OR (android app*)) OR (cellular app*)) OR (cellphone App*)) OR (cellular phone app*)) OR (health care app*)

AND

((((((((((((((((((periop*) OR (peri-op*)) OR (surgery)) OR (surgical)) OR (pre-op*)) OR (preop*)) OR (postop*)) OR (post-op*)) OR (intraop*)) OR (intra-op*)) OR (prehospital)) OR (pre-hospital)) OR (posthospital)) OR (post-hospital)) OR (inhospital)) OR (in-hospital)) OR (pre-surg*)) OR (presurg*)) OR (postsurg*)) OR (post-surg*)

Figure 2: PRISMA Flowchart of Study Selection

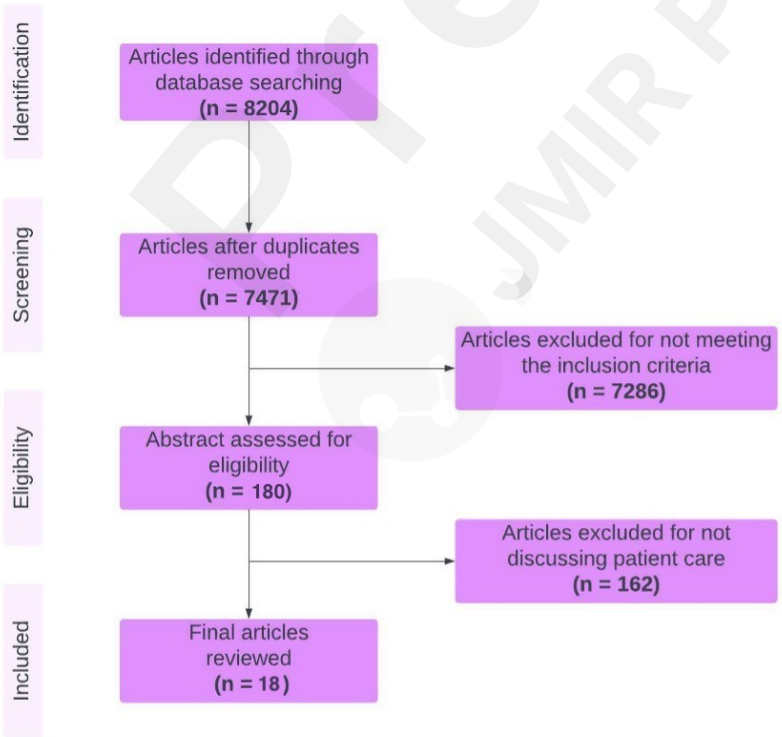

Table 1: Description of Included Studies

Study	Year	Country	Study design	Specialty (procedures included)	Sample size (n)	Name of application	Themes of application identified	Specific features	Format	Outcome measures	Study outcomes
Morte et al (1)	2021	United States	Single-arm study	General surgery (Elective cholecystectomy, interval appendectomy, colectomy, bariatric surgery and open hernia repairs)	100	MCare	Patient education and instruction	Perioperative educational materials; Text message reminders of time-sensitive events	Text messages	- Usability	- Average SUS of 86 (>90th percentile) - 86% of patients felt that the application improved their surgical experience
Williems et al (9)	2021	Netherlands	Cross-sectional study	Orthopedics (Surgery for musculoskeletal disorders)	526	Patient Journey	Patient education and instruction	Educational materials on preoperative exercises, surgery, and rehabilitation	iOS and Android apps	- Usability - User attitude - User experience	- Median SUS of 85 - Positive attitude toward information provided via app (eHIQ median 78) - Did not improve users' confidence in discussing health with others or motivation to manage health
Ke et al (19)	2021	Canada	Single-arm study	Obstetrics (Caesarean delivery)	36	C-Care	Complication monitoring; Pain monitoring and control; Patient education and instruction	Education materials on perioperative anaesthetic topics; Self-monitoring questionnaire on pain and complications	iOS app	- User engagement - User satisfaction	- Median of 3 out of five self-monitoring questionnaires completed per user - Median of 15 application visits over 30 days per user - Median patient satisfaction was 7.5 out of 10
Anthony et al (20)	2020	United States	Randomised controlled trial	Orthopedics (Operative fixation of a traumatic upper or lower fracture)	82	N/A	Pain monitoring and control	Acceptance and Commitment Therapy delivered through text messages	Text messages	- Amount of opioid pain medication consumed - Changes in patient-reported pain scores,	- 36.5% less opioid tablets used by intervention group - Lower postoperative

