# REDUCING PREVENTABLE EMERGENCY DEPARTMENT VISITS AFTER COLORECTAL SURGERY BY IMPROVING PATIENT-PHYSICIAN COMMUNICATION USING MOBILE HEALTH APPLICATIONS

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**ABSTRACT (ENGLISH)**

**Introduction:** Unplanned emergency department visits and readmissions after surgery are common and represent a significant cost burden on the healthcare system. A notable portion of these unplanned visits are the result of expected complications or normal recovery after surgery, suggesting that improved coordination and communication in the outpatient setting could help reduce unplanned healthcare utilization. Telemedicine applications have demonstrated significant benefits in improving patient-physician communication. The objective of this thesis was to assess if telemedicine applications could reduce unplanned emergency department visits and readmissions in postoperative colorectal patients.

**Methods:** First, a systematic review was performed to assess current telemedicine interventions and their effect on emergency department visits and readmissions. Second, a retrospective cohort of all patients undergoing elective major abdominopelvic colorectal surgery from 2017-2019 were reviewed to assess the rate and reasons underlying emergency department visits after surgery. These visits were then graded on a spectrum of preventability to determine an overall rate of potentially preventable healthcare utilization. Lastly, we implemented a mobile phone app with a patient-physician communication feature and assessed its effect on potentially preventable ED visits after surgery in a prospective cohort by comparing it to a retrospective cohort using coarsened-exact matching.

**Results:** 29 studies were included in the systematic review and meta-analysis. There was no overall reduction in 30-day ED visit in the telemedicine group (RR: 0.89, 95%CI: 0.70 – 1.12). There was no overall reduction in 30-day readmissions either (RR: 0.90, 95%CI: 0.74 – 1.09). In the retrospective cohort, 625 patients were included in the final analysis of which 110(17.6%) patients presented to the ED within 30 days. After review, 51.8% of visits were considered potentially preventable. The most common causes of preventable ED visits were superficial wound infection (24.6%), non-infectious gastrointestinal issues (19.3%), and minor bleeding (14.0%). Lastly, our prospective cohort study demonstrated that the use of a mobile app was associated with fewer preventable ED visits (IRR 0.34, p=0.043) and shorter LOS (3.2 vs. 4.6 days, p=0.011) after colorectal surgery.

**Conclusion:** Telemedicine has variable outcomes throughout surgery, suggesting that surgical specialties with a moderate-high return rate and a significant proportion of potentially preventable visits are likely to represent the best targets for telemedicine-based interventions. Colorectal surgery in our center has both features. Finally, use of a mobile app was associated with fewer potentially preventable ED visits and shorter length of stay after major elective colorectal surgery, likely due to enhanced post-discharge monitoring and patient-provider communication.

**RÉSUMÉ (FRENCH ABSTRACT)**

**Introduction:** Les visites non planifiées aux urgences et les réadmissions après une chirurgie sont courantes et représentent un fardeau financier important pour le système de santé. Une partie notable de ces visites non planifiées est le résultat de complications attendues ou d'une récupération normale après la chirurgie, ce qui suggère qu'une coordination et une communication améliorées avec les patients ambulatoires pourraient aider à réduire l'utilisation non planifiée des soins de santé. Les applications de télémédecine ont démontré des avantages significatifs dans l'amélioration de la communication entre patient et médecin. L'objectif de cette thèse était d'évaluer si les applications de télémédecine pouvaient réduire les visites non planifiées aux urgences et les réadmissions chez les patients colorectaux postopératoires.

**Méthode:** Premièrement, une revue systématique a été réalisée pour évaluer les interventions de télémédecine actuelles et leur effet sur les visites aux urgences et les réadmissions. Deuxièmement, une cohorte rétrospective de tous les patients subissant une chirurgie colorectale abdomino-pelvienne majeure élective de 2017 à 2019 a été revue pour évaluer le taux et les raisons sous-tendant les visites aux urgences après la chirurgie. Ces visites ont ensuite été classées selon un spectre d'évitable a non-évitable pour déterminer un taux global d'utilisation des soins de santé potentiellement évitable. Enfin, nous avons mis en œuvre une application de téléphonie mobile avec une fonction de communication patient-médecin et évalué son effet sur les visites aux urgences potentiellement évitables après une intervention chirurgicale dans une cohorte prospective en la comparant à une cohorte rétrospective en utilisant l'appariement grossier-exact.

**Résultats:** 29 études ont été incluses dans la revue systématique et la méta-analyse. Il n'y avait pas de réduction globale du nombre de visites à l'urgence de 30 jours dans le groupe télémédecine (RR: 0,89, IC à 95%: 0,70 - 1,12). Il n'y avait pas non plus de réduction globale des réadmissions à 30 jours (RR: 0,90, IC à 95%: 0,74 - 1,09). Dans la cohorte rétrospective, 625 patients ont été inclus dans l'analyse finale dont 110 (17,6%) patients se sont présentés à l'urgence dans les 30 jours. Après examen, 51,8% des visites ont été jugées potentiellement évitables. Les causes les plus courantes de visites à l'urgence évitables étaient l'infection des plaies superficielles (24,6%), les problèmes gastro-intestinaux non infectieux (19,3%) et les saignements mineurs (14,0%). Enfin, notre étude de cohorte prospective a démontré que l'utilisation d'une application mobile était associée à moins de visites à l'urgence évitables (IRR 0,34, p = 0,043) et à une durée de vie plus courte (3,2 vs 4,6 jours, p = 0,011) après une chirurgie colorectale.

**Conclusion:** La télémédecine a des résultats variables à travers les sous-specialites chirurgicales mais les études suggèrent que les spécialités chirurgicales avec un taux de retour aux urgences modéré-élevé et une proportion significative de visites potentiellement évitables sont susceptibles de représenter les meilleures cibles pour les interventions basées sur la télémédecine. La chirurgie colorectale dans notre centre présente ces deux caractéristiques. Enfin, l'utilisation d'une application mobile était associée à moins de visites à l'urgence potentiellement évitables et à une durée de séjour plus courte après une chirurgie colorectale élective majeure, probablement en raison de l'amélioration du suivi post-congé et de la communication patient et médecin.

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I would also like to thank Dr. Eric Latimer, my co-supervisor, whose insight and advice always proved crucial in taking this thesis the extra mile forward. His expertise in health economics highlighted key discussion points for the viability of the current research, many of which are reflected in the discussion points of several of the chapters. His statistical knowledge helped me identify areas in which our results could be improved, thus strengthening our conclusions throughout. Beyond this, Dr. Latimer's approach to me as as student was wonderfully calm and encouraging, which only furthered my motivation at the times where it was most needed.

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**CONTRIBUTION OF AUTHORS**

Jules Eustache (JE) is the author of this thesis. He is the principal author for all three manuscripts that formulate this thesis. With regards to the included studies, JE was involved in study design and implementation, data collection, statistical analysis and interpretation, and drafting and editing of manuscripts. Dr. Lawrence Lee (LL) contributed to the study designs, statistical analyses, and extensively reviewed the manuscript and thesis elements. Dr. Eric Latimer (EL) contributed to the statistical designs and extensively contributed to the review of the included manuscripts and thesis elements. Contributions of other co-authors on manuscripts are described below.

Manuscript 1

**Eustache J**, El-Kefraoui C, Ekmekjian T, Latimer E, Lee L. Do postoperative telemedicine interventions with a communication feature reduce emergency department visits and readmissions? – A systematic review and meta-analysis.

- Study conception and design: JE, CE, TE, EL, LL
- Data acquisition: JE, CE, TE
- Analysis and interpretation of data: JE, CE, EL, LL
- Drafting of manuscript: JE, CE, TE, EL, LL

Manuscript 2

**Eustache J,** Hopkins B, Trepanier M, Kaneva P, Fiore Jr JF, Fried GM, Feldman LS, Lee L. High incidence of potentially preventable emergency department visits after major elective colorectal surgery.

- Study conception and design: JE, BH, MT, KP, JFF, GMF, LSF, LL
- Data acquisition: JE, BH, MT
- Analysis and interpretation of data: JE, BH, MT, LL
- Drafting of manuscript: JE, BH, MT, KP, JFF, GMF, LSF, LL

Manuscript 3

**Eustache J,** Renaud J, Hopkins B, Trepanier M, Kaneva P, Liberman S, Charlebois P, Stein B, Fiore Jr JF, Feldman LS, Latimer E, Lee L. A mobile app improves patient-physician communication and reduces emergency department visits after colorectal surgery.

- Study conception and design: All authors

- Data acquisition: JE, BH, MT, JR, PK
- Analysis and interpretation of data: JE, BH, MT, EL, LL
- Drafting of manuscript: All authors

## CHAPTER 1 – Introduction and Literature Review

### 1.1 Introduction

Inefficient use of emergency department (ED) resources is a major contributor to growing healthcare expenditures, with an estimated $38 billion in annual wasteful expenditures within the US healthcare system(1). Unplanned ED visits after colorectal surgery are common and contribute to this burden, with nearly 1 in 5 patients presenting within 30 days of surgery(2).

The few studies that have assessed the indications for ED visits and readmissions in this patient population show that while a portion of these visits are for reasons requiring inpatient care, most visits do not require readmission(2, 3). Indeed, over half of visits are often either an issue related to an expected, but non-urgent complication from the surgery, or because of a finding that is part of the normal postoperative recovery process(3, 4). Wood *et al.* highlighted this finding in a prospective study assessing colorectal surgery patients across 15 academic hospitals, which found that 11.6% of patients visited the ED without requiring subsequent readmission (19.8% of total patients presented to the hospital overall)(3). Surgical site infections (SSI) accounted for just over a third of reasons for consultation, with other wound issues and urinary tract infections (UTI) together accounting for another 20% of cases(4).

Across surgical specialties, SSIs represent a primary driver behind unplanned postoperative healthcare utilization, accounting for approximately 20% of postoperative readmissions and a massive 1.6 billion in annual healthcare costs in North America(5). This finding is extremely concerning as most SSIs can easily be managed in an outpatient setting when identified in a timely manner. Similarly, non-infectious wound concerns and UTIs are both conditions that are routinely managed in an outpatient setting.

If these conditions can be managed as an outpatient, why is it that patients present to the ED for them? The answer lies in a lack of access to specialized care for postoperative patients. Indeed, in a survey of colorectal surgery patients, Jones *et al.* found that patients were routinely advised to present to the emergency department for assessment in the event of a postoperative issue(6). This represents an inefficient and costly use of ED resources, one that could easily be minimized if patients were able to access quality outpatient postoperative care.

Healthcare is in the middle of a technological boom, with mobile health (mHealth) apps flooding the market. In North America, over 80% of adults own a smartphone with app capability, and 58% of these

have downloaded at least one mHealth app(7, 8), a statistic that is expected to grow exponentially with younger generations. mHealth apps have demonstrated benefits in self-management of chronic conditions such as diabetes, chronic lung disease, and cardiovascular disease(9). Even more exciting is mHealth's capacity to improve communication. Indeed, mHealth has already proven an innovative way to enhance patient-physician communication, one that had success in improving outcomes in the management of several medical conditions(10). Further catalyzed by the current COVID-19 pandemic, the use of remote medical platforms to connect with patients is seeing explosive growth with market analysts predicting that the telehealth market will hit $560 billion by 2027(11).

Despite this, adoption of mHealth interventions in surgical patient populations remains limited, in part due limited publications in the field. Indeed, results of studies assessing the benefits of telemedicine interventions on unplanned healthcare utilization in postoperative patients show significant heterogeneity in observed effects(12-15). In an era of evidence-based medicine, the lack of supporting studies regarding mHealth in surgical patients is likely a driving factor behind the delay in adoption of such tools. Considering this, our group sought to contribute to the growing body of evidence in the context of surgical patients by first surveying the available literature for novel interventions in postoperative patients, followed by a formal assessment of our colorectal surgery patient's postoperative needs, and finally implementing our own novel mHealth tool to improve our postoperative outcomes.

## 1.2 Thesis Objectives

**1.2.1** To systematically review the literature regarding mHealth applications on postoperative healthcare utilization in order to identify and define knowledge gaps in the field.

**1.2.2** To estimate the incidence of emergency department visits after colorectal surgery and categorize them as preventable/nonpreventable, to establish the incidence of visits that could benefit from intervention that aim to reduce healthcare utilization.

**1.2.3** To assess the effect of a novel mHealth app that enhances patient-physician communication on preventable emergency department visits in the postoperative period.

## 1.3 Preamble to Manuscript 1

Implementation of telehealth interventions in postoperative patients remains limited. Furthermore, a consensus on whether such interventions influence unplanned postoperative healthcare utilization is yet to be reached, likely the product of small study sizes and significant heterogeneity in effects across surgical specialties. To identify existing interventions and their effects we performed a formal systematic review of available literature with the intent to assess if a variety of telehealth interventions (mHealth, email, telephone, videoconferencing, etc.) could reduce ED visits and readmissions following surgery. The results of the review and meta-analysis are presented in Manuscript 1 below. This manuscript was accepted for publication into Surgical Endoscopy.

## 1.4 MANUSCRIPT 1: Do postoperative telemedicine interventions with a communication feature reduce emergency department visits and readmissions? – A systematic review and meta-analysis.

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### 1.4.1 ABSTRACT

**Introduction:** Unplanned emergency department visits and readmissions after surgery are common and represent a significant cost-burden on the healthcare system. A notable portion of these unplanned visits are the result of expected complications or normal recovery after surgery, suggesting that improved coordination and communication in the outpatient setting could help reduce unplanned healthcare utilization. Telemedicine applications have demonstrated significant benefits in improving patient-physician communication and as such may have a role in limiting unplanned emergency department visits and readmissions in postoperative patients.

**Methods:** Major electronic databases (MEDLINE, CENTRAL, CINAHL, Embase, and Scopus) were searched for randomized controlled trials and cohort studies in surgical patients examining the effect of postoperative telemedicine interventions with a communication feature on 30-day readmissions and emergency department visits as compared to current standard postoperative follow-up. The search was limited to English publications. The search was re-run prior to manuscript submission to include relevant recent literature. All surgical subspecialties will be included. A set of two independent reviewers assessed eligibility, extracted data, and evaluated risk of bias using standardized tools (Rob 2.0, ROBINS-I). Our primary outcomes of interest were 30-day ED visits and readmissions. Our secondary outcomes were patient satisfaction with the intervention.

**Results:** 29 studies were included in the final analysis. Fourteen studies were RCTs, and the remaining fifteen were cohort studies. Eighteen studies reported 30-day ED visit as an outcome. There was no overall reduction in 30-day ED visit in the telemedicine group (RR: 0.89, 95%CI: 0.70 – 1.12). Twenty-two studies reported 30-day readmission as an outcome. The overall pooled estimate did not show a difference in this outcome (RR: 0.90, 95%CI: 0.74 – 1.09). Fifteen studies reported a metric of patient satisfaction regarding utilization of the telemedicine intervention. All studies demonstrated high levels of satisfaction (>80%) with the telemedicine intervention.

**Discussion:** This review fails to demonstrate a clear reduction ED visits and readmissions to support use of a telemedicine intervention across the board. This may be in part explained by significant heterogeneity in the proportions of potentially preventable visits in each surgical specialty. As such, targeting interventions to specific surgical settings may prove most useful. Furthermore, patients appear to be generally satisfied with such interventions.

### 1.4.2 INTRODUCTION:

Unplanned emergency department visits and readmissions after surgery are common and represent a significant cost-burden on the healthcare system (16, 17). A notable portion of these unplanned visits are the result of expected complications or normal recovery after surgery, suggesting that improved coordination and communication in the outpatient setting could help reduce unplanned healthcare utilization (16). Additionally, common reasons for presentation, such as surgical site infections, may not require emergency department resources and can potentially be managed on an outpatient basis if identified in a timely and reliable fashion (16). In many of these cases, accessibility to specialized outpatient post-surgical care appears to be a limiting factor.

Mobile phone usage and smartphone technology has spread rapidly worldwide, with an estimated 5 billion people owning a mobile device. Telemedicine applications have demonstrated significant benefits in various aspects of perioperative care, such as promoting treatment adherence or remote monitoring for early identification of complications (18). Several studies also suggest that telemedicine may have a role in limiting unplanned emergency department visits and readmissions (18); this finding is in part explained by the improvement in patient-surgeon communication through mobile application-based telemedicine, which may improve access to care and patient-provider communication.

There are several studies that have investigated the effect of telemedicine interventions on outpatient resource utilization, including emergency department visits and readmissions(12, 13, 15, 19-39). However, the data are equivocal. The available literature does not report a consistent benefit for telemedicine interventions in reducing emergency room visits and readmissions. There may be heterogeneity in the telemedicine interventions as well as the target patient population (21, 40-42). Therefore, we sought to perform a systematic review and meta-analysis to determine the effect of postoperative telemedical interventions with a communication feature on 30-day emergency room visits and readmissions in patient undergoing surgery.

### 1.4.3 METHODS:

**Data Sources and Searches:**

The following six databases were searched for relevant studies on February 17 2020: MEDLINE (via Ovid 1946 to February 14, 2020; via PubMed, 2020/2/1 to 2020/2/17); The Cochrane CENTRAL Register of Controlled Trials & Cochrane Database of Systematic Reviews (via Wiley, from Inception to Issue 2 of 12,

February 2020); CINAHL (from inception to 2020 February 17); Embase (via Ovid 1947 to 2020 February 14), and Scopus (via Elsevier).

The search strategies designed by a librarian used text words and relevant indexing to identify studies on telemedical interventions and their effect on readmissions and postoperative visits to the emergency department and readmissions.

The MEDLINE strategy (Appendix 1) was applied to all databases, with modifications to search terms as necessary. No language limits were applied. Search strategies were peer-reviewed by a second librarian. In addition to the bibliographic databases, clinical trials registries (ClinicalTrials.gov; International Clinical Trials Registry Platform ICTRP) were searches for unpublished studies.

Further studies were identified in Web of Science and Scopus (July 22, 2020) by carrying out citation searches for the reference lists of included studies. The Medline strategy was rerun prior to submission (October 8, 2020).

**Eligibility Criteria:**

Studies had to be published in English. Studies were included if they were a comparative study, including randomized controlled trials, cohort studies (prospective and retrospective), and case-control studies. All surgery domains were included, however surgeries had to be performed in a hospital setting thus excluding minor procedure clinics. The main study intervention had to include a communication feature between patient and care team via a telemedicine platform, including telephone calls, video calls, email follow-up, and app/web-based follow-ups. The interventions also had to be targeted towards the immediate (ie. <30 days from surgery) postoperative period. Studies needed to compare a telemedicine intervention to a comparison group managed by traditional postoperative care. Furthermore, only studies that reported 30-day emergency department visits or readmissions were included.

**Study selection:**

Using a standardized case-report form, 2 independent reviewers screened titles, abstracts, and full-text articles for eligible studies. Disagreements were resolved by consensus or by means of a tiebreaker with a third independent reviewer when necessary. We made use of two online systematic review software to facilitate the screening process, namely Rayyan for the abstract screening and Covidence for the full text screening.

**Data Extraction:**

Two reviewers independently performed data extraction for each selected article. Included data points were study design, country of publication, source of funding, type of surgery, and surgical setting (ambulatory vs. inpatient). With regards to intervention details, data points included the type of intervention (telephone, app, web-based, email), who from the care team was on the receiving end of the communication feature (nurse, physician, assistant, resident), whether or not the intervention was patient-initiated or required prompting, and the number of patients recruited to each comparative arm of the study.

The primary outcomes were 30-day emergency department visits and hospital readmissions. The secondary outcome was patient satisfaction and/or patient experience with the telemedicine intervention as reported by each individual study.

**Risk of Bias Assessment:**

Risk of bias assessment was performed by two independent reviewers using validated tools. Disagreements were resolved by consensus. For randomized controlled trials (RCTs), risk of bias was performed using the Cochrane Risk-of-Bias 2.0 (RoB 2.0) tool (43). For non-randomized studies, risk of bias was performed using the Risk Of Bias in Non-randomized Studies – of Interventions (ROBINS-I) tool (44). Use of the ROBINS-I tool requires a pre-emptive definition of potential confounder identified by the study authors. After discussion and literature review, we determined that level of education, age of patients, socioeconomic status, and user satisfaction with the intervention were important domains of potential confounding that could affect the results of telemedicine interventions on postoperative ED visits and readmissions.

**Data Synthesis and Analysis:**

Risk Ratio estimates for unplanned emergency department visits or readmissions comparing patients with telemedicine follow-up and those with standard of care were calculated by pooling study-specific estimates using a random-effects model (Dersimonian and Laird method). Heterogeneity was tested by means of the $I^2$ statistic. Analysis was carried out by study type, separating RCTs from non-randomized studies due to concerns regarding bias. Subgroup analysis was further carried out by study quality and by surgical subspecialty. Due to heterogeneity in the reporting of satisfaction, a qualitative summary was reported.

### 1.4.4 RESULTS:

**Search Results**

The initial database and grey literature search identified 3759 citations, from which 1887 duplicates were removed. A total of 1872 records were excluded following title and abstract screening. 78 articles underwent full-text review to assess eligibility, of which 54 records were excluded in reasons highlighted in Figure 1. Five (5) additional studies were included following screening of reference and citations lists as well as an update of the original Medline search. A total of 29 studies were included in the narrative review (Table 1).

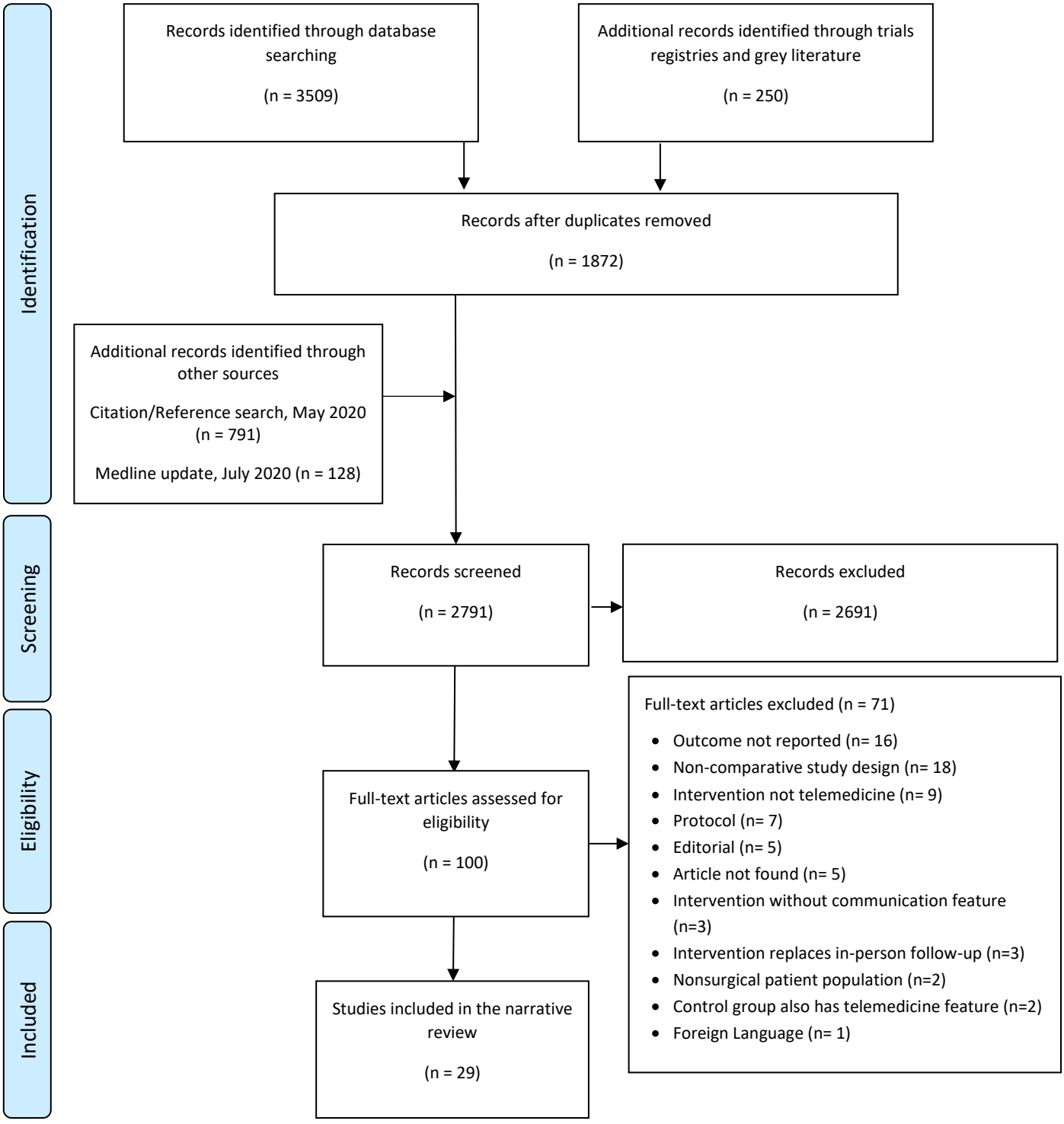


**Figure 1. PRISMA flow diagram of search and selection strategy.**

**Study Characteristics:**

Fourteen studies were RCTs(14, 15, 19, 20, 22-25, 30, 32, 35, 37, 38, 45), and the remaining fifteen were cohort studies(12, 13, 21, 26-29, 31, 33, 34, 36, 39, 46-48). Publication dates ranged from 2004 to 2020. Fifteen studies were from the United States(13, 14, 20, 26, 28, 29, 31-34, 36, 39, 46-48), and 7 from Canada(19, 21, 25, 27, 30, 35, 37). Other countries that were represented in the included studies included Italy, Norway, Australia, Denmark, and Spain (12, 22-24, 38, 45).

Twenty-five of the studies included patients operated in an inpatient setting(12-15, 20, 22-26, 28-35, 37-39, 45-48), three studies were on ambulatory surgeries(19, 21, 36), and one study included a mixed cohort of inpatient and ambulatory surgeries(27). Abdominal and pelvic surgery was the most represented field, accounting for nine studies(13, 20, 24, 28, 29, 33, 38, 39, 48). Cardiac surgery accounted for 6 studies(23, 30, 31, 35, 37, 47). The remaining surgical specialties represented were urology, vascular surgery, breast surgery, orthopedics, otorhinolaryngology, and one study which included an assortment of surgical specialties(12, 14, 15, 19, 21, 22, 25-27, 32, 34, 36, 45, 46).

**Characteristics of Interventions:**

Interventions included were healthcare professional initiated telephone follow-ups (n = 16)(14, 22-26, 28, 29, 35-38, 45-48), follow-up using a cellphone application (n = 6)(13, 15, 19, 27, 31, 32), video-conference follow-up (n = 4)(12, 20, 30, 33), email follow-up (n=2)(21, 39), and text-message follow-up (n =1)(34).

Twenty-five studies(12, 13, 19, 20, 22, 24-33, 35-39) involved an intervention that prompted the patient to engage with the healthcare team, three studies(15, 21, 34) involved interventions that required the patient to initiate contact, and one study had a mixed approach where scheduled telephone calls were executed by the healthcare team but the patients also had access to a 24/7 hotline to access specialized care(23).

On the healthcare end of the communication platform, nursing staff were the most represented with 15 studies having nurse and nursing specialists be the primary point of contact for patients(14, 21-25, 29, 30, 32, 35-38, 45-47). Four studies(19, 27, 33, 34) had surgeons as the primary point of contact, three studies had physician assistants(20, 26, 48), and the remaining six studies had a multidisciplinary team often comprised of members from the nursing staff, surgeons, residents, or physician assistants(12, 13, 15, 28, 31, 39, 46).

**Methodologic Quality of Studies:**

Amongst RCTs, five studies(19, 24, 32, 38, 45) were deemed to have a low risk of bias, seven studies(20, 22, 23, 25, 30, 35, 37) had some concerns for bias, and two studies had a high risk of bias(14, 15). In the non-randomized studies, three studies(12, 28, 36) were deemed to have a moderate risk of bias, ten studies(13, 21, 27, 29, 31, 33, 34, 39, 46, 47) had a serious risk of bias, and two studies(26, 48) had a critical risk of bias. There were no studies deemed to be at low risk of bias.

**Main Outcomes**

Eighteen studies(13-15, 19-21, 27, 30, 33, 35-39, 45-48) reported 30-day ED visit as an outcome (Figure 2). There was no overall reduction in 30-day ED visit in the telemedicine group (RR: 0.89, 95%CI: 0.70 – 1.12). Nine RCTs(14, 15, 19, 20, 30, 35, 37, 38, 45) reported 30-day ED visit as an outcome (Figure 3), with no individual study reporting a statistically significant difference between the intervention and control groups. The pooled estimate (RR: 1.00, 95%CI 0.79 – 1.26) also reported no difference. Subgroup analysis by study quality showed similar results. Heterogeneity amongst RCTs was low. Nine non-randomized studies(13, 21, 27, 33, 36, 39, 46-48) reported 30-day ED visit as an outcome (Figure 4), with one study demonstrating a statistically significant difference (46). The overall pooled (RR: 0.73, 95%CI: 0.48 – 1.10) estimate did not show a difference in 30-day ED visits between the telemedicine and control groups.

Twenty-two studies(12-14, 20, 22, 23, 26-30, 32, 33, 35-39, 45-48) reported 30-day readmission as an outcome (Figure 5). The overall pooled estimate did not show a difference in this outcome (RR: 0.90, 95%CI: 0.74 – 1.09). Ten RCTs(14, 20, 22, 23, 30, 32, 35, 37, 38, 45) reported 30-day readmission as an outcome (Figure 6), with no individual study showing a statistically significant difference. There was no overall reduction in readmissions in the telemedicine group amongst RCTs (RR: 1.08, 95%CI: 0.84 – 1.38). Subgroup analysis by study quality showed similar results. Heterogeneity amongst RCTs for 30-day readmissions was low. Twelve non-randomized studies(12, 13, 26-29, 33, 36, 39, 46-48) reported 30-day readmissions as an outcome (Figure 7). One study reported fewer readmissions in the telemedicine group (28). The pooled estimate for non-randomized studies reported a small reduction in 30-day readmissions in the telemedicine group (RR: 0.73, 95%CI: 0.55 – 0.99), which was statistically significant.

**Subgroup analysis – Surgical Subspecialty (Appendix 1 & 2)**

Six studies(13, 20, 33, 38, 39, 48) in the abdominal/pelvic surgery category reported 30-day ED visits, for an overall risk ratio of 0.99 (95%CI: 0.73 – 1.35). In breast surgery, two studies(19, 27) reported this outcome with an overall risk ratio of 0.19 (95%CI: 0.03 – 1.03). In cardiac surgery, four studies(30, 35, 37, 47) reported it with an overall risk ratio of 1.09 (95%CI: 0.84 – 1.42). In urological surgery, three studies(14, 21, 36) reported it with an overall risk ratio of 0.47 (95%CI: 0.25 – 0.89), which was statistically significant.

Eight studies(13, 20, 28, 29, 33, 38, 39, 48) in the abdominal/pelvic surgery category reported 30-day readmissions, for an overall risk ratio of 0.79 (95%CI: 0.56 – 1.10). In cardiac surgery, five studies(23, 30, 35, 37, 47) reported this outcome with an overall risk ratio of 1.15 (95%CI: 0.84 – 1.58). In vascular surgery, three studies(12, 26, 32) reported it for an overall risk ratio of 0.97 (95%CI:0.30 – 3.19). In orthopedic surgery, two studies(22, 45) reported it for an overall risk ratio of 1.00 (95%CI: 0.19 – 5.37). In urologic surgery, two studies(14, 36) reported it for an overall risk ratio of 1.09 (95%CI: 0.18 – 6.71). The remaining surgical specialties either did not report or only one study reported the outcome.