										measured by PROMIS	PROMIS Pain Intensity score in intervention group
Premkumar et al (21)	2018	United States	Single-arm study	Orthopedics (Total hip or knee arthroplasty)	183	N/A	Complication monitoring; Pain monitoring and control	Daily information collection on patient-reported opioid consumption and pain	Text messages	- User engagement	- Overall response rate of 96.1%, defined as completion of at least 50% of twice-daily SMS post-operative questions for six weeks
Rojas et al (22)	2019	United States	Randomised controlled trial	Orthopedics (Musculoskeletal tumor patients)	14	N/A	Pain monitoring and control	CBT intervention text messages giving general postoperative guidance and encouragement	Text messages	- User engagement - Pain score - Patient reported opioid use	- 90% completion rate of all questions in intervention group - Intervention group used less of daily prescribed opioid medication
Goz et al (23)	2019	United States	Single-arm study	Orthopedics (Spine surgery)	21	N/A	Patient education and instruction	Text messages to address common postoperative concerns of patients undergoing spine surgery	Text messages	- User satisfaction	- Average rating of the application on a 1 to 5 scale with 5 being “very useful” was 4.57
Wittig-Wells et al (24)	2019	United States	Randomised controlled trial	Orthopedics (Hip or knee arthroplasty)	29	N/A	Patient education and instruction	Daily pre-set cellular telephone alarm as a reminder for adults to take prescribed aspirin twice daily as antithrombotic therapy	Pre-set phone alarms	- Self-reported medication adherence	- Intervention group had lower rates of forgetting aspirin (29.7% vs 59.5%)
van Dijk-Huisman et al (25)	2019	The Netherlands	Non-randomised trial	Orthopedics (Total hip or knee arthroplasty)	97	Hospital Fit	Functional recovery; Patient education and instruction	Objective exercise monitoring with accelerometer and real-time feedback; Provides personalised exercise program	Smartphone app with accelerometer	- Time spent physically active - Functional recovery on POD1	- Intervention group patients stood and walked on POD1 for an average increase of 28.43 min over control

											- Odds of achieving functional recovery on POD1 was 3.08 times higher
Belarmino et al (26)	2019	United States	Single-arm study	Urology (Robotic assisted radical prostatectomy)	20	N/A	Patient education and instruction; Functional recovery; Pain monitoring and control	Perioperative reminders to perform Kegel exercises, ambulate and hydrate	IOS app	- User satisfaction	- 15 men (75%) who completed the satisfaction survey found the app easy to use and understand
Felbaum et al (27)	2018	United States	Single-arm study	Neurosurgery (Routine neurosurgery procedures)	56	TrackMyRecovery	Patient education and instruction; Pain monitoring and control; Complication monitoring; Clear communication	Patient-specific pre- and post-operative instructions; Pain scores and wound images can be reported through the app	iOS and Android app	- Successful registration and use of app - Compliance with reading instructions - Surgery cancellation - Postoperative complications within 6 weeks - Readmissions within 30 days - Number of perioperative phone calls	- - 54/56 patients successfully registered, downloaded, and complied with instructions both before and after surgery - There were no cancelled surgeries or readmissions. - There was 1 postoperative complication. - 8/54 patients called the office for a surgery related question.
Heuser et al. (28)	2021	Canada	Retrospective cohort study	Bariatric surgery (Roux-en-Y gastric bypass, sleeve gastrectomy)	854	N/A	Patient education and instruction; Pain monitoring and control; Complication monitoring	Notification reminders before surgery; Perioperative educational materials; Postoperative symptoms and health care utilization monitoring	IOS and Android app	- Postoperative outcomes (LOS, ED visits, readmission) - Patient-reported self-care and health care utilization outcomes - User engagement - User satisfaction	- Use of the app was not associated with the rates of prolonged length of stay, ED visits, and readmission - 48.5% of surveyed patient reported the app helped them avoid phone calls to the hospital. 13.0%

											avoided ED visits - 66.2% of patients completed the daily health check survey at least once in the first week after the surgery - 94.8% of surveyed patients would recommend the app to other patients
van Hout et al. (29)	2022	The Netherlands	Single-arm study	General surgery (Inguinal hernia repair)	242	Q1.6 Hernia Inguinal	Pain monitoring and control; Complication monitoring	Continuous digital patient outcome measurement using non-intrusive, short questions	IOS and Android app	- Chronic post-operative inguinal pain - User compliance - Patient satisfaction - Other PROs (wound healing, pain, physical limitation and potential recurrence)	- After months 3, 6 and 11, respectively, 3.0%, 4.4% and 4.5% of patients reported inguinal pain or discomfort (NRS ≥ 4) - Compliance with the application was 91.7% after 14 days, 69.0% after 3 months and 28.8% after one year - 92.8% of patients preferred the app over standard care
Sousa et al. (30)	2019	Brazil	Single-arm study	Maxillofacial surgery (Orthognathic surgery)	30	OrtogApp	Patient education and instruction; Clear communication	Provides five learning content sessions essential for managing perioperative care; Email contact with specialist nurses	IOS and Android app	- Usability - User satisfaction	- Average SUS of 79.8 - Satisfaction index was 82.9%
Ashraf et al. (31)	2021	United Kingdom	Single-arm study	General surgery (Colorectal surgery)	17	N/A	Patient education and instruction; Complication monitoring	Three main components: education, physical and psychological	iOS app	- Uptake and interaction - Usability	- 10/17 patients introduced to the app downloaded it and registered

								functional measurements (questionnaires and journal), and postoperative wound monitoring			- Average number of interactions was 24 per patient - Interaction with the journal was the most frequent (33.7% of all usage)
Abdeen et al. (32)	2022	United States	Non-randomised trial	Orthopedics (Total hip or knee arthroplasty)	274	N/A	Patient education and instruction	Customized messages including appointment reminders for pre-anesthetic appointment, links to educational videos, and real-time text message reminders to perform the requisite tasks of the peri-operative protocols	iOS and Android app	- Compliance to chlorhexidine gluconate shower and hydration protocol - LOS - Surgical site infection - 90-day readmission	- App-users had increased adherence to the hydration protocol (OR = 3.17; P=.003) - App-use was associated with shorter LOS - There was no difference in adherence to chlorhexidine gluconate, readmission, or surgical site infection
van der Meij et al. (33)	2018	The Netherlands	Randomised controlled trial	General surgery and Gynecology (Laparoscopic cholecystectomy, hernia inguinal surgery or laparoscopic adnexal surgery)	344	ikHerstel	Functional recovery; Patient education and instruction; Clear communication	Recovery advice based on personalised convalescence plan; Information about the perioperative period; Monitoring and feedback on recovery; E-consult feature	Smartphone app, website and activity tracker	- Time elapsing between surgery and return to normal activities after surgery, measured by PROMIS Physical Function item	- Median time until return to normal activities was 21 days in the intervention group and 26 days in the control group (HR 1.38; p=0.007).
Pickens et al. (34)	2019	United States	Single-arm study	General surgery (Hepatectomy, distal pancreatectomy, pancreatico-duodenectomy)	122	N/A	Patient education and instruction; Complication monitoring	Pre-operative scheduled task reminders for both General preparation; Daily post-discharge health checks with customized responses to guide out-of-hospital care	Web-based platform	- User engagement - User satisfaction - PROs (post-operative pain, nausea, opiate use, compliance to ERAS®	- Application adoption was 93% and in-hospital engagement was 88% - Satisfaction rate was high with 86% recommending

			pathway items) - Quality-of-life assessed by QoR-15 and PROMIS	the application - Patients completed 62% of PROs - The 30-day end-of-study PROMIS survey was completed by 41% of participants

Acronyms
- SUS: System Usability Scale
- eHIQ: eHealth Impact Questionnaire
- ERAS®: Enhanced Recovery After Surgery
- PROMIS: Patient-Reported Outcomes Measurement Information System
- LOS: Length of stay
- SMS: Short message service
- CBT: Cognitive behavioral therapy
- POD: Postoperative day
- PRO: Patient reported outcomes
- ED: Emergency department
- NRS: Numeric rating scale
- OR: Odds ratio
- HR: Hazards ratio
- QoR-15: Quality of Recovery 15 question survey

Table 2. Peri-operative characteristics of an ideal peri-operative smartphone application

A. General characteristics should:
1. Be simple to download, easy to use, quick to learn, and not overly cumbersome or technically complex.
2. Be designed to send out time-sensitive text messages directly to the patient rather than rely on the patient to open the application to view instructions or information
3. Reflect simple instructions that are easily interpreted
4. Be introduced early in the pre-operative period
5. Solidify the understanding of pre-operative counselling and prepare and guide patients optimally through the perioperative period
6. Provide an interface that allows for interactions with surgical care providers.
7. Have the option to allow for push notifications
8. Have a multimodal approach, including clear, concise videos or gamification that playfully encourages patients to acquire useful knowledge and engage in tasks
9. Provide advanced functions, such as personal logs with appointments and a more personalized prognosis
10. Provide clear expectations and guidelines that optimally guide and prepare patients for surgery and rehabilitation
11. Have multiple reminders for self-monitoring
12. Allow for user feedback and provide important avenues for improvement and guidance for future designs, such as real-time traffic data
13. Provide motivational features for increase of long-term user engagement
14. Allow for goal-setting and self-reflection
B. Information and instructions provided by the application should:
1. Be clear and provided in a timely fashion
2. Be provided in a plain language style and refrain from technical terms
3. Incorporate information from existing pamphlets
4. Not be overly optimistic
5. Provide adequate reference data that is up-to-date
6. Have input and collaboration from experts, surgical care providers and patients
7. Provide sufficient information regarding:
a. General information about the clinic/hospital and the surgical care providers that will be encountered
b. Practical pre-operative medical information:
i. Pathophysiology and anatomy
ii. Pre-operative exercises
c. About the surgery/procedure/operation
d. Information about the stay in hospital
i. Overview of the day
ii. Brief overviews on key peri-operative anesthetic topics
iii. General preparation for surgery
iv. Medications
v. Eating schedule
vi. Pain control
e. Day-to-day expectations of the post-operative period:
i. Overview of the recovery course
ii. Mobility, advice on when to be active, resume physical/sexual activities and/or return to work

iii. Food and dietary implications of surgery iv. Bowel and bladder function v. Body hygiene vi. Sleep and delirium vii. Bleeding viii. Pain control ix. Medications x. Wound care, infections and scar management xi. Allergies xii. Clinical course deviations xiii. Complications f. Psychological wellbeing and mental health 8. Be aligned with information previously provided by the surgical care team 9. When appropriate, provide clear videos with exercises tailored to the condition, recovery, and functional tasks 10. Provided by different types of media such as: a. Photos of the operating room b. Videos of post-operative rehabilitation exercises 11. Be ideally personalized and provide access to personal electronic health record 12. Provide reference data from peers 13. Be able to be used on a continuous timeline as opposed to jumping back to a previous phase of recovery instead of continuing with the current phase

Table 3. Data metrics that should be included in the user attitude-based questionnaire

Questionnaires should include data metrics such as:
● Does the application improve the overall surgical experience? ● Does the application provide essential peri-operative reminders? ● Does the application clarify information from the preoperative appointment? ● Would the patient like to have this application available during future surgery? ● Was there any conflicting information relayed from the surgeon during counseling and the text messages sent by the application? ● What is the patient's attitude toward the Information and Presentation provided via the application? ● Did the application improve the patient's confidence in discussing health with others? ● Did the application motivate the patient to manage their health? ● What was the overall satisfaction with the application? ● What were the most appreciated and used parts of the application?