**Secondary Outcomes**

Fifteen studies reported a metric of patient satisfaction regarding utilization of the telemedicine intervention (Table S1)(12, 14, 19, 20, 25, 27-29, 31-33, 35, 37-39). Most studies only assessed satisfaction directly related to the intervention without assessing satisfaction in the control group. All studies demonstrated high levels of satisfaction (>80%) with the telemedicine intervention(12, 14, 19, 20, 25, 27-29, 31-33, 35, 37-39). Common themes in the patient experiences and comments highlighted improvements in patient insecurity about their recovery, satisfaction with ease of access to the care team, patient expectations of the recovery process, and in patient confidence with the quality of care received in the outpatient recovery period (12, 25, 31, 37, 39). In the study by Nikolian *et al.*, 85% of patients reported preferring remote follow-up as their preferred method of follow-up over in-person visits(33). Similarly, Hwang *et al.* found that 95% of users in the intervention group thought telemedicine was “better for patient care” in comparison to in-person follow-up(27). Two studies assessed convenience reporting very high convenience scores (95%, 97% respectively) with the telemedicine application(19, 27). Overall, satisfaction assessment with interventions was overwhelmingly positive from the patient perspective (12, 19, 20, 25, 27-29, 31-33, 35, 37-39).

**1.4.5 DISCUSSION :**

This systematic review is a summary of 29 studies assessing the effectiveness of telemedicine interventions that enhance patient-healthcare team communication on reducing unplanned 30-day ED visits and readmissions after surgery. The pooled estimates did not demonstrate an overall reduction in either of these outcomes in favour of the telemedicine intervention, although there was significant heterogeneity in the types of interventions and the study populations. Only the subgroup anaylsis of non-randomized studies showed a small but statistically significant reduction in 30-day readmissions, although this result should be interpreted with caution given the inherent risk fo bias. However, there was a high satisfaction with the telemedicine intervention in all studies that reported this outcome. These results may be in part explained by the incidence of and the reasons for which patients present to the emergency department in each surgical subspecialty. In the present study, only studies that investigated telemedicine interventions after breast and urologic procedures showed a decrease in 30-day ED visits, whereas studies in abdominopelvic, cardiac, and vascular surgery did not show any differences. These subspecialties may have different reasons for ED visits and readmissions that may not be able to be managed by telemedicine. For example, a meta-analysis of hospital readmissions after aortic valve replacement found that 17% of patients return for an unplanned visit, but a high proportion (81%) of readmissions were for reasons that they considered non-preventable(23). It may be that having such a high proportion of unpreventable visits that cannot be managed remotely is likely to dilute the effect of telemedicine interventions on reducing potentially preventable visits. Similar findings are present in the fields of vascular surgery, where a large Medicare-based study found that most ED visits and readmissions were for heart failure, pneumonia, and surgical complications (40).

Conversely, in colorectal surgery, a significant portion of unplanned healthcare visits in the postoperative period are likely to be for potentially preventable. Indeed, Iqbal *et al.* studied the effect of their telehealth intervention of new ileostomy patients, who are often at risk for dehydration, a largely preventable indication for ED visit and readmissions(28). In their study, patients received a daily phone call for the first 21 days following ileostomy creation to assess output and provide advice accordingly. Their study showed a dramatic reduction in ED visits following implementation of their telemedicine intervention (65% pre-intervention vs. 16% post-intervention). Similarly, patients undergoing breast surgery most often consult in the postoperative period for wound-related problems, which can often be managed on an outpatient basis (49). In this patient population, the effects of telemedicine interventions seems to be promising,

with both Hwang *et al.* and Rao *et al.* showing significant reductions in ED visits (27, 34). These studies suggest that telemedicine interventions may be most effective in surgical populationss that have a high proportion of potentially preventable visits.

Second, the overall rate of ED visits and readmission in each surgical subspecialty may play a role. There are significant variations in the rates of ED visits and readmissions by surgical specialty, ranging anywhere between 3 and 30% (16, 17). Among specialties with low baseline rates, telehealth interventions have not been shown to decrease unplanned ED visits and readmissions, likely due to power limitations. Hodgins *et al.* and Szots *et al.* assessed their telemedicine intervention in patients undergoing elective knee and hip arthroplasty, which has a baseline readmission rate of 4-6% (25, 42). Clari *et al.* studied a similar orthopedic surgery population and neither study demonstrated significant reduction in their ED visits or readmissions with the intervention(22). In fact, the readmission rates were 1.4% and 2.8% for Clari *et al.* and Szots *et al.* respectively, indicating that these studies showed a lower overall readmission rate than what is expected in the speciality(22, 45).

Furthermore, the significant heterogeneity in the characteristics of interventions delivered may play a role in their efficacy. For example, several studies had pre-set telephone calls on certain post-operative days. While these calls did enhance communication with patients, any issue or concern that arose in the time between or after planned phone calls would leave the patient unable to access feedback from a specialized healthcare professional. It could reasonably be suggested that having an open-line of communication allowing patients to communicate all concerns may be more effective. Second, several studies provided patients in the control group with contact information to reach the specialized clinic. This open channel of communication in the control group is likely to undermine the true effect of the telemedicine interventions being assessed, and may explain why these studies were unable to demonstrate an effect.

While this review fails to demonstrate a clear reduction ED visits and readmissions to support use of a telemedicine intervention, patient satisfaction with the interventions may be sufficient to support their use. Indeed, satisfaction in all studies that reported it was overwhelmingly positive. Comments received from patients in individual studies highlighted that having open line of communication made patients feel more secure in their recovery period, as it allowed patients to express concerns and ask questions to a care team that could provide individualized and specialty-specific outpatient care. There may be other

metrics by which to assess the effectiveness of these interventions beyond 30-day ED visits and readmissions. Both Nikolian *et al.* and Armstrong *et al.* highlight that patient convenience is improved with telemedicine interventions, a finding that is in part attributed to time saved by avoiding an in-person visit(19, 33). Together, these findings suggest that such interventions may be useful as quality improvement measures to enhance surgical patient experience.

***Limitations***

Our systematic review has several limitations. First, the wide range of surgical specialties included will inherently induce significant heterogeneity in the baseline populations of each study. As a result, we were unable to make strong conclusions as to the benefit of telemedicine applications on unplanned hospital visits given that each specialty has differing complications risks and as a result may differentially benefit from such an intervention. Second, the large majority of included non-randomized studies were deemed to be at serious or critical risk of bias, thus any interpretation of pooled estimates should be done with caution. Lastly, there was significant heterogeneity in the interventions being delivered whether it be modality (email, app, phone call), patient vs. HCP-initiated, or which member of the healthcare team was on the receiving end. In addition, the studies included come from a breadth of locations across the globe, each with a different healthcare system. Certain countries may have access to more resources for surgical patients which could skew the effects of telemedicine interventions overall. Health economic outcomes were also poorly reported, and it is unclear what resources are required for each of the telehealth interventions.

***Conclusion***

This review fails to demonstrate a clear reduction ED visits and readmissions to support use of a telemedicine intervention across the board. This may be in part explained by significant heterogeneity in the proportions of potentially preventable visits in each surgical specialty. As such, targeting interventions to specific surgical settings that have a greater frequency of potentially preventable ED visits may prove most useful. Furthermore, patient appear to be generally satisfied with such interventions.

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**FIGURES**

## Table 1. Details of studies included in review and meta-analysis.

| Study | Country | Design | Specialty | Surgical Setting | Description of intervention | Sample Size(exp/ control) | Quality |
|---|---|---|---|---|---|---|---|
| Armstrong 2017 | Canada | Randomized controlled trial | Breast | Ambulatory | App-based intervention with regular questionnaires assessing pain and recovery. Patients also had email access to care team to address questions. | 32/33 | Low |
| Bednarski 2019 | United States | Randomized controlled trial | Abdominal/ Pelvic | Inpatient | Videoconference scheduled for POD2, one day after patient discharge. Patients could also send instant messages to care team in case of questions or concerns. | 14/16 | Some concerns |
| Clari 2015 | Italy | Randomized controlled trial | Orthopedic | Inpatient | Telephone call by specialized orthopedic nurse made 24-96 hours after discharge. A standard script was used to assess recovery, but patients could also express concerns and ask questions specific to their recovery. | 110/109 | Some concerns |
| Danielsen 2020 | Norway | Randomized controlled trial | Cardiac | Inpatient | Telephone call on day 2 and 9 following hospital discharge. Patients also had access to a 24/7 support hotline staffed by nurse practitioners to answer all questions related to their recovery. | 141/141 | Some concerns |
| Harrison 2011 | Australia | Randomized controlled trial | Abdominal/ Pelvic | Inpatient | Telephone call made at day 3 and 10 after discharge. Each call was scripted to assess recovery and to address common problems. Patients had the opportunity to raise specific concerns regarding their recovery. The intervention was delivered by a specialized nurse. | 38/36 | Low |
| Hodgins 2008 | Canada | Randomized controlled trial | Orthopedic | Inpatient | Telephone call from a specialized orthopedic nurse to patients within 24-72 hours following discharge. The purpose of the call was to assess recovery and provide follow-up care if needed. | 216/222 | Some concerns |
| Inman 2011 | United States | Randomized controlled trial | Urologic | Inpatient | Telephone follow-up 3-5 days following discharge from a specialized urology nurse. The nurse followed an algorithm of education reinforcement. Patient concerns were elicited and addressed. | 30/30 | High |

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|---|---|---|---|---|---|---|---|
| Keeping-Burke 2013 | Canada | Randomized controlled trial | Cardiac | Inpatient | Patients received a videoconference follow-up every day in the week following discharge. Vital signs were monitored with help of a caregiver who was trained in using a blood pressure cuff and other monitors. The sessions addressed recovery and concerns expressed by the patient. It also addressed healing of surgical wounds via video. | 91/91 | Some concerns |
| Mousa 2019 | United States | Randomized controlled trial | Vascular | Inpatient | App-based follow-up delivered by means of a tablet. Patients also received a set of medical devices for home monitoring of weight, blood pressure, temperature, and oxygen saturation. Patients could engage with the care team by phone or through a messaging feature in the app. Patients could initiate contact at any time. | 16/14 | Low |
| Nodal 2010 | Spain | Randomized controlled trial | Mixed | Inpatient | App-based follow up. Patients received a mobile phone with which they could send photos of their wounds to the care team. Patients also had a pulse-oximeter to report oxygen saturation. Care team could contact the patient if concerned. Patients could call the hospital at any time if concerned. | 156/154 | High |
| Sawatzky 2013 | Canada | Randomized controlled trial | Cardiac | Inpatient | Telephone call from nurse practitioner made 2-3 days following discharge. A standard script was used to assess recovery, but the patient could also discuss other concerns and questions. Extra calls could be made if determined to be necessary. Patients did not have a direct line to the care team. | 95/105 | Some concerns |
| Szots 2016 | Denmark | Randomized controlled trial | Orthopedic | Inpatient | Patients received a telephone call from a specialized orthopedic nurse on day 4 and 14 following discharge. Patient recovery was assessed with a standard questionnaire. Patients were able to express concerns and receive medical advice. | 54/54 | Low |
| Tranmer 2004 | Canada | Randomized controlled trial | Cardiac | Inpatient | Telephone call by specialized cardiac nurse at 3 and 5 days following discharge, then weekly for 4 more weeks. Sessions were individually tailored to each patient. | 102/98 | Some concerns |
| Young 2013 | Australia | Randomized controlled trial | Abdominal/ Pelvic | Inpatient | Telephone call made at day 3 and 10 after discharge. Each call was scripted to assess recovery and to address common problems. Patients had the opportunity to raise specific concerns regarding their recovery. The intervention was delivered by a specialized nurse. | 398/377 | Low |

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|---|---|---|---|---|---|---|---|
| Borsuk 2019 | United States | Cohort study | Abdominal/ Pelvic | Inpatient | App-based intervention with text-messaging feature allowing patient-care team interaction. | 123/113 | Serious |
| Chua 2017 | Canada | Cohort study | Urologic | Ambulatory | Email based intervention where patients were instructed to take photos on postoperative day 1-7, 10, 14, 21, 28, 35, and 42 and email them to a specialized urology nurse. Advice was given to patients via email based on submitted images. Patients could also email with concerns at any time. | 81/15 | Serious |
| Hornick 2016 | United States | Cohort study | Vascular | Inpatient | Telephone call made by a single medical assistant was made within 1 week of hospital discharge. At least two attempts were made but no more than five to reach the patient. Patients could express their concerns, and this was discussed with attending surgeon who would advise patient as to the course to follow. | 131/36 | Critical |
| Hwang 2016 | Canada | Cohort study | Breast | Mixed | App-based platform where patients were asked to take a photo of their wounds postoperatively on days 1, 3, 7, and 14. The patients could also discuss their recovery with the surgeon via a messaging feature. Patients were encouraged to ask questions or express concerns. The surgeon answered within 24 hours. | 35/37 | Serious |
| Iqbal 2017 | United States | Cohort study | Abdominal/ Pelvic | Inpatient | Telephone call carried out by specialized nurse practitioner every day for the first 21 days of the postoperative period. Patients were able to freely discuss stoma management and related issues with the nurse. | 32/23 | Moderate |
| Jalilvand 2016 | United States | Cohort study | Abdominal/ Pelvic | Inpatient | Telephone call on day 1, 3, and 7 following discharge. Phone calls addressed patient issues and provided advice as necessary. Patients also had access to direct lines to care team, which they could contact at their discretion. | 261/264 | Serious |
| Lovasik 2020 | United States | Cohort study | Abdominal/ Pelvic | Inpatient | Patients received a phone call from the care team's advance practice provider (APP) on post-discharge day 2 or 3. The phone call included assessing clinical status and concerning symptoms. A second follow-up call was made in case the patient was deemed to be high risk. | 186/311 | Critical |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| McElroy 2016 | United States | Cohort study | Cardiac | Inpatient | App-based follow-up where patients received a tablet and a Bluetooth enabled pulse oximeter, heart rate monitor, blood pressure cuff, and weight scale. Patients completed daily questionnaires. Patients were contacted in case of abnormal biometrics or responses with a scheduled teleconference visit. | 27/416 | Serious |
| Nikolian 2018 | United States | Cohort study | Abdominal/ Pelvic | Inpatient | Videoconference follow up delivered by surgical residents supervised by attending surgeon. Patients were scheduled for an eClinic visit on Tuesday/Wednesdays following their discharge. Patients could express and discuss their concerns and if needed, were scheduled for another eClinic appointment later. | 233/485 | Serious |
| Rao 2012 | United States | Cohort study | Breast | Inpatient | Patients had access to a short messaging system directly with treating surgeon. Patients texted drain outputs each morning and received instructions from surgeon. | 51/51 | Serious |
| Robaldo 2010 | Italy | Cohort study | Vascular | Inpatient | Web-based videoconference follow up. They received vital sign monitoring devices and a videophone. The surgical wound, blood pressure, heart rate, and psychological state of the patients were assessed evert 4h for the first 48 hours after discharge. This was assessed by means of a videoconference call. The patients also had access to the surgeon's contact information whenever necessary, day or night. | 67/498 | Moderate |
| Shah 2020 | United States | Cohort study | Otorhinolary ngology | Inpatient | Patients were contacted by the lead surgeon or nurse practitioner within 72h of discharge from the hospital. Patient recovery was assessed, and concerns were addressed. In select cases, patient could have a supplemental videoconference to have their wound assessed. | 91/78 | Serious |
| Shaughnessy 2020 | United States | Cohort study | Cardiac | Inpatient | Patient assigned to the remote patient monitoring (RPM) program were assigned a nurse navigator and supplied with a kit consisting of Bluetooth-enabled pressure cuff, heart rate monitor, pulse oximeter, and scale. Patient data was transmitted wirelessly to the navigator. Patients were contacted weekly to discuss their recovery. Patients who failed to transmit data for | 32/51 | Serious |

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|---|---|---|---|---|---|---|---|
| | | | | | 48 hours were contacted. Abnormal biometrics resulted in contacting the patient. | | |
| Tackitt 2016 | United States | Cohort study | Urologic | Ambulatory | Telephone call from a specialized nurse to the patient within 24 to 48 hours following discharge. If unable to reach patient, 3 attempts were made. | 27/54 | Moderate |
| Zand 2019 | United States | Cohort study | Abdominal/ Pelvic | Inpatient | Email-based program where patients filled out email questionnaires and uploaded pictures of their wounds. Patients could ask questions which were answered by the care team. | 64/64 | Serious |