- What was the overall satisfaction with the amount of information provided?
- Would the patient recommend the application to other patients?
- To what extent did the patient feel that the application was supportive in addition to the information given by health professionals?
- What were the strengths and limitations of the application?
- Did the application provide patients with knowledge about their surgery and anesthesia, potential complications to monitor for, and the recovery process after?
- What would the patient want to change about the application?
- Why did the patient not use the mobile application?

Statements and Declarations

Declaration of conflicting interest: there is no conflicting interest to be declared

Funding statement: this study was not funded

Ethical approval: This study was approved by LSHTM's ethics committee (reference number: 27003) on May 5th, 2022. As this project is a systematic/literature review only, it was assessed by the Research Governance and Integrity Office as not requiring ethical approval from the ethics committee.

Data availability statement: data will be available upon reasonable request to the

corresponding author

Reference List

1) Morte K, Marenco C, Lammers D, Bingham J, Sohn V, Eckert M. Utilization of mobile application improves perioperative education and patient satisfaction in general surgery patients. Am J Surg. 2021 Apr;221(4):788-792. doi: 10.1016/j.amjsurg.2020.03.034. Epub 2020 Apr 16. PMID: 32381263.
2) Mezei G, Chung F. Return hospital visits and hospital readmissions after ambulatory surgery. Ann Surg. 1999 Nov;230(5):721-7. doi: 10.1097/00000658-199911000-00016. PMID: 10561098; PMCID: PMC1420928.
3) Bruce J, Russell EM, Mollison J, Krukowski ZH. The measurement and monitoring of surgical adverse events. Health Technol Assess. 2001;5(22):1-194. doi: 10.3310/hta5220. PMID: 11532239.
4) Smith HK, Manjaly JG, Yousri T, Upadhyay N, Taylor H, Nicol SG, Livingstone JA. Informed consent in trauma: does written information improve patient recall of risks? A prospective randomised study. Injury. 2012 Sep;43(9):1534-8. doi: 10.1016/j.injury.2011.06.419. Epub 2011 Jul 22. PMID: 21782171.
5) Uzzaman MM, Sinha S, Shaygi B, Vitish-Sharma P, Loizides S, Myint F. Evaluation of patient's understanding and recall of the consent process after open inguinal hernia repairs. Int J Surg. 2012;10(1):5-10. doi: 10.1016/j.ijsu.2011.10.003. Epub 2011 Oct 25. PMID: 22051351.
6) Semple JL, Armstrong KA. Mobile applications for postoperative monitoring after discharge. CMAJ. 2017 Jan 9;189(1):E22-E24. doi: 10.1503/cmaj.160195. Epub 2016 Dec 5. PMID: 27920015; PMCID: PMC5224949.
7) Pan S, Rong LQ. Mobile Applications in Clinical and Perioperative Care for Anesthesia: Narrative Review. J Med Internet Res. 2021 Sep 17;23(9):e25115. doi: 10.2196/25115. PMID: 34533468; PMCID: PMC8486987.
8) Mosa AS, Yoo I, Sheets L. A systematic review of healthcare applications for smartphones. BMC Med Inform Decis Mak. 2012 Jul 10;12:67. doi: 10.1186/1472-6947-12-67. PMID: 22781312; PMCID: PMC3534499.
9) Willems SJ, Coppieters MW, Pronk Y, Diks MJF, van der Heijden KWAP, Rooker S, Scholten-Peeters GGM. A Clinical Journey Mobile Health App for Perioperative Patients: Cross-sectional Study. JMIR Hum Factors. 2021 Feb 8;8(1):e20694. doi: 10.2196/20694. PMID: 33555262; PMCID: PMC7899805.
10) Elbert NJ, van Os-Medendorp H, van Renselaar W, Ekeland AG, Hakkaart-van Roijen L, Raat H, Nijsten TE, Pasmans SG. Effectiveness and cost-effectiveness of ehealth interventions in somatic diseases: a systematic review of systematic reviews and meta-analyses. J Med Internet Res. 2014 Apr 16;16(4):e110. doi: 10.2196/jmir.2790. https://www.jmir.org/2014/4/e110/
11) Wantland Dean J, Portillo Carmen J, Holzemer William L, Slaughter Rob, McGhee Eva M. The effectiveness of web-based vs. non-web-based interventions: a meta-analysis of behavioral change outcomes. J Med Internet Res. 2004 Nov 10;6(4):e40. doi: 10.2196/jmir.6.4.e40. https://www.jmir.org/2004/4/e40/
12) Walker C, Swerissen H, Belfrage J. Self-management: its place in the management of chronic illnesses. Aust Health Rev. 2003;26(2):34–42. doi: 10.1071/ah030034a.
13) Brooke, J., Jordan, P. W., Thomas, B., Weerdmeester, B. A., & McClelland, I. L. (1996). Usability evaluation in industry.
14) Stauber A, Schüßler N, Palmdorf S, Schürholz N, Bruns D, Osterbrink J, Nestler N. RECOVER-E - a mobile app for patients undergoing total knee or hip replacement: study protocol. BMC Musculoskelet Disord. 2020 Feb 4;21(1):71. doi:

10.1186/s12891-020-3090-2. PMID: 32019529; PMCID: PMC7001367.
15) Martínez-Ramos C, Cerdán MT, López RS. Mobile phone-based telemedicine system for the home follow-up of patients undergoing ambulatory surgery. Telemed J E Health 2009; 15:531–7.
16) Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ (Clinical research ed.) 2009;339:b2535. doi: 10.1136/bmj.b2535.
17) Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. [cited 2022 July 6]; Available from: http://www.epidem.com/
18) Jocelyn Clark. How to peer review a qualitative manuscript. BMJ [Internet]. 2003 [cited 2022 July 6];219–35. Available from: https://bmjopen.bmj.com/content/suppl/2012/01/12/bmjopen-2011-000138.DC1/BMJ_Open_IMG_Physician_Migration_RATS_Checklist.pdf
19) Ke JXC, George RB, Wozney L, Munro A. Perioperative mobile application for mothers undergoing Cesarean delivery: a prospective cohort study on patient engagement. Can J Anaesth. 2021 Apr;68(4):505-513. doi: 10.1007/s12630-020-01907-x. Epub 2021 Jan 9. PMID: 33420678; PMCID: PMC7794079.
20) Anthony CA, Rojas EO, Keffala V, Glass NA, Shah AS, Miller BJ, Hogue M, Willey MC, Karam M, Marsh JL. Acceptance and Commitment Therapy Delivered via a Mobile Phone Messaging Robot to Decrease Postoperative Opioid Use in Patients With Orthopedic Trauma: Randomized Controlled Trial. J Med Internet Res. 2020 Jul 29;22(7):e17750. doi: 10.2196/17750. PMID: 32723723; PMCID: PMC7458063.
21) Premkumar A, Lovecchio FC, Stepan JG, Kahlenberg CA, Blevins JL, Albert TJ, Cross MB. A Novel Mobile Phone Text Messaging Platform Improves Collection of Patient-Reported Post-operative Pain and Opioid Use Following Orthopedic Surgery. HSS J. 2019 Feb;15(1):37-41. doi: 10.1007/s11420-018-9635-3. Epub 2018 Oct 22. PMID: 30863231; PMCID: PMC6384206.
22) Rojas EO, Anthony CA, Kain J, Glass N, Shah AS, Smith T, Miller BJ. Automated Mobile Phone Messaging Utilizing a Cognitive Behavioral Intervention: A Pilot Investigation. Iowa Orthop J. 2019;39(2):85-91. PMID: 32577113; PMCID: PMC7047297.
23) Goz V, Anthony C, Pugely A, Lawrence B, Spina N, Brodke D, Spiker WR. Software-Based Postoperative Communication With Patients Undergoing Spine Surgery. Global Spine J. 2019 Feb;9(1):14-17. doi: 10.1177/2192568217728047. Epub 2018 May 22. PMID: 30775203; PMCID: PMC6362547.
24) Wittig-Wells D, Higgins M, Carter J, Davis E, Holmes E, Jacob A, Samms-McPherson J, Simms S. Impact of a Preset Daily Cell Phone Alarm on Medication Adherence for Aspirin as Antithrombotic Therapy. Orthop Nurs. 2019 Sep/Oct;38(5):311-316. doi: 10.1097/NOR.0000000000000592. PMID: 31568119.
25) van Dijk-Huisman HC, Weemaes ATR, Boymans TAEJ, Lenssen AF, de Bie RA. Smartphone App with an Accelerometer Enhances Patients' Physical Activity Following Elective Orthopedic Surgery: A Pilot Study. Sensors (Basel). 2020 Aug 2;20(15):4317. doi: 10.3390/s20154317. PMID: 32748876; PMCID: PMC7436024.
26) Belarmino A, Walsh R, Alshak M, Patel N, Wu R, Hu JC. Feasibility of a Mobile Health Application To Monitor Recovery and Patient-reported Outcomes after Robot-assisted Radical Prostatectomy. Eur Urol Oncol. 2019 Jul;2(4):425-428. doi: 10.1016/j.euo.2018.08.016. Epub 2018 Sep 10. PMID: 31277778.
27) Felbaum DR, Stewart JJ, Anaizi AN, Sandhu FA, Nair MN, Voyadzis JM.

Implementation and Evaluation of a Smartphone Application for the Perioperative Care of Neurosurgery Patients at an Academic Medical Center: Implications for Patient Satisfaction, Surgery Cancelations, and Readmissions. Oper Neurosurg (Hagerstown). 2018 Mar 1;14(3):303-311. doi: 10.1093/ons/opx112. PMID: 28541569.