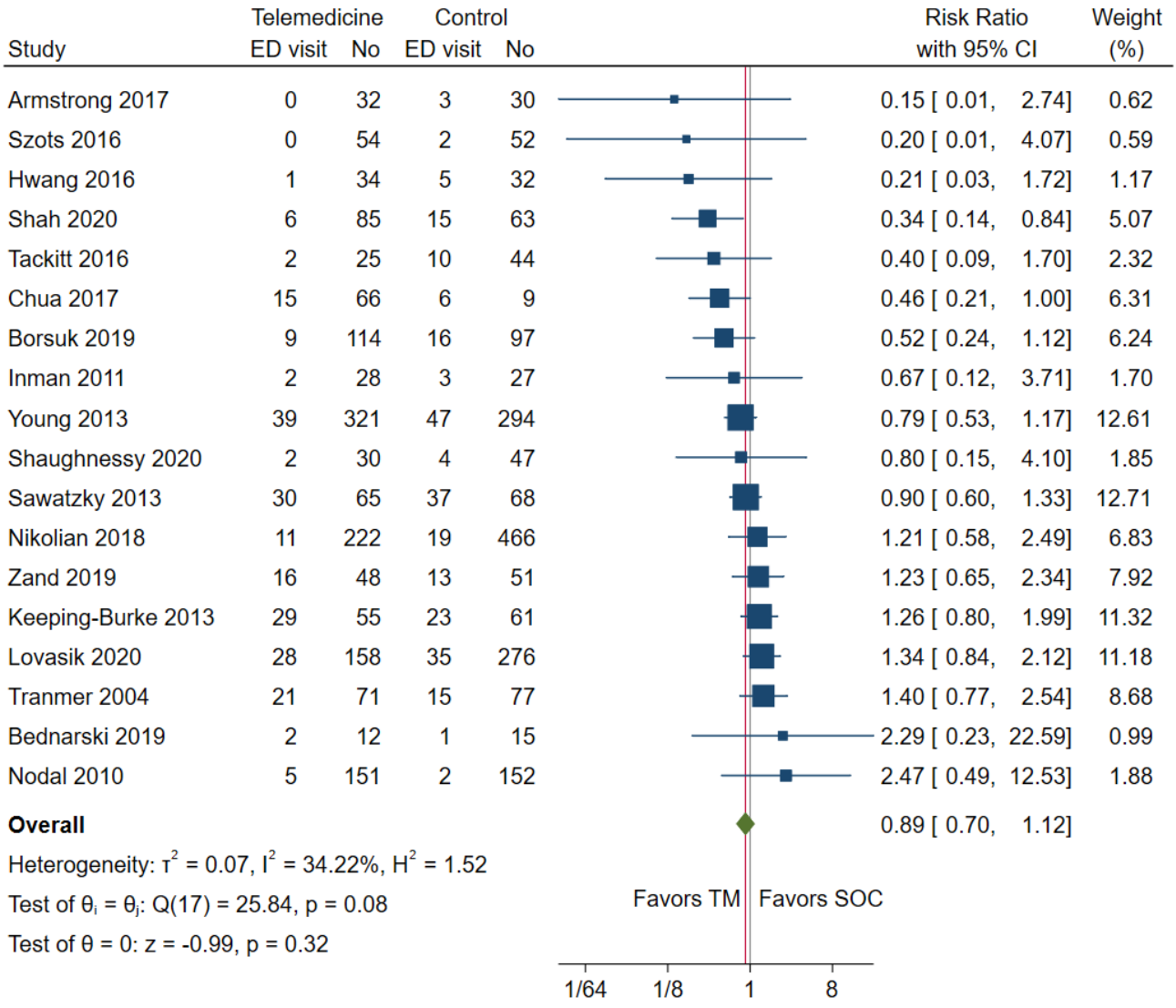


**Figure 2: Forest plot of all studies (randomized & non-randomized) reporting 30-day ED visits**

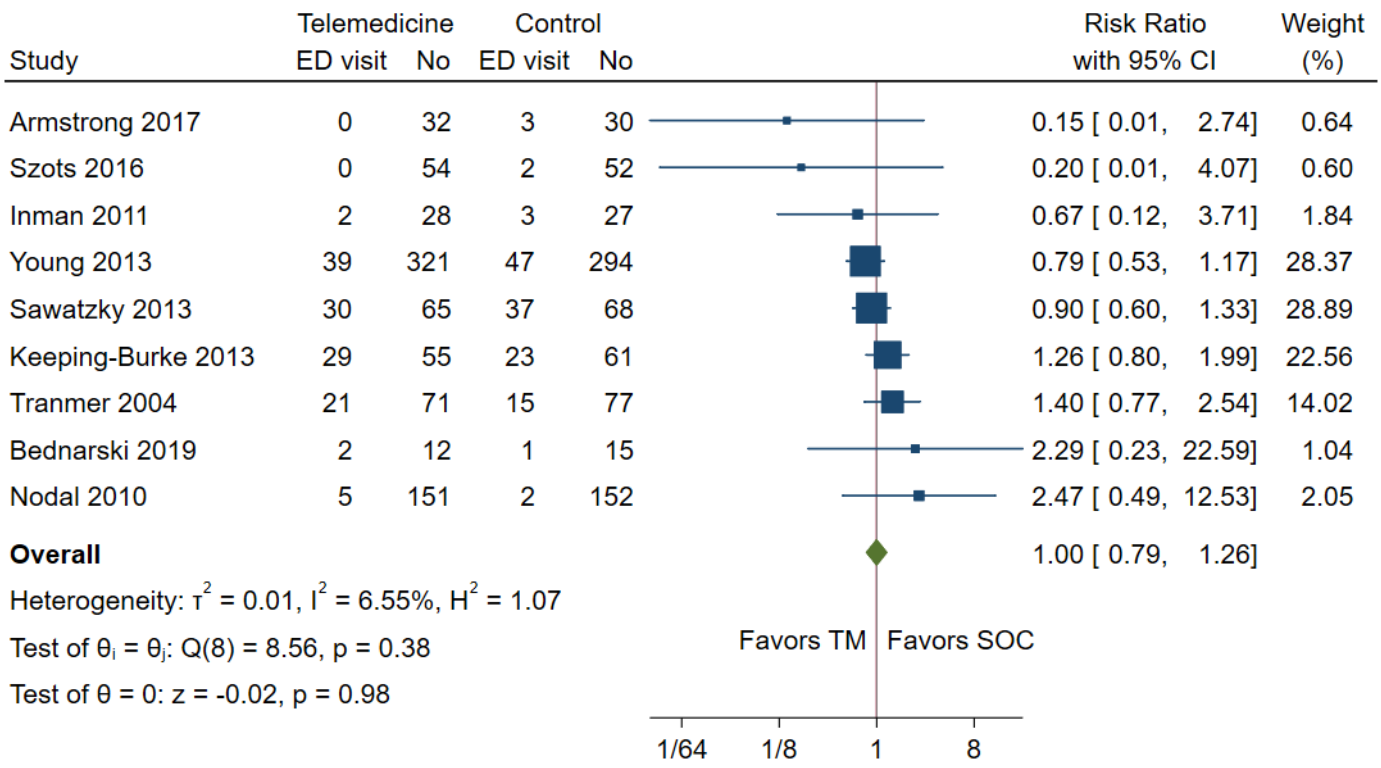


**Figure 3: Forest plot of RCTs reporting 30-day ED visits.**

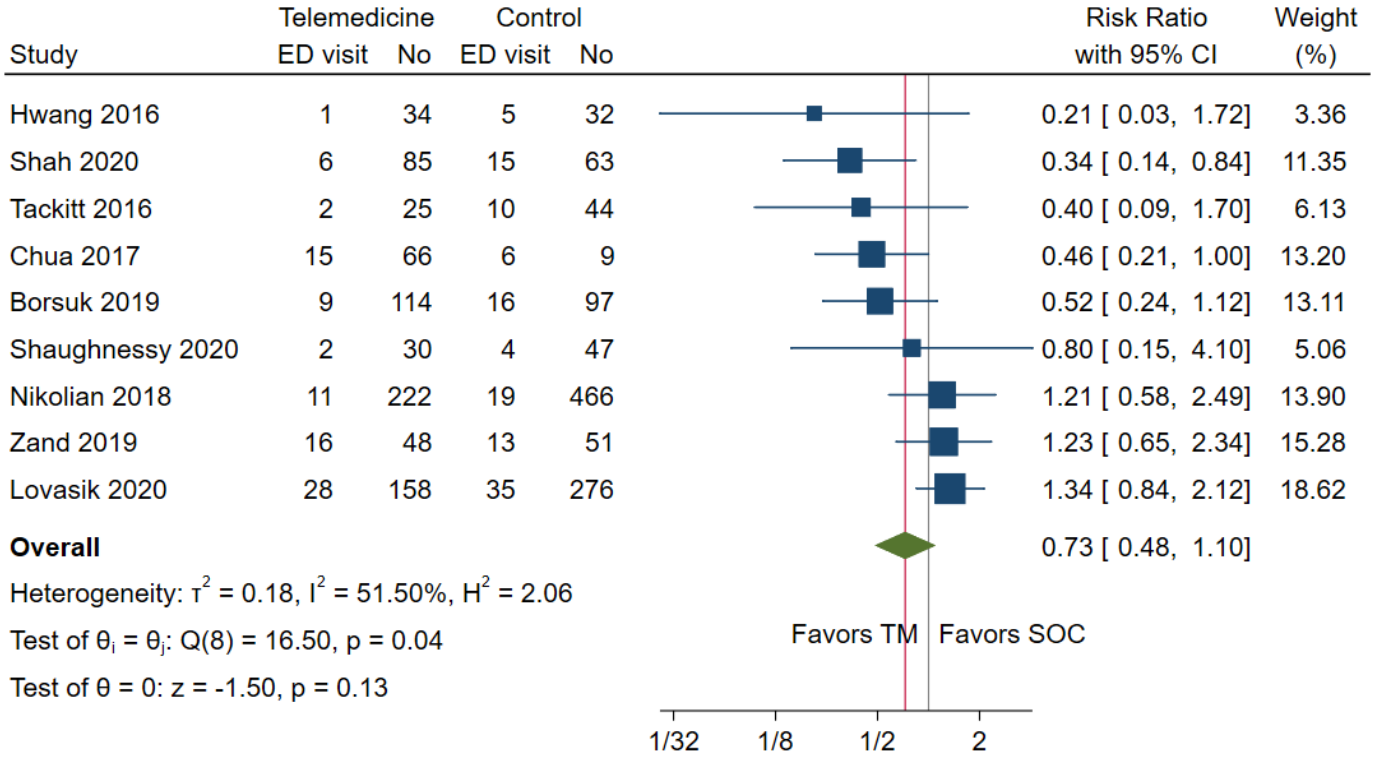


**Figure 4: Forest plot of non-randomized studies reporting 30-day visits.**

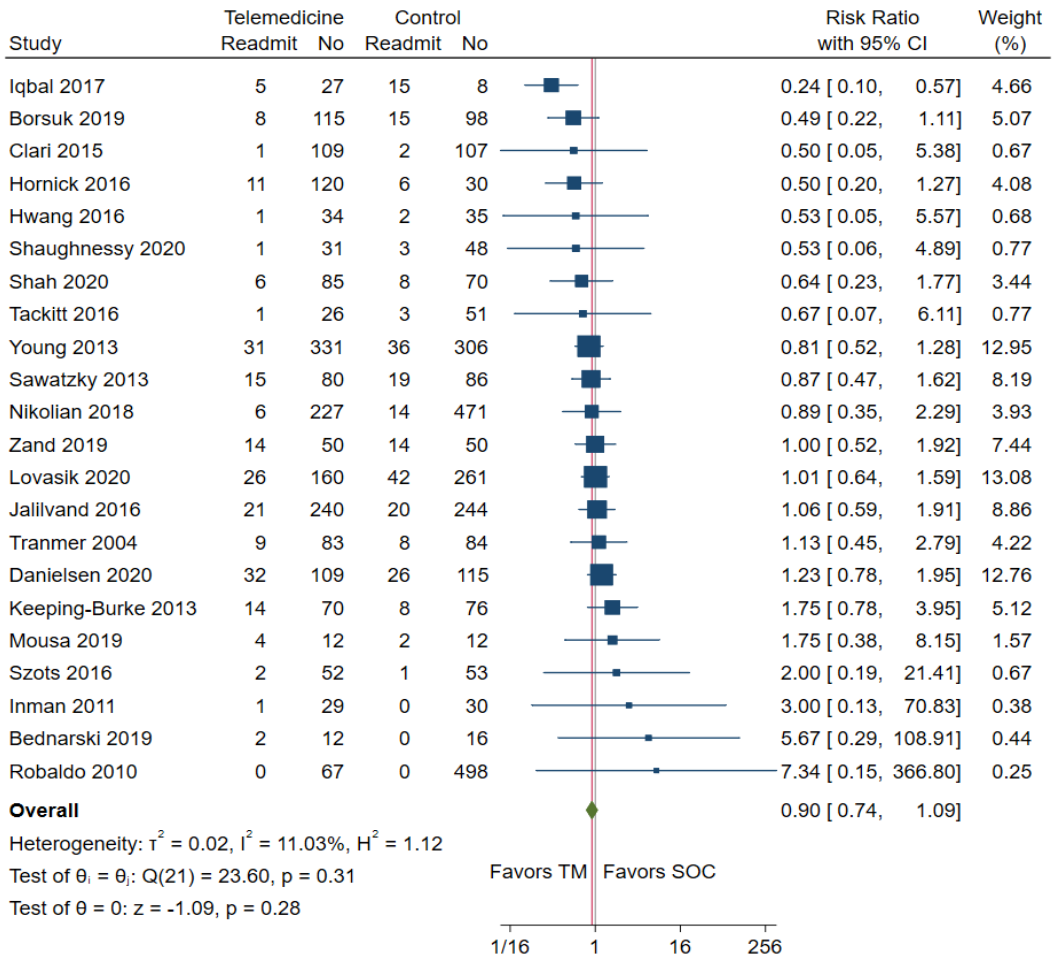


**Figure 5: Forest plot of all studies reporting 30-day readmissions.**

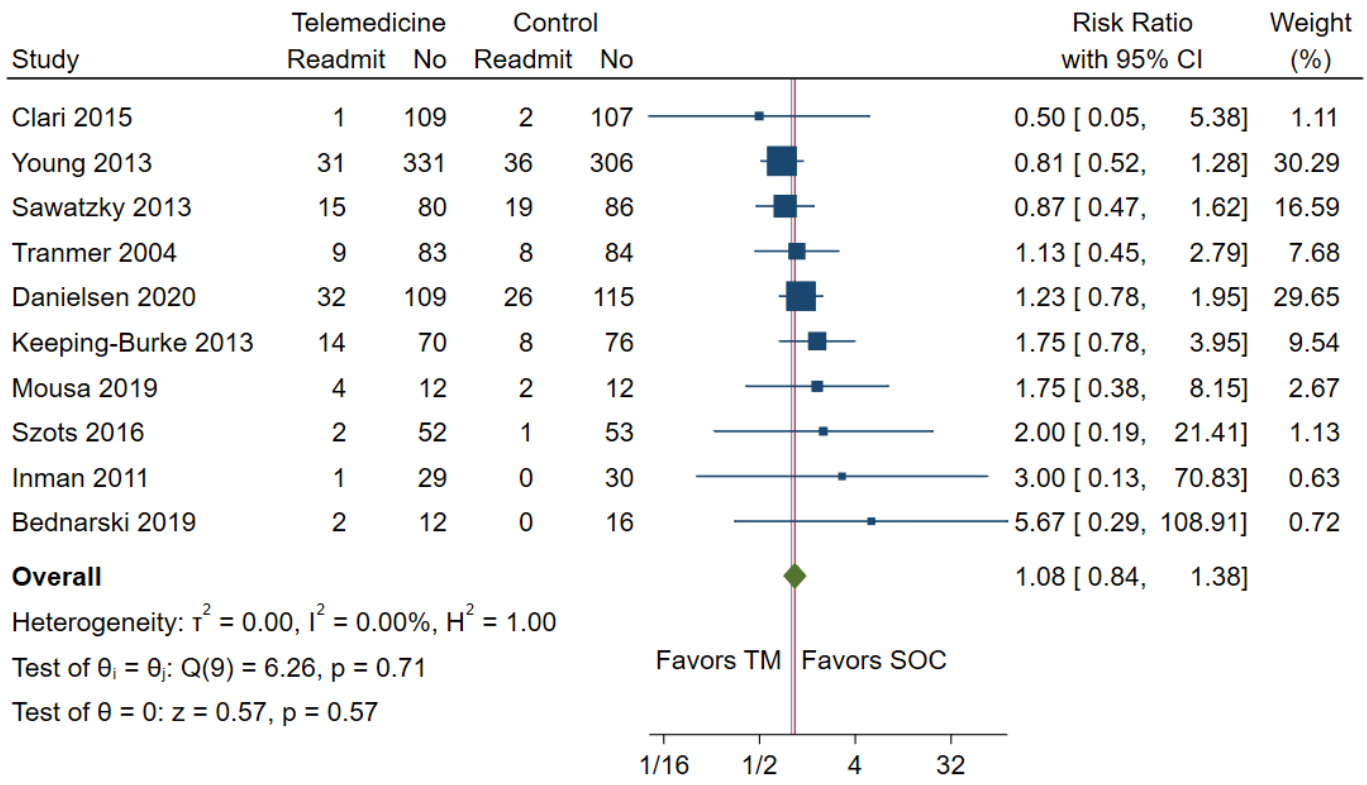


**Figure 6: Forest plot of all RCTs reporting 30-day readmissions.**

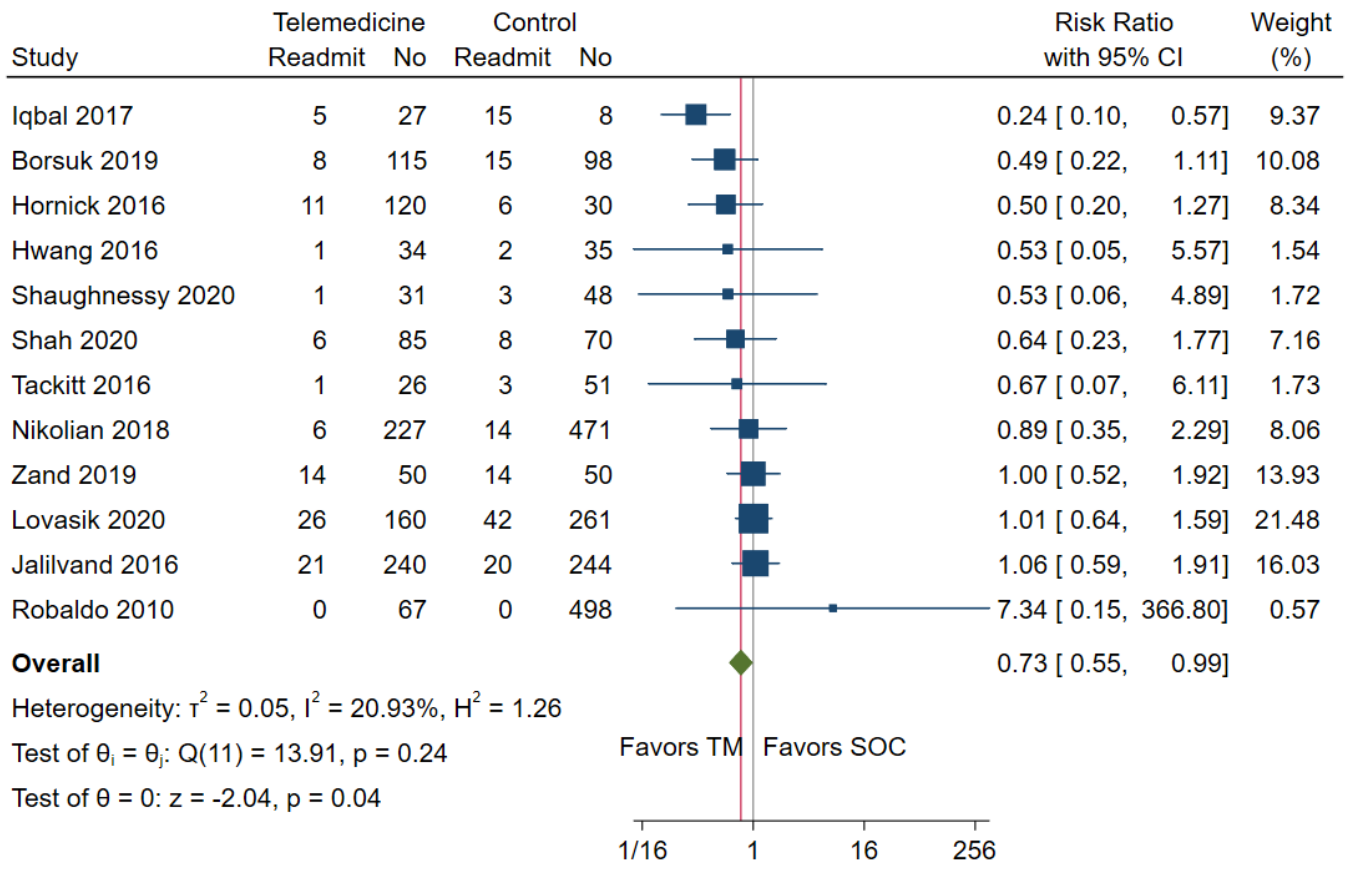


**Figure 7: Forest plot of all non-randomized studies reporting 30-day readmissions.**

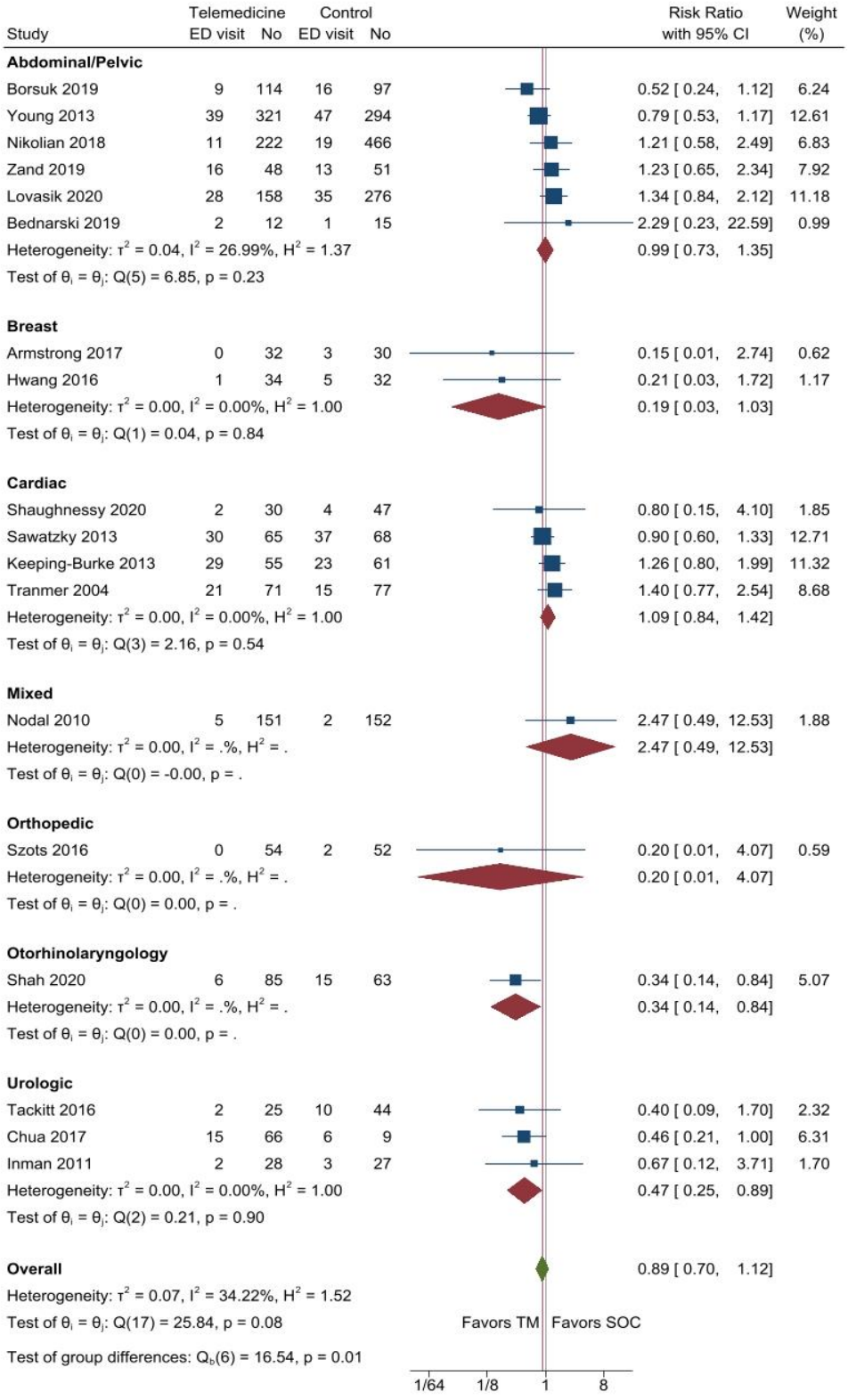


**Figure S1. Forest plot of ED visits by subspecialty.**

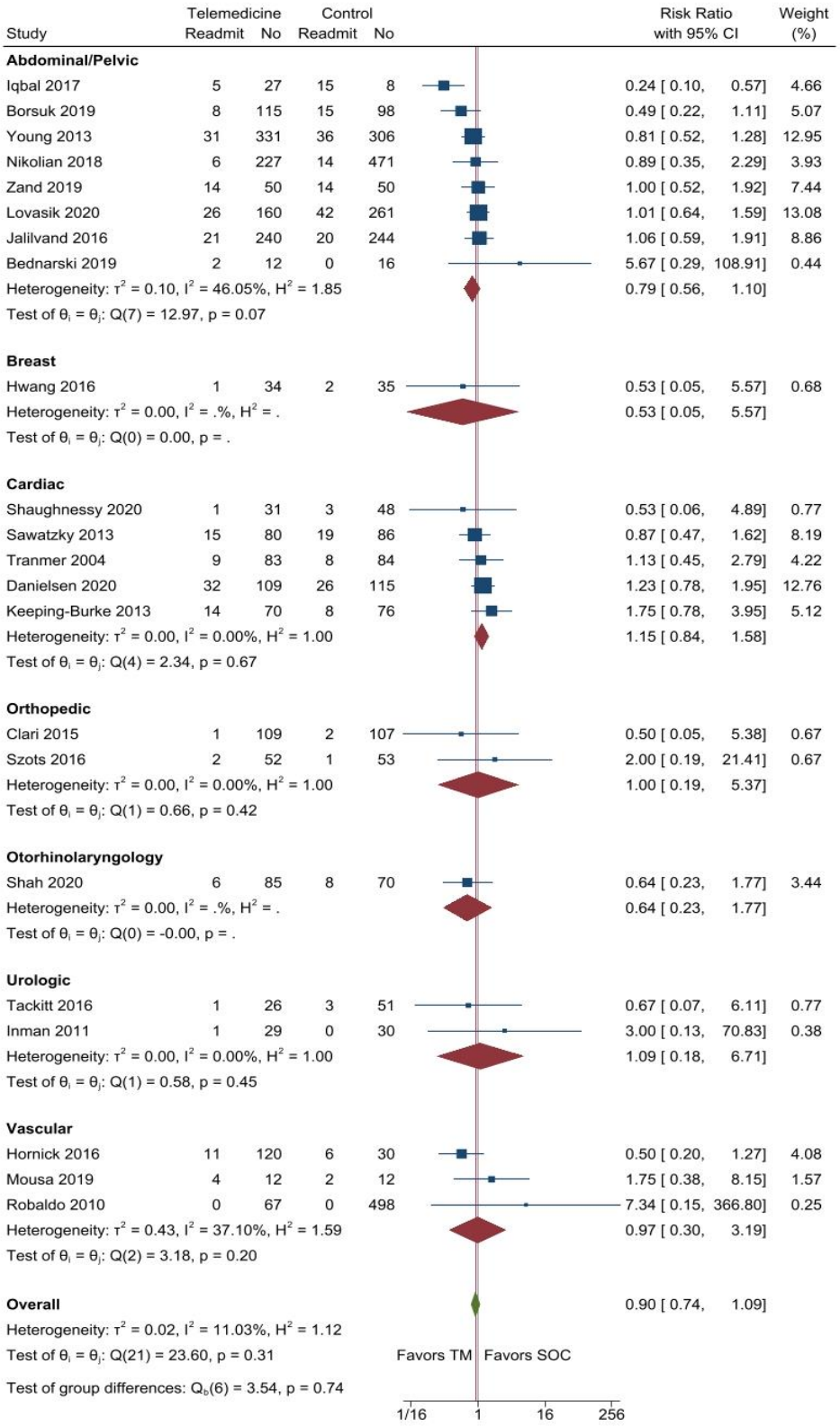


**Figure S2. Forest plot of readmissions by subspecialty.**

**Table S1: Qualitative descriptions of results describing patient satisfaction with telemedicine intervention.**

| Study ID | Satisfaction Scale | Results |
|---|---|---|
| Hodgins *et al.* | Likert-type Scale | "More than 80% of the participants in the intervention group rated the call as helpful or extremely helpful"<br><br>"Responses were thematically coded into one of five categories:<br>• (a) social value or public relations (28%; e.g., "nice for them to call," "even my car dealer calls to see how things are going")<br>• (b) utility value (25%; e.g., "opportunity to ask questions," "get advice")<br>• (c) supportive value (25%; e.g., "reassuring," "boost confidence")<br>• (d) multiple source value (11%; i.e., combination of utility, supportive, and social values)<br>• (e) no value.<br><br>Only 11% of the participants (n = 15) who had received a follow-up call perceived that it had no value." |