28) Heuser J, Maeda A, Yang L, Masino C, Duggal S, Jackson T, Okrainec A. Impact of a Mobile App to Support Home Recovery of Patients Undergoing Bariatric Surgery. J Surg Res. 2021 May;261:179-184. doi: 10.1016/j.jss.2020.12.005. Epub 2021 Jan 12. PMID: 33444947.
29) van Hout L, Bökkerink WJV, Vriens PWHE. Clinical feasibility of the Q1.6 Inguinal Hernia application: a prospective cohort study. Hernia. 2023 Apr;27(2):449–58. Sousa CS, Turrini RNT. Development of an educational mobile application for patients submitted to orthognathic surgery. Rev Lat Am Enfermagem. 2019 Jul 18;27:e3143. doi: 10.1590/1518-8345.2904.3143. PMID: 31340340; PMCID: PMC6687363.
30) Ashraf H, Anderson RG, Anderson DJ, Moug SJ. Feasibility of a perioperative smartphone application in colorectal surgery. Br J Surg. 2021 Sep 27;108(9):e282-e283. doi: 10.1093/bjs/znab143. PMID: 34409440.
31) Abdeen A, Monárrez R, Drew JM, Kennedy KF. Use of a Smart-Phone Mobile Application is Associated With Improved Compliance and Reduced Length of Stay in Patients Undergoing Primary Total Joint Arthroplasty of the Hip and Knee. J Arthroplasty. 2022 Aug;37(8):1534-1540. doi: 10.1016/j.arth.2022.03.068. Epub 2022 Mar 25. PMID: 35341922.
32) 4.van der Meij E, Anema JR, Leclercq WKG, Bongers MY, Consten ECJ, Schraffordt Koops SE, et al. Personalised perioperative care by e-health after intermediate-grade abdominal surgery: a multicentre, single-blind, randomised, placebo-controlled trial. Lancet. 2018 Jul 7;392(10141):51–9.
33) Pickens R, Cochran A, Tezber K, Berry R, Bhattacharya E, Koo D, King L, Iannitti DA, Martinie JB, Baker EH, Ocuin LM, Hunt J, Vrochides D. Using a Mobile Application for Real-Time Collection of Patient-Reported Outcomes in Hepatopancreatobiliary Surgery within an ERAS® Pathway. Am Surg. 2019 Aug 1;85(8):909-917. PMID: 32051068.
34) Fredericks S, Yau T. Educational intervention reduces complications and rehospitalizations after heart surgery. West J Nurs Res. 2013 Nov;35(10):1251-65. doi: 10.1177/0193945913490081. Epub 2013 May 29. PMID: 23720096.
35) Aiello FA, Gross ER, Krajewski A, Fuller R, Morgan A, Duffy A, Longo W, Kozol R, Chandawarkar R. Post-appendectomy visits to the emergency department within the global period: a target for cost containment. Am J Surg. 2010 Sep;200(3):357-62. doi: 10.1016/j.amjsurg.2009.10.010. PMID: 20800714.
36) Clark NM, Feldman CH, Evans D, Levison MJ, Wasilewski Y, Mellins RB. The impact of health education on frequency and cost of health care use by low income children with asthma. J Allergy Clin Immunol. 1986 Jul;78(1 Pt 1):108-15. doi: 10.1016/0091-6749(86)90122-3. PMID: 3088085.
37) Karam JA, Sundre SM, Smith GL. Cost/benefit analysis of patient education. J Healthc Educ Train. 1986 Fall;1(2):15-9. PMID: 10312198.
38) McDonald DA, Siegmeth R, Deakin AH, Kinninmonth AW, Scott NB. An enhanced recovery programme for primary total knee arthroplasty in the United Kingdom--follow up at one year. Knee. 2012;19(5):525–529. doi: 10.1016/j.knee.2011.07.012.
39) Vo V, Auroy L, Sarradon-Eck A. Patients' perceptions of mhealth apps: meta-ethnographic review of qualitative studies. JMIR mHealth uHealth. 2019 Jul 10;7(7):e13817. doi: 10.2196/13817. https://mhealth.jmir.org/2019/7/e13817/

40) Bauer A, Iles-Shih M, Ghomi R, Rue Tessa, Grover Tess, Kincler Naomi, Miller Monica, Katon Wayne J. Acceptability of mhealth augmentation of collaborative care: a mixed methods pilot study. Gen Hosp Psychiatry. 2018;51:22–29. doi: 10.1016/j.genhosppsych.2017.11.010.
41) Mertes SC, Raut S, Khanduja V. Integrated care pathways in lower-limb arthroplasty: are they effective in reducing length of hospital stay? Int Orthop. 2013;37(6):1157–1163. doi: 10.1007/s00264-013-1829-1.
42) Siggeirsdottir K, Olafsson O, Jonsson H, Iwarsson S, Gudnason V, Jonsson BY. Short hospital stay augmented with education and home-based rehabilitation improves function and quality of life after hip replacement: randomized study of 50 patients with 6 months of follow-up. Acta Orthop. 2005;76(4):555–562. doi: 10.1080/17453670510041565.
43) Ibrahim MS, Khan MA, Nizam I, Haddad FS. Peri-operative interventions producing better functional outcomes and enhanced recovery following total hip and knee arthroplasty: an evidence-based review. BMC Med. 2013;11:37. doi: 10.1186/1741-7015-11-37.
44) Mahomed NN, Liang MH, Cook EF, Daltroy LH, Fortin PR, Fossel AH, et al. The importance of patient expectations in predicting functional outcomes after total joint arthroplasty. J Rheumatol. 2002;29(6):1273–1279.
45) Sandberg E, Sharma R, Sandberg W. Deficits in retention for verbally presented medical information. Anesthesiology. 2012 Oct;117(4):772–9. doi: 10.1097/ALN.0b013e31826a4b02. https://pubs.asahq.org/anesthesiology/article-lookup/doi/10.1097/ALN.0b013e31826a4b02.
46) Timmers Thomas, Janssen Loes, Pronk Yvette, van der Zwaard Babette C, Koëter Sander, van Oostveen Dirk, de Boer Stefan, Kremers Keetie, Rutten Sebastiaan, Das Dirk, van Geenen Rutger Ci, Koenraadt Koen Lm, Kusters Rob, van der Weegen Walter. Assessing the efficacy of an educational smartphone or tablet app with subdivided and interactive content to increase patients' medical knowledge: randomized controlled trial. JMIR mHealth uHealth. 2018 Dec 21;6(12):e10742. doi: 10.2196/10742. https://mhealth.jmir.org/2018/12/e10742/
47) Khaleel I, Wimmer BC, Peterson GM, Zaidi STR, Roehrer E, Cummings E, Lee K. Health information overload among health consumers: a scoping review. Patient Educ Couns. 2020 Jan;103(1):15–32. doi: 10.1016/j.pec.2019.08.008.
48) Houts PS, Doak CC, Doak LG, Loscalzo MJ. The role of pictures in improving health communication: a review of research on attention, comprehension, recall, and adherence. Patient Educ Couns. 2006 May;61(2):173–90. doi: 10.1016/j.pec.2005.05.004.
49) Bol N, Smets EM, Rutgers MM, Burgers JA, de Haes HC, Loos EF, van Weert JC. Do videos improve website satisfaction and recall of online cancer-related information in older lung cancer patients? Patient Educ Couns. 2013 Sep;92(3):404–12. doi: 10.1016/j.pec.2013.06.004.
50) De La Cruz Monroy MFI, Mosahebi A. The use of smartphone applications (apps) for enhancing communication with surgical patients: a systematic review of the literature. Surg Innov. 2019 Apr;26(2):244–259. doi: 10.1177/1553350618819517.
51) Simpao AF, Lingappan AM, Ahumada LM, Rehman MA, Gálvez Jorge A. Perioperative smartphone apps and devices for patient-centered care. J Med Syst. 2015 Sep;39(9):102. doi: 10.1007/s10916-015-0310-7.
52) Nguyen N, Leveille E, Guadagno E, Kalisya LM, Poenaru D. Use of mobile health technologies for postoperative care in paediatric surgery: A systematic review. J Telemed Telecare. 2022 Jun;28(5):331-341. doi: 10.1177/1357633X20934682. Epub

2020 Jun 30.
53) Castillo E, McIsaac C, MacDougall B, Wilson D, Kohr R. Post-caesarean section surgical site infection surveillance using an online database and mobile phone technology. J Obstet Gynaecol Can. 2017;39(645–51):e1.
54) Fawsitt CG, Meaney S, Greene RA, Corcoran P. Surgical site infection after caesarean section? There is an app for that: results from a feasibility study on costs and benefits. Ir Med J. 2017;110:635.
55) DeNicola N, Grossman D, Marko K, et al. Telehealth interventions to improve obstetric and gynecologic health outcomes: a systematic review. Obstet Gynecol. 2020;135:371–382. doi: 10.1097/AOG.0000000000003646.
56) Bush J, Barlow DE, Echols J, Wilkerson J, Bellevin K. Impact of a Mobile health application on user engagement and pregnancy outcomes among Wyoming Medicaid members. Telemed J E Health. 2017;23:891–898. doi: 10.1089/tmj.2016.0242.
57) Mackillop L, Hirst JE, Bartlett KJ, et al. Comparing the efficacy of a mobile phone-based blood glucose management system with standard clinic care in women with gestational diabetes: randomized controlled trial. JMIR MHealth UHealth. 2018 doi: 10.2196/mhealth.9512.
58) Miremberg H, Ben-Ari T, Betzer T, et al. The impact of a daily smartphone-based feedback system among women with gestational diabetes on compliance, glycemic control, satisfaction, and pregnancy outcome: a randomized controlled trial. Am J Obstet Gynecol 2018; 218: P453.E1-7.
59) Sung JH, Lee DY, Min KP, Park CY. Peripartum management of gestational diabetes using a digital health care service: a pilot, randomized controlled study. Clin Ther. 2019;41:2426–2434. doi: 10.1016/j.clinthera.2019.09.005.
60) Pastora-Bernal JM, Martín-Valero Rocio, Barón-López Francisco Javier, Estebanez-Pérez María José. Evidence of benefit of telerehabitation after orthopedic surgery: a systematic review. J Med Internet Res. 2017 Apr 28;19(4):e142. doi: 10.2196/jmir.6836. https://www.jmir.org/2017/4/e142/
61) Birch S, Stilling M, Mechlenburg I, Hansen TB. Effectiveness of a physiotherapist delivered cognitive-behavioral patient education for patients who undergoes operation for total knee arthroplasty: a protocol of a randomized controlled trial. BMC Musculoskelet Disord. 2017;18(1):116. doi: 10.1186/s12891-017-1476-6.
62) Dahlberg K, Jaensson M, Nilsson U. “Let the patient decide” - Person-centered postoperative follow-up contacts, initiated via a phone app after day surgery: secondary analysis of a randomized controlled trial. Int J Surg Lond Engl. 2019;61:33–37. doi: 10.1016/j.ijsu.2018.11.022.
63) Seto E, Morita P, Tomkun J, Lee Theresa M, Ross Heather, Reid-Haughian Cheryl, Kaboff Andrew, Mulholland Deb, Cafazzo Joseph A. Implementation of a heart failure telemonitoring system in home care nursing: feasibility study. JMIR Med Inform. 2019 Jul 26;7(3):e11722. doi: 10.2196/11722.
64) Vo V, Auroy L, Sarradon-Eck A. Patients' perceptions of mhealth apps: meta-ethnographic review of qualitative studies. JMIR mHealth uHealth. 2019 Jul 10;7(7):e13817. doi: 10.2196/13817.
65) Martinez P. A qualitative study on patient perceptions towards mHealth technology among high risk, chronic disease patients. Harvard Medical School. 2015. [2021-01-14].
66) Robinson G, Merav A. Informed consent: recall by patients tested postoperatively. Ann Thorac Surg. 1976 Sep;22(3):209-12. doi: 10.1016/s0003-4975(10)64904-1. PMID: 962403.
67) Dicianno Brad E, Parmanto Bambang, Fairman Andrea D, Crytzer Theresa M, Yu