| Hwang et al. | Custom satisfaction questionnaire – unspecified | "Responses indicated that 90% did not have difficulty using the app and would recommend e-monitoring to a friend or colleague."<br>"95% found the app convenient to use and felt it was better for patient care when compared with standard post-op follow-up"<br>"All patients trusted the virtual care platform to keep their personal information private and secure" |
| Mousa *et al.* | Patient Satisfaction Questionnaire (PSQ-18) | "[Intervention] patients reported trends for higher satisfaction in terms of general satisfaction, technical quality, and accessibility for PSQ-18 survey questions (4.2 vs 3.7, p = 0.072; 4.5 vs. 4.1, p =0.081; and 4.2 vs 3.8, p = 0.063), respectively." |
| Nikolian *et al.* | 5-point Likert-type scale | "Regarding patient explanation of eClinic [intervention], scheduling ease, user interface, timeliness, and overall experience, 77% to 94% of eClinic patients were "satisfied" or "highly satisfied" with their eClinic experience. Furthermore, 85% of patients desired eClinic as their preferred future follow-up after surgery, and 88% of patients would recommend eClinic follow-up to a friend or family member." |
| Sawatzky *et al.* | Two questions from the Client Satisfaction Questionnaire (CSQ-8) addressing satisfaction with "quality of | "At 2 and 6 weeks, the intervention group participants were significantly more satisfied with the 'quality of service' received. Similar trends emerged for satisfaction with the 'amount of help' received, with non-significant differences at baseline and significantly higher satisfaction score in the intervention group at 2 and 6 weeks." |

| | | |
|---|---|---|
| | the services" and the "amount of help" received. | |
| Tranmer *et al.* | Patient satisfaction questionnaire developed by Shortell et al. | "The score for the 'meeting needs after hospitalization' were higher for the intervention than the control group. In particular, the recovery-item scores were consistently higher for patients in the intervention group:<br>• Achieving the best recovery possible, 71.3 versus 63.5, p = .03;<br>• Knowing what to expect during recovery, 70.3 versus 65.7, p = .23;<br>• Side effect information, 61.5 versus 54.0, p = .05;<br>• Complication information, 63.2 versus 56.7, p = .11;<br>• Help with decisions about care, 66.6 versus 59.0, p = .06;<br>• Recognizing potential problems, 59.6 versus 56.7, p = .48;<br>• Identifying depressive feelings, 51.0 versus 46.9, p = .32<br>Despite this positive trend, these measures did not yield statistically significant results" |
| Young *et al.* | Single question assessing satisfaction with assistance received by research nurse | 79.4% of patients selected "Agree Very Much" when asked "I was satisfied with the assistance I received from the research nurse." |
| Zand *et al.* | Custom questionnaire evaluating patient experience in the intervention | "Patients expressed overall satisfaction with the program, with 81% describing their experience as excellent and 94% describing the amount of TCSS [intervention] questions as reasonable. Patients reported that without participation in the TCSS pathway, they would most likely have used a phone call to the doctor's office as a resource for care (94%). Additionally, 56% of patients felt their recovery would have had a different result without participation in the TCSS program." |
| Iqbal *et al.* | Custom satisfaction survey to asses patient experience and perception on a Likert-type scale (1-5; 5, excellent and 1, poor). Adapted from EORTC IN-PATSAT32. | "The average score was 4.69 (95% CI: 4.51 – 4.66), on a scale of 1-5, indicated excellent patient satisfaction regarding the education and outpatient support provided in the postoperative period. Of note, all patients gave the information provided to them over the phone regarding their treatment a grade of 5." |
| Jalilvand *et al.* | Hospital Consumer Assessment of Healthcare Providers and Systems Survey (HCAHPS) | "[…] did not find a difference with respect to patients' perception of physician communication ($97^{th}$ versus $98^{th}$ percentile) or overall hospital rating ($69^{th}$ versus $68^{th}$ percentile). However, there appeared to be improvement in patient satisfaction regarding communication about medications ($59^{th}$ versus $27^{th}$ percentile) and understanding of discharge information ($98^{th}$ versus $93^{rd}$ percentile) in the care-coached [intervention] versus control groups. Additionally, patients in the care-coached group were more likely to recommend the hospital ($85^{th}$ versus $74^{th}$ percentile). |

| | | |
|---|---|---|
| McElroy *et al.* | Custom satisfaction survey – 5-point Likert scale (1 = disagree, 5 = agree). | "Overall, patients and healthcare providers reported satisfaction scores of 4.9 +/- 0.5 and 4.9 +/- 0.2, respectively. Patients also reported feeling more confident in the quality of care they received during the recuperation period." |
| Robaldo *et al.* | Custom satisfaction survey – 11-point scale to grade insecurity, scepticism, enthusiasm and satisfaction. | "At discharge, the questionnaire showed that there was insecurity in both groups: 87% in group A [intervention] vs. 79% in group B ($P > 0.05$). In group A [intervention], insecurity decreased after the first video connection and disappeared after the 8$^{th}$ day postoperatively. In group B [control], insecurity persisted even after the 8$^{th}$ day postoperatively. At this time the proportions expressing insecurity were 2% in group A vs. 85% in group B ($P < 0.0001$). Satisfaction increased immediately after the return to the family environment in both groups." |
| Bednarski *et al.* | Custom satisfaction survey – 20-item questionnaire | "There were no significant differences between the treatment arms for any of the questionnaire items. Nearly all respondents in both arms did not feel they needed to be kept in the hospital for a longer period of time to recovery from surgery ($P = 0.462$)."<br><br>100% of patients in both groups reported being "satisfied" or "very satisfied" with the cancer surgery, from the time they first met the surgeon and including up until the second week after surgery. |
| Armstrong *et al.* | 5-point Likert-scale | "There was no statistically significant difference in satisfaction scores between groups (IRR, 0.95; 95% CI: 0.76 – 1.20; p = .70). However, the group using the mobile app reported higher convenience scores than did the group receiving in-person follow-up care (IRR, 1.39; 95%CI, 1.09 – 1.77; p = .008). Thirty-one patients in the mobile app group (97%) agreed or strongly agreed that the type of follow-up care was convenient. Only 16 patients in the in-person group (48%) agreed or strongly agreed that the type of follow-up care they received was convenient." |
| Inman *et al.* | Self-reported satisfaction with single question asking for perceived helpfulness of the call. | "All but one patient (29/30) in the intervention group described the call as helpful." |

## CHAPTER 2 – Identifying the number of and reasons for unplanned emergency department visits after major elective colorectal surgery

### 2.1 Preamble to Manuscript 2

The systematic review presented in Chapter 1 failed to demonstrate a global benefit of telemedicine interventions on reducing unplanned healthcare utilization after surgery from multiple subspecialties. These results may be in part explained by the incidence of and the reasons for which patients present to the emergency department in each surgical subspecialty. Certain subspecialties may have different reasons for ED visits and readmissions that may not be able to be managed by telemedicine. For example, a meta-analysis of hospital readmissions after cardiac surgery patients undergoing aortic valve replacement reported that over 80% of readmissions were for reasons that they considered non-preventable. It may be that having such a high proportion of unpreventable visits that cannot be managed remotely is likely to dilute the effect of telemedicine interventions on reducing potentially preventable visits. Similar findings are present in the fields of vascular surgery, where postoperative presentations are usually for heart failure, pneumonia, and surgical complications, many of which are not preventable.

In colorectal surgery specifically, approximately 20% of patients will have an unplanned 30-day emergency visit, with over half of these visits not requiring readmission, suggesting that an important proportion of visits may be potentially preventable. Current literature has focused primarily on reasons for readmission, yet few studies have characterized the nature of non-readmission ED visits. By identifying the reasons behind these unplanned visits, we may be able to establish targeted quality improvement initiatives to minimize preventable healthcare utilization and its associated cost burden.

The objective of this next manuscript was to characterize ED resource utilization after elective colorectal surgery by: (1) identifying the reasons patients presented to the ED within 30 days of surgery and (2) determining if these visits were potentially preventable based on their usage of ED-specific resources. This manuscript was accepted for publication into Surgical Endoscopy.

## 2.2 MANUSCRIPT 2: High incidence of potentially preventable emergency department visits after major elective colorectal surgery.

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### 2.2.1 ABSTRACT

**Introduction:** Emergency department (ED) visits after surgery represent a significant cost burden on the healthcare system. Furthermore, many ED visits are related to issues of healthcare delivery services and may be avoidable. Few studies have assessed the reasons for ED visits after colorectal surgery. The main objectives of this study were to: (1) identify the reasons why patients presented to the ED within 30 postoperative days and (2) determine if these visits were potentially preventable.

**Methods:** A retrospective chart review was conducted on elective major colorectal surgery cases performed in a single center between 01/2017-07/2019. Data collected included demographics, medical history, intraoperative details, postoperative complications, ED visits within 30 postoperative days, and readmissions. Each ED visit was assessed by two reviewers and graded on a scale adapted from the New York University ED algorithm. The gradings were: (1) non-emergent, (2) emergent but treatable in an ambulatory setting, (3) emergent/ED-care required but preventable if timely outpatient care was available, and (4) emergent/ED-care required and non-preventable. Grades 1-3 were deemed potentially preventable. Logistic regression identified independent predictors of potentially preventable visits.

**Results:** 625 patients were included in the final analysis. 110(17.6%) patients presented to the ED within 30 days. The most common cause of ED visit were ileus/small bowel obstruction (SBO)(16.4%), superficial wound infection(15.5%), genitourinary issues(10.9%), and non-infectious gastrointestinal issues (nausea, malnutrition, diarrhea, high output stomas)(10.9%). After review, 51.8% of visits were considered potentially preventable (Grade 1-3). The most common causes of preventable ED visits were superficial wound infection(24.6%), non-infectious gastrointestinal issues(19.3%), and minor bleeding(14.0%). Creation of a new stoma was the only independent risk factor for potentially preventable ED visits(OR 2.14, 95%CI 1.03-4.47).

**Conclusion:** Approximately half of ED visits within 30 days of discharge were potentially preventable. These findings indicate a need to improve access to outpatient care to reduce preventable ED visits after elective colorectal surgery.

### 2.2.2 INTRODUCTION

Inefficient use of emergency department (ED) resources is a major contributor to growing healthcare expenditures(1). Indeed, a significant proportion of ED visits are for conditions that could be treated in the outpatient setting, resulting in an estimated $38 billion in wasteful expenditures annually within the U.S. healthcare system(1).

Unplanned ED visits occur frequently in abdominal surgery, where 15-20% of postoperative patients will seek care within 30 days of surgery(50-52). In colorectal surgery specifically, approximately 20% of patients will have an unplanned 30-day emergency visit, with over half of these visits not requiring readmission, suggesting that these visits may be potentially preventable (2). Current literature has focused primarily on reasons for readmission, yet few studies have characterized the nature of non-readmission ED visits. By identifying the reasons behind these unplanned visits, we can establish targeted quality improvement initiatives to minimize preventable healthcare utilization and its associated cost burden.

This study aims to characterize ED resource utilization after elective colorectal surgery by: (1) identifying the reasons patients presented to the ED within 30 days of surgery and (2) determining if these visits were potentially preventable based on their usage of ED-specific resources.

### 2.2.3 METHODS

After approval by the McGill University Health Centre (MUHC) Institutional Review Board, a retrospective chart review was conducted on all elective inpatient major colorectal surgery cases performed in a single high-volume academic center between January 2017 and July 2019. Major colorectal surgery includes any surgery with an intra-abdominal component (laparoscopic & open) that required bowel resection with or without anastomosis. Emergency surgeries, day surgeries, and surgeries without an abdominal component (transanal procedures) were excluded. Given the primary outcome was 30-day unplanned ED visits, patients with primary length of stay over 30 days were also excluded.

Data was collected for preoperative, intraoperative, and 30 days postoperative periods. Preoperative variables included patient demographics (age, sex, body mass index), comorbidities via the Charlson Comorbidity Index (CCI), indication for surgery, preoperative opioid use, and steroid use defined as the need for intraoperative dosing with stress-dose corticosteroids. Intraoperative data included surgery type, surgical approach (laparoscopic, open, converted), presence of a new stoma at the end of surgery, operative duration, intraoperative complications, blood loss, and the amount of administered blood

products. Postoperative variables included hospital length of stay, mortality within 30 days, ED visit within 30 postoperative days, reason for ED visit, readmission, and reason for readmission. Reasons for ED visits were categorized into broad categories as follows: Wound complications, organ space infections/anastomotic leak, genitourinary, cardiopulmonary, venous thromboembolism (VTE), bleeding, non-infectious gastrointestinal (which includes high output stoma, non-obstructive nausea/vomiting), issues pertaining to stoma appliances and drains, pain control, ileus/small bowel obstruction, and other.

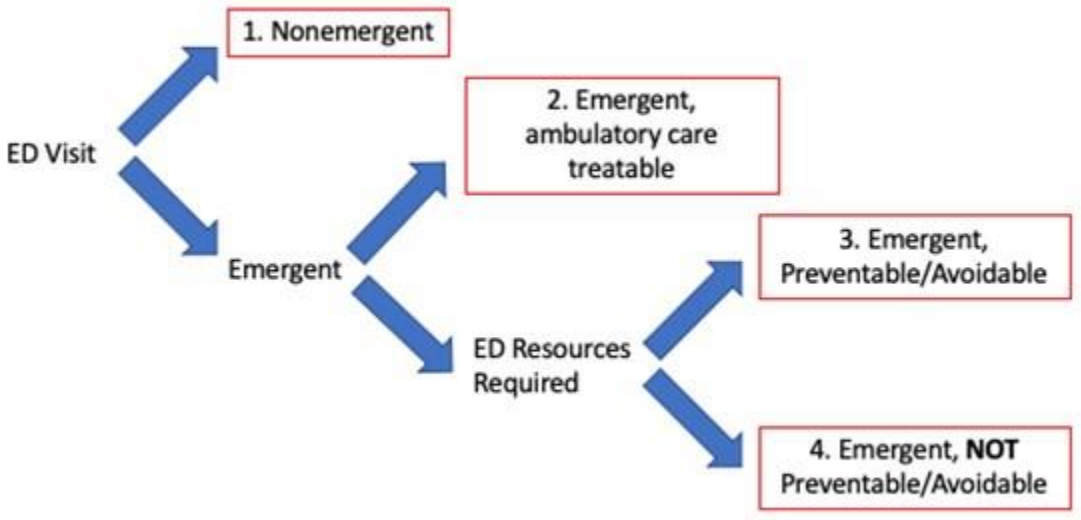


**Figure 1: Algorithm for ED visits following colorectal surgery (adapted from NYU ED Algorithm)**

Each ED visit was reviewed by two independent reviewers and graded on potential preventability based on ED resource utilization. Any disagreement in grading was resolved by means of a tie-breaker using a third independent reviewer. A grading scale of 1-4 was adapted from the New York University ED algorithm, depicted in Figure 1 (53). The gradings were: (1) non-emergent, (2) emergent but treatable in an ambulatory care setting, (3) emergent/ED-care required but preventable if timely outpatient care was available, and (4) emergent/ED-care required and non-preventable. This algorithm was initially developed to classify ED utilization by the NYU Center for Health and Public Service Research. Using a panel of experts, the authors examined 6000 ED records based on several components including, but not limited to, diagnoses and resources used in the ED. These were then categorized into four categories, similar to those outlined here. This tool has since been validated and used in larger studies since its initial

creation(54). Visits were graded based on what resources were used, without judgment on the appropriateness in the clinical context. Any visit that required a resource specific to the ED (ex. CT scan, ultrasound, IV hydration, etc.) was assigned a Grade 3 or 4. Cases were considered non-preventable if the nature of the condition was unpredictable or could not have been dealt with remotely by a specialist colorectal physician (ie. unrelated to colorectal surgery, cardiopulmonary issues etc.) Grades 1-3 were deemed potentially preventable.

Statistical analyses were all performed using the open-source R statistical platform. The study population was initially divided by outcome into patients who had an unplanned ED visit within 30 days and patients who did not. A weighted kappa-statistic was calculated to evaluate inter-rater reliability regarding grading of potential preventability. Univariate analysis comparing categorical variables (Sex, Opioid Use, Steroid Use, Indications for OR, Operative details, Operative approach, New Stoma, and Operative complications) was performed using a Pearson's Chi-Squared Test. Univariate analysis comparing continuous variables (Age, BMI, CCI, ASA, Operative Time, Blood loss, Length of stay) was done using a two sample t-test. Reasons for visits were tabulated by frequency of occurrence, and a percentage of total visits was calculated. A similar process was executed for potentially preventable visits. To identify potential risk factors for preventable visits, a multivariate logistical regression was fitted to model potentially preventable visits (outcome) using age, sex, ASA, indication for OR, new stoma, and operative approach as covariates. From this, 95% confidence intervals for the estimated odds ratio were calculated.

**2.2.4 RESULTS**

A total of 625 patients underwent inpatient major colorectal surgery and were included in the final analysis. There were 110 patients (17.6%) who presented to the ED within 30 days from the date of surgery, and 515 patients who did not present to the ED. Univariate analysis between both groups demonstrates that patients who presented to the ED were younger, more likely to be treated for inflammatory bowel disease (IBD), and less likely to be treated for a neoplastic process (Table 1). The remaining preoperative and intraoperative details were similar between groups.

The most common causes of all (potentially preventable and non-preventable) ED visits were SBO/ileus and wound complications accounting for 16.36% and 15.45% respectively (Table 2). The distribution of causes for all visits are outlined in Table 2. After review of all ED visits and resource utilization, 57 (51.8%) of the visits were deemed to be potentially preventable, ie. Grades 1-3. The percent agreement was 70.9% with a Cohen's kappa score of 0.58. A third independent reviewer was used as tiebreaker for the 29.1%

of disagreements. The most common causes of potentially preventable ED visits were wound complications (24.56%), non-infectious GI issues (19.3%), and bleeding (14.0%). The remaining distribution of reasons for preventable visits is outlined is outlined in Table 3. Of the patients who presented to the ED, 47 were readmitted (43.6%). The most common causes of readmission were ileus/SBO (35.4%) and organ space infection/anastomotic leak (22.9%) (Table 4).

We performed multivariate logistic regression to identify potential risk factors to identify patients likely to return to the ED for potentially preventable reasons. Potential confounders adjusted for included presence of a new stoma, age, ASA score, operative approach, and indication for OR. Creation of a new stoma was the only independent risk factor for potentially preventable ED visits with an OR of 1.86 (95%CI 1.02 – 3.28).

**2.2.5 DISCUSSION**

Our study demonstrates that a significant portion of patients undergoing elective major colorectal surgery have unplanned ED visits within 30 days, with many of these not requiring readmission or ED-specific resources. This confirms the need for improved outpatient postoperative care and represents an avenue for quality improvement efforts.

Overall, this study suggests that a significant portion of potentially preventable ED visits may stem from a lack of accessibility to specialized post-operative care, with no direct access often until the standard follow-up with the surgeon several weeks later. This poses a problem with seeking appropriate medical care in the event of complications, which often arise in the first few weeks following surgery. Indeed, a qualitative study by Jones *et al.* reported that 68% of colorectal patients at one center were advised to seek care at the nearest ED in the event of a potential complication, highlighting a missing link in our ability to deliver quality post-operative care(6). Based on this, several groups including our own have implemented or are currently implementing active post-discharge surveillance programs in an effort to limit unplanned ED visits and readmission, with promising results (55, 56). Indeed, Borsuk *et al.* demonstrated that patients benefiting from active surveillance following colorectal surgery had significantly lower odds of unplanned ED visits when compared to the control group (55). Most interesting however, was the 22.8% of patients who despite communicating “significant clinical complaints” were successfully managed without ED involvement or readmission, a direct result of care successfully coordinated using the applications chat function (55). Similarly, Carrier *et al.* demonstrated that enhanced surgeon-patient communication using a text-message based outpatient follow-up tool was associated

with improved detection of postoperative complications and lower overall ED unplanned visits (56). Together, these findings highlight the many benefits of improved communication between patients and surgeon in the outpatient setting which can easily be achieved by harnessing the widespread availability of smartphone technology.

Our study defines grades of preventability solely on the utilization of ED-specific resources. This classification method, derived from the validated NYU ED algorithm(53, 54), provides a more objective measure of preventability, one that can be executed with moderate inter-rater reliability as seen by our calculated Cohen's Kappa statistic. The concept of preventability itself is highly dependent on setting-specific resources. Indeed, in our setting, access to CT scanners or providing intravenous hydration in clinic are very limited and, as such, many of our patients may be sent to the ED for these reasons. Other centers where these resources are more accessible on an outpatient basis may not need to send their patients to the ED. Therefore, while grading of preventability on ED-specific resources is objective, the definition of ED-specific resources may vary among centers.

Wound-related complications were the primary reason behind potentially preventable ED visits in our cohort. This is largely in-keeping with the available literature, in which surgical site infections (SSIs) represent the most common infection in the postoperative period, accounting for over $1.6 billion in incurred costs on the healthcare system annually (57). SSIs may be able to be managed in an ambulatory setting if identified early on. Furthermore, nearly half of patients who presented for wound-related concerns were found to have normal appearing wounds, highlighting a shortcoming in patient education with regards to the normal healing process. In the context of widespread accessibility to smartphone technology, telemedicine represents a viable solution (58). Indeed, several studies have demonstrated that in controlled settings, remote wound monitoring is feasible and effective(5, 59). Additionally, telemedicine-based interventions have previously been shown to be effective in reinforcing patient education and promoting patient engagement in their recovery, which could easily be adapted to enhance patient understanding of the normal healing process (60). As such, telemedicine represents a potential solution to managing wound-related issues by providing a simple platform for remote monitoring of wounds, while simultaneously promoting patient education on the normal recovery process.

Non-infectious gastrointestinal issues were the second most common reason for potentially preventable ED visits, largely driven by delayed recognition of high output stomas. Dehydration and electrolyte imbalances are complications of high output stomas that often affect new ostomates (61, 62). Similar to SSIs, these complications may be able to be managed in an ambulatory setting with anti-motility agents

and proper fluid intake but require early recognition. Patients may not know how to properly adjust their fluid intake or antidiarrheals when ostomy output increases, which may further exacerbate the problem. Part of this issue can be addressed by promoting patient engagement in their stoma care through educational programs, an approach that has previously be demonstrated to be effective (61). While such a program exists in our center, the current study suggests that greater encompassing of our new ostomy patients is warranted. Addressing the issue of high-output stomas could be achieved through enhanced patient education with specific emphasis on monitoring of stoma output and simple guidelines on appropriate initial management. Much like wound related issues, stoma management could be incorporated into simple telemedicine applications that could allow patients to remotely report their stoma output to their clinical team, thus promoting patient engagement while simultaneously providing a safety net in which the clinical care team is able to identify and manage stoma complications early in their development(55, 63).

This study is subject to limitations. Our center is a high-volume referral center that treats patients from the entirety of Quebec. Due to lack of a provincial central electronic medical record (EMR), our patient records are limited to ED visits within our center thus potentially missing any patients who presented to the ED at other centers in the province, or patients who presented at their local clinic. As such, we are likely underestimating the true proportion of unplanned healthcare visits. Second, the retrospective nature of the study limits the collection of information to the accuracy and completeness of medical records. However, to account for this we elected to grade preventability using an objective measure of "ED-specific resources" in an effort to minimize bias that would have occurred had we elected to judge the "appropriateness" of specific interventions during the visit.

In conclusion, we demonstrate that a significant portion of ED visits following elective colorectal surgery are potentially preventable. Reasons underlying these visits are potentially the result of incomplete patient education, compounded by a lack of accessibility to specialized outpatient care. Smartphone technology represents an avenue via which we could combine enhanced patient education with simple remote monitoring tools to improve patient outcomes in the 30 days following surgery. With this in mind, we are currently assessing the ability of a mobile-based application to reduce unplanned and potentially preventable ED visits in a prospective study.

**2.2.6 ACKNOWLEDGMENTS**

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### 2.2.7 DISCLOSURES

Dr Fiore reported receiving research funding from Merck and receiving honorarium as a research consultant to Shionogi. Dr Feldman reported receiving research funding from Theator, Merck and Johnson & Johnson and an educational grant from Medtronic. Dr Lee reported receiving research funding from Johnson & Johnson and is a consultant for Stryker. Dr. Eustache, Dr. Hopkins, Dr. Trepanier, M. Kaneva reported no relevant disclosures.

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**FIGURES**

**Table 1: Preoperative and intraoperative variables comparison in patient who did or did not present to the ED within 30 days of surgery.**

| | No ED visit (N=515) | ED visit (N=110) | p value |
|---|---|---|---|
| **Age** | | | **0.027** |
| - mean | 62.1 | 58.4 | |
| **Sex** | | | 0.164 |
| - F | 234 (45.4%) | 42 (38.2%) | |
| - M | 281 (54.6%) | 68 (61.8%) | |
| **BMI** | | | 0.075 |
| - mean | 25.9 | 27 | |
| **CCI** | | | 0.281 |
| - mean | 3.95 | 3.65 | |
| **ASA** | | | 0.930 |
| - mean | 2.33 | 2.34 | |
| **Recent Opioid Use** | | | 0.311 |
| - No | 501 (97.3%) | 105 (95.5%) | |
| - Yes | 14 (2.7%) | 5 (4.5%) | |
| **Recent Steroid Use** | | | 0.121 |
| - No | 488 (94.8%) | 100 (90.9%) | |
| - Yes | 27 (5.2%) | 10 (9.1%) | |
| **Indication for OR** | | | **0.023** |
| - Neoplastic | 324 (62.9%) | 57 (51.8%) | |
| - Stoma | 78 (15.1%) | 16 (14.5%) | |
| - IBD | 68 (13.2%) | 27 (24.5%) | |
| - Benign Disease | 45 (8.7%) | 10 (9.1%) | |
| **Operative Details** | | | 0.121 |
| - Colon | 287 (55.7%) | 49 (44.5%) | |
| - Colon & Rectum | 23 (4.5%) | 9 (8.2%) | |
| - Other | 97 (18.8%) | 24 (21.8%) | |
| - Rectal | 108 (21.0%) | 28 (25.5%) | |
| **Operative Approach** | | | 0.212 |
| - Laparoscopic | 351 (68.2%) | 67 (60.9%) | |
| - Open | 129 (25.0%) | 31 (28.2%) | |
| - Converted | 35 (6.8%) | 12 (10.9%) | |
| **New Stoma** | | | **0.004** |
| - No | 411 (79.8%) | 74 (67.3%) | |
| - Yes | 104 (20.2%) | 36 (32.7%) | |
| **Operative Time (min)** | | | 0.189 |
| - mean | 188 | 201 | |
| **Blood Loss (mL)** | | | 0.321 |
| - mean | 191 | 234 | |
| **Operative Complications** | | | 0.365 |
| - No | 456 (88.5%) | 94 (85.5%) | |
| - Yes | 59 (11.5%) | 16 (14.5%) | |
| **Length of Stay (days)** | | | 0.359 |
| - mean | 4.96 | 4.55 | |

**Table 2: Reasons for all (preventable and non-preventable) ED visits.**

| Reason | Freq | Percent |
|---|---|---|
| SBO/Ileus | 18 | 16.36 |
| Wound Complication | 17 | 15.45 |
| Other | 13 | 11.82 |
| Genitourinary | 12 | 10.91 |
| Noninfectious GI issues | 12 | 10.91 |
| Bleeding | 11 | 10.00 |
| Organ Space Infection/Anastomotic leak | 11 | 10.00 |
| Pain Control | 7 | 6.36 |
| Cardiopulmonary | 3 | 2.73 |
| Stoma & Drain Issues | 3 | 2.73 |
| VTE | 3 | 2.73 |

**Table 3: Most common presentations for potentially preventable ED visits.**

| Reason | Freq | Percent |
|---|---|---|
| Wound Complication | 14 | 24.56 |
| Noninfectious GI issues | 11 | 19.30 |
| Bleeding | 8 | 14.04 |
| Other | 8 | 14.04 |
| Genitourinary | 6 | 10.53 |
| Pain Control | 5 | 8.77 |
| Stoma & Drain Issues | 3 | 5.26 |
| SBO/Ileus | 1 | 1.75 |
| VTE | 1 | 1.75 |

**Table 4: Most common reasons for readmissions.**

| Reason | Freq | Percent |
|---|---|---|
| SBO/Ileus | 17 | 35.42 |
| Organ Space Infection/Anastomotic Leak | 11 | 22.92 |
| Genitourinary | 5 | 10.42 |
| Noninfectious GI issues | 4 | 8.33 |
| Bleeding | 3 | 6.25 |
| Other | 2 | 4.17 |
| VTE | 2 | 4.17 |
| Wound complication | 2 | 4.17 |
| Cardiopulmonary | 1 | 2.08 |
| Pain control | 1 | 2.08 |

## CHAPTER 3 – Implementing a mobile phone app that promotes patient-physician communication to reduce emergency department visits after elective colorectal surgery.

### 3.1 Preamble to Manuscript 3

In Chapter 1, we found that telemedicine interventions did not demonstrate an overall benefit to reducing healthcare utilization after surgery when pooling all surgical specialties. We proposed that this finding was in part due to the variable baseline rate of unplanned ED visits or the proportion of visits that are potentially preventable in each surgical specialty. Based on this, we hypothesized that surgical specialties with a moderate-high return rate and a significant proportion of potentially preventable visits are likely to represent the best targets for telemedicine-based interventions.

Patients undergoing elective abdominopelvic colorectal surgery represent a prime target for interventions that seek to reduce unplanned healthcare utilization. Indeed, the retrospective chart review performed in Chapter 2 found that half of emergency department visits after elective colorectal surgery in our center were potentially preventable and did not require ED-specific resources or readmission. Patients often presented for wound concerns, non-infectious gastrointestinal issues, and minor bleeding, all of which could be managed if patients had access to specialized care in the postoperative outpatient period. This represents a target for quality improvement in the way we deliver care to postoperative colorectal patients. mHealth provides a convenient and easily accessible means to provide remote specialized care to postoperative patients

Based on this, we implemented a phone-based mobile app for post-discharge monitoring with patient-provider communication ability, which we hypothesized would reduce ED visits after elective abdominopelvic colorectal surgery. This manuscript was accepted for publication into Diseases of Colon & Rectum.

## 3.2 MANUSCRIPT 3: A mobile app improves patient-physician communication and reduces emergency department visits after colorectal surgery.

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### 3.2.1 ABSTRACT

**BACKGROUND:** Emergency department(ED) visits after colorectal surgery are common and require significant healthcare resources. However, many visits may be avoidable with better access to care. Mobile health technologies can facilitate patient access to healthcare providers.

**OBJECTIVE:** We hypothesized that a mobile app for post-discharge monitoring with patient-provider communication ability would reduce emergency visits after elective abdominopelvic colorectal surgery.

**DESIGN:** Prospective cohort study with a regression analysis after coarsened exact matching.

**SETTING:** A single colorectal referral centre from 05/2019–09/2020.

**PATIENTS:** 114 patients were recruited to the intervention (APP+) and were matched to a retrospective cohort of 608 patients (APP-) from the 24 months preceding the study. All patient were managed according to an enhanced recovery pathway.

**INTERVENTIONS:** A mobile phone app comprised of patient education material, daily questionnaires assessing post-discharge recovery, and patient-provider chat function.

**MAIN OUTCOME MEASURES:** The primary outcome was potentially preventable 30-day ED visits, defined according to the validated NYU ED algorithm. Secondary outcomes included initial hospital length of stay(LOS), complications, total ED visits, readmissions, and app usability.

**RESULTS:** Coarsened-exact matching resulted in a matched sample of 94 APP+ and 256 APP-. APP+ was associated with fewer preventable ED visits(IRR 0.34, p=0.043) and shorter LOS (3.2 vs. 4.6 days, p=0.011). There were no differences in 30-day complications, total number of ED visits, and readmissions. Patient-reported usability of the mobile app was high (SUS score 84.5(SD 17.6)), with 88% of patients reporting that the app improved their ability to communicate with their surgeon.

**LIMITATIONS:** We did not account for health literacy and social support, both of which may affect healthcare utilization. We did not perform a cost analysis, which may be a potential barrier to implementation of telemedicine interventions.

**CONCLUSION:** Use of a mobile app was associated with fewer potentially preventable ED visits and shorter length of stay after major elective colorectal surgery, likely due to enhanced post-discharge monitoring and patient-provider communication.

### 3.2.2 INTRODUCTION

Emergency department (ED) visits are common after elective colorectal surgery, representing a significant cost and resource burden on the healthcare system as well as being distressing to patients. On average 20% of patients(3) will present to the ED with over half not requiring readmission, suggesting that a significant portion of visits are potentially preventable(3). These preventable ED visits may be targets for quality improvement.

Healthcare is in the middle of a technological boom, with mobile health (mHealth) apps flooding the market. In North America, over 80% of adults own a smartphone with app capability, and 58% of these have downloaded at least one mHealth app(7, 8). mHealth may provide innovative ways to enhance patient-physician communication, with benefits in the management of several medical conditions(10).

Across surgical subspecialties, mHealth have been applied in the care of perioperative patients, with some studies demonstrating benefits in adherence to treatments and in monitoring of postoperative complications(64). With regards to ED visits and readmissions however, much of the data remains equivocal. A systematic review by our group failed to demonstrate a clear reduction in ED visits and readmissions with the use of mHealth(64). Furthermore, the results of this systematic review suggested that specialties with high return rates and high rates of potentially preventable ED visits were likely to benefit most from interventions that supplemented postoperative care.(64) Colorectal surgery represents such a specialty with nearly 1 in 5 patients presenting to the ED within 30 days and at least half of those not requiring readmission.(3) Therefore, the aim of our study was to assess whether implementation of a mobile app with a patient-physician messaging feature would be associated with a reduced rate of potentially preventable ED visits after elective colorectal surgery.

### 3.2.3 METHODS

A prospective cohort quality improvement study was performed at a single high-volume colorectal referral centre from May 2019 – September 2020. The study protocol was reviewed and approved by the hospital's institutional review board (IRB) prior to the onset of the study.

*Eligibility:*

Patients were eligible for recruitment if they were scheduled to undergo elective abdominopelvic colorectal surgery from one of four colorectal surgeons at our center. Surgeries included colectomies, rectal resections, small bowel resection, and stoma surgeries. Patients seen solely for anorectal

procedures without an abdominal component were not eligible for recruitment. Patients were eligible for inclusion if they or an immediate caretaker in the same household were in the possession of a mobile smartphone, understood verbal and written English or French, and were comfortable with downloading, installing, and using mobile applications on their device. Patients were excluded if they had medical comorbidities that precluded their ability to respond to or understand questionnaires (ie. Cognitive) or were unable to read or understand English or French. Recruitment initially occurred during the preoperative clinic visit, however with the onset of the COVID-19 pandemic and the shutdown of in-person visits, approximately half of patients were recruited via telephone prior to their surgery or during their in-hospital stay.

*Intervention:*

Patients were offered the CareSense mobile app (MedTrak Inc., Conshohocken, PA), a fully customizable commercially available, HIPAA-compliant mobile app. The app comprised of patient education material on the expected postoperative course, daily questionnaires assessing post-discharge recovery, and patient-provider chat function. The patient education materials were digitized versions of our paper copy education materials (also available online at: http://www.muhcpatienteducation.ca/DATA/GUIDE/170_en~v~bowel-surgery-montreal-general-hospital.pdf). The app's functionality started upon installation at the pre-operative evaluation, usually 3-4 weeks prior to surgery. At this time, patients had access to educational resources, preoperative reminders, and could contact the care team regarding questions or concerns. Starting on Postoperative Day 0 (POD0), patients were asked daily if they had been discharged from hospital. If they answered No, no further questions were sent to the patient, to avoid redundancy with the in-hospital medical team. Once discharged, the patient received a "Daily Health Check" which consisted of 10 questions shown in Figure 1. Any positive finding to the "Daily Health Check" sent an automatic email notification to the care coordinator and treating surgeon, who could then contact the patient to address the finding.

**Daily Health Check**

1. Have you had fevers or chills in the past 24 hours?
2. Have you been able to eat or drink in the past 24 hours?
3. Have you had any nausea in the past 24 hours?
4. Have you had any vomiting in the past 24 hours?
5. Did you increase your pain medication in the last 24 hours?
6. Has the area around your wound become red in the past 24 hours?
7. Has the area around your wound become swollen in the past 24 hours?
8. Is there a bad smell coming from your wound?
9. Is fluid leaking from your wound?

**Figure 1: "Daily Health Check" questionnaire sent to patients following discharge from hospital.**

Furthermore, a positive answer to questions regarding wound appearance (Fig 1, Q6-9) prompted the patient to upload a photograph of the wound to the app, should they choose to do so. Completion of the daily questionnaires was not mandatory and done at the discretion of the patient.

Patients also had access to a chat feature which sent direct messages to the care coordinator and their treating surgeon. Patients were advised that chat messages were monitored from 7am-5pm, 7 days a week. Questions sent outside of these working hours were answered the next day. Patients were strongly advised that, should an emergency arise outside of working hours, they should present themselves to the Emergency Department for assessment. Patient questioned were either answered via the chat function or a telephone call was made in certain circumstances.

*Outcomes:*

The primary outcome of interest was the number of potentially preventable emergency department (ED) visits a 30-days. Potentially preventable is defined on the basis of ED-resource utilization. A grading scale of 1-4 was adapted from the New York University ED algorithm, initially developed to classify ED utilization by the NYU Center for Health and Public Service Research (Figure 2)(65). The gradings were: (1) non-emergent, (2) emergent but treatable in an ambulatory care setting, (3) emergent/ED-care required but preventable if timely outpatient care was available, and (4) emergent/ED-care required and non-preventable. Utilization of ED-specific resources (CT scan, Ultrasound, etc.) was automatically classified as a Grade 3 or 4. Cases in which the nature of the condition could not have been safely dealt with remotely

by a specialist surgeon were also deemed non-preventable (ie. Chest pain, shortness of breath, etc.). Grades 1-3 were considered potentially preventable. Each ED visit was reviewed independently by two reviewers, with a third independent reviewer in case of disagreement. Reasons for ED visits were divided into broad categories as follows: Genitourinary, Cardiopulmonary, Bleeding, Wound Complications, Stoma appliance & Drain issues, Organ Space Infections/Anastomotic leak, Non-infectious gastrointestinal (GI) issues (high output stoma, ileus, bowel obstruction), and Other. Secondary outcomes were clinical outcomes including 30-day readmissions, overall incidence and number of ED-visits, complications, mortality, and mean hospital length of stay (HLOS) during primary admission, as well as patient-reported usability and satisfaction with the app.

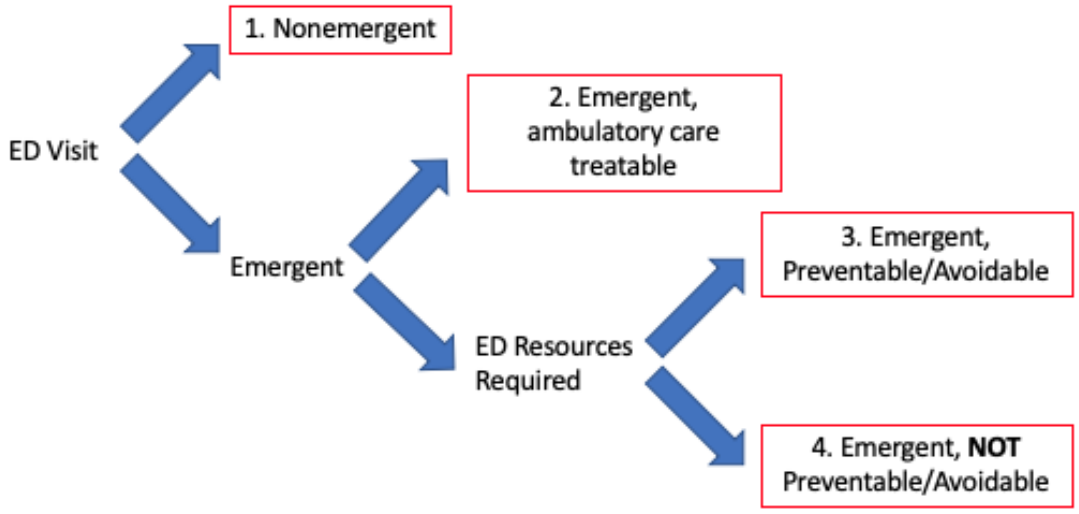


**Figure 2: Grading of potential preventability of ED-visits, adapted from the NYU ED Algorithm.**

At 30 days after surgery, patients were sent a questionnaire assessing their experience with the app which included measures of app usability, likelihood to recommend, perceived effect on communication with care team, and an open feedback App-usability was measured by the System Usability Scale (SUS). The SUS is a standardized tool that assesses intention to use, perceived usefulness, and perceived ease. It is scored on a scale of 100, with scores of 80.3 and above representing a Grade "A" usability. A 3-point Likert scale question assessing the effect of the app on communication between the patient and the physician was asked with the following options: "Worsened Communication", "No Change", and "Improved

Communication." Patients were asked to rate on a scale of 1-10 how likely they would be to recommend the app to another patient undergoing surgery. Lastly, patients could provide feedback and comments by means of an open-ended survey. These comments were analyzed according to the grounded theory approach.

Additionally, we reviewed all messages sent by patients and categorized them into the following categories: Medical/Recovery concerns, Administrative (ie. Follow-up, test results, insurance forms), Prescription Renewals, and App-related issues.

*Comparison & Matching process:*

To assess whether the implementation of the Caresense App had an effect on potentially preventable ED visits, we compared the prospective cohort (APP+) to a retrospective cohort (APP-) of colorectal patients who had undergone surgery in the 24 months preceding the study start date. APP+ and APP- patients were matched using a coarsened-exact matching process on age, sex, comorbidities, cancer diagnosis, planned stoma, and operative approach (laparoscopic vs. open). The matching algorithm was iteratively adjusted until there were no imbalances in these matching variables.

*Statistical Analysis:*

All statistical analyses were executed using the Stata software package (Stata v16.0, StataCorp). Descriptive statistics for the APP+ cohort were generated as means with 95% confidence intervals for continuous outcomes and as frequency & percentages for categorical variables.

Coarsened exact matching was used to match the APP+ and APP- groups to assess for outcome differences. All outcome comparisons were performed on the matched cohorts. Appropriate regressions were used and adjusted for matching weights. Poisson regressions were applied to compare count data such as potentially preventable ED visits and total number of ED visits, reported as incidence rate ratios. Sensitivity analyses were carried out to assess for zero-inflation and overdispersion. Logistic regressions were applied to compare dichotomous outcomes, reported as odds ratios. Linear regressions were applied to compare continuous data such as HLOS, reported as mean difference. Sensitivity analyses were done using generalized linear modeling with a gamma distribution for length of stay data (due to the right-skewedness of these data(66)), but the results were similar in magnitude and statistical significance as multiple linear regression. Therefore, the results of the multiple linear regression were reported. Similarly, a sensitivity analysis was done using zero-inflated Poisson to assess the number of preventable ED visits, but the results were similar in magnitude and significance as the standard Poisson regression. As such,

the results of the Poisson regression are reported. All regression analyses were adjusted for the matching weights. All statistics were reported with a 95% confidence interval and p-values.

### 3.2.4 RESULTS

*Mobile app (Caresense) cohort*

A total of 114 patients were recruited to the prospective Caresense app cohort. The patient population was predominantly male, with mean (SD) age 56.1 (13.1), 72.8% cancer, 25.4% rectal resection, 23.7% new stoma, and 83.3% laparoscopic (Table 1). In this unmatched cohort, 15 patients (13.2%) presented to the emergency department within 30 days for a total of 17 visits. The most common reasons for readmission was non-infectious gastrointestinal issues (6 visits, 37.5%) and organ space infections/anastomotic leaks (4 visits, 25.0%). A total of 8 patients (7.0%) required readmission.

*Matched comparison*

The Caresense cohort was matched to a retrospective cohort of 608 patients using coarsened-exact matching on age, sex, comorbidities, cancer diagnosis, planned stoma, and operative approach. Matching resulted in a matched sample of 94 APP+ and 256 APP- patients with well-balanced patient characteristics (Table 1).

*Potentially Preventable ED-visits:*

The APP+ group had 14 patients (15%) present for a total of 15 ED visits at 30 days, of which 4 were determined to be potentially preventable. The APP- group had 38 patients (15%) present for a total of 41 visits, of which 23 were deemed to be potentially preventable. There was a significant independent decrease in preventable ED visits in the APP+ group (adjusted IRR 0.34 (95%CI: 0.12 – 0.97, p = 0.043). Poisson data may be prone to overdispersion which reduces the validity of the Poisson model, however our data found that the mean number of preventable visits was equal to the variance.

The common reasons for potentially preventable ED-visits were wound complications (26%) and minor bleeding (22%) in the APP- cohort, and ostomy appliance and drain issues (50%) in the APP+ group (Table 2).

*Secondary Outcomes:*

Patients in the APP+ cohort had a statistically significant reduction in mean HLOS as compared to the APP- cohort (Table 3). There was no statistical difference noted in number of patients with 30-day complications, 30-day ED visits, or readmissions (Table 3). The reasons for all 30-day ED visits (preventable & not preventable) differed between cohorts, with SBO/Ileus and Organ Space Infection/Anastomotic Leak being the most common in the APP+ cohort, and Wound Complications and Bleeding being most common in the APP- cohort (Table 4).

*App usage, usability, and satisfaction:*

A total of 63 patients (55%) used the app's chat messaging feature, for a total of 871 messages over the study period. Of patients who contacted the care team, 88.7% contacted for advice or concerns regarding their recovery, 66.1% contacted for administrative purposes (follow-up, reports, insurance forms), 21% contacted for prescription renewals, and 21% contacted for concerns regarding issues with the app platform.

A total of 41 (36%) patients returned the follow-up questionnaire assessing usability and satisfaction. Patient-reported usability as measured by the SUS score was 84.5 (SD 17.6). A high proportion of patients (88%) indicated that the app improved their ability to communicate with their surgeon. When asked to rate how likely patients were to recommend the app to another patient undergoing surgery (Likert scale 1-10), patients scored the app a 9.4 (SD 1.5).

Patients were furthermore asked for their feedback regarding their experience through an open-ended survey. A central theme in the feedback comments was that patients felt more secure after discharge because of the ability to easily communicate with their provider. Several representative patient comments (edited for clarity) are shown below:

*"I think this is the best way to communicate with the doctor. It feels secure to know you have an app to contact them at any time for urgent situations. I highly recommend using this app as it saves time for both sides, the doctor and the patient."*

*"Fantastic tool, especially to communicate with surgery team. Prompt responses. Very useful in the first days after surgery. I recommend it very much. Had some small complications after surgery and was able to communicate with surgeon and got very positive feedback that was helpful in understanding the situation."*

### 3.2.5 DISCUSSION

The current study demonstrates that use of a mobile app with a messaging feature was associated with fewer potentially preventable ED visits and a shorter LOS after major elective colorectal surgery. Furthermore, feedback from patients highlighted high usability and a general sense of security in having direct access to their treating surgeon during the initial recovery period after discharge.

These results are consistent with other studies evaluating the effectiveness of mHealth interventions to minimize unplanned healthcare utilization after colorectal surgery(13, 28, 56). For example, Borsuk *et al.* instituted an active post-discharge surveillance program centered on a text-messaging platform that allowed colorectal surgery patients to initiate direct contact with their care team (surgeon, nurses, care coordinators etc.)(13). They found that the intervention group had significantly less ED visits and readmissions, in addition to a significantly shorter hospital length of stay (2.6 vs. 4.7 days)(13). Patient satisfaction with the intervention was also high.(13, 28) Together with the current report, these studies suggest that enhanced communication between patient and care teams in the outpatient period can have significant effects on patient well-being, clinical outcomes, and associated costs. In other studies, higher patient satisfaction was associated with lower ED visits but increased in-hospital medical expenditures.(67, 68) In this study user satisfaction was high, likely due to the enhanced patient-physician communication through the app, despite potentially lower resource utilization. Therefore, this platform may be a potential avenue to increase patient satisfaction without requiring increased medical expenditures.

However, the benefit of mHealth interventions may not be generalizable to all surgical subspecialties. High-acuity or complex specialties that have a high incidence of unavoidable ED visits such as cardiac and vascular procedures may not be amenable to mHealth interventions.(23, 40) Procedures that have a high return rate and a significant proportion of potentially preventable visits are likely to represent the best targets for telemedicine-based interventions. Patient undergoing major abdominopelvic colorectal surgery stand to benefit most from such interventions as they have a high rate of ED visits (20%), many of which are potentially preventable(3). Indeed, patients often presented to the ED for wound concerns, urinary tract symptoms, and non-infectious gastrointestinal issues such as high output stomas(3, 13, 28). In the current study, many of these issues were managed remotely through the app, or patients were directed to the clinic for management rather than the ED. Similarly, Borsuk *et al.* highlighted that these ED-visit “saves” occurred in nearly a quarter of their patients and were often for complaints such as pain,

wound concerns, and vomiting, all of which they managed remotely (13). Together, these results highlight a notable benefit of mHealth platforms in colorectal surgery given the high proportion of preventable visits in this population. The app that was used in this study is one of many mHealth apps that are available. Any of these applications can be used and would likely have had the same effect in this study. As long as the app is user-friendly, is customizable to allow for institution-specific material, and includes a patient-physician communication feature, the specific app itself is likely to be less important than its contents. The specific app or platform should be dictated according to availability, user preference, and costs.

Interestingly, APP+ was associated with shorter LOS. There may be several reasons for this finding. First, treating physicians may have become more comfortable sending patients home prior to full recovery as they gained experience and confidence with the post-discharge follow-up ability of the app (as well as the patients' use of this app to communicate concerning symptoms). Second, APP+ patients may have been more motivated to return home and be more active in their recovery process. While we did not measure patient activation or health literacy, it may have been higher for the participants of this study. High patient activation has been previously