Daihua X, Pramana Gede, Coughenour Derek, Petrazzi Alan A. Perspectives on the evolution of mobile (mHealth) technologies and application to rehabilitation. Phys Ther. 2015 Mar;95(3):397–405. doi: 10.2522/ptj.20130534. http://europepmc.org/abstract/MED/24925075.

68) Daemen E, Flinsenberg I, Van LE, Cuppen R, Rajae-Joordens R. The effect of experience on system usability scale ratings. J Usability Stud. 2012;7(Issue 2):56–67. [Google Scholar]
69) 18. Sauro J. A Practical Guide to the System Usability Scale: Background, Benchmarks & Best Practices. Scotts Valley, California: Createspace Independent Publishing Platform; 2011, Apr 20.
70) Kelly L, Ziebland S, Jenkinson C. Measuring the effects of online health information: Scale validation for the e-Health Impact Questionnaire. Patient Educ Couns. 2015 Nov;98(11):1418–24. doi: 10.1016/j.pec.2015.06.008.
71) Zhao Y, Ni Q, Zhou R. What factors influence the mobile health service adoption? a meta-analysis and the moderating role of age. International Journal of Information Management. 2018 Dec;43:342–350. doi: 10.1016/j.ijinfomgt.2017.08.006.
72) Gill P, Stewart K, Treasure E, Chadwick B. Methods of data collection in qualitative research: interviews and focus groups. Br Dent J. 2008 Mar 22;204(6):291–5. doi: 10.1038/bdj.2008.192.
73) Keesara S, Jonas A, Schulman K. Covid-19 and health care's digital revolution. N Engl J Med. 2020 doi: 10.1056/NEJMp2005835.
74) Ke JX, George RB, Wozney L, Chorney JL. Patient-centred perioperative mobile application in cesarean delivery: needs assessment and development. Can J Anesth. 2019;66:1194–1201. doi: 10.1007/s12630-019-01392-x.
75) Mackert M, Mabry-Flynn A, Champlin S, Donovan EE, Pounders K. Health literacy and health information technology adoption: the potential for a new digital divide. J Med Internet Res. 2016 doi: 10.2196/jmir.6349.
76) Hughson JA, Daly JO, Woodward-Kron R, Hajek J, Story D. The rise of pregnancy apps and the implications for culturally and linguistically diverse women: narrative review. JMIR MHealth UHealth. 2018;6:e189. doi: 10.2196/mhealth.9119.
77) Kim H, Zhang Y. Health information seeking of low socioeconomic status Hispanic adults using smartphones. Aslib J Inf Manag. 2015;67:542–561. doi: 10.1108/AJIM-12-2014-0181.
78) Vangeepuram N, Mayer V, Fei K, et al. Smartphone ownership and perspectives on health apps among a vulnerable population in East Harlem. New York. Mhealth. 2018 doi: 10.21037/mhealth.2018.07.02.
79) Niksch AL. mHealth in pediatrics-finding healthcare solutions for the next generation. Mhealth. 2015 Mar 25;1:7. doi: 10.3978/j.issn.2306-9740.2015.03.09. PMID: 28293567; PMCID: PMC5344144.
80) Ciechanowicz S, Setty T, Robson E, et al. Development and evaluation of an obstetric quality-of-recovery score (ObsQoR-11) after elective caesarean delivery. Br J Anaesth. 2019;122:69–78. doi: 10.1016/j.bja.2018.06.011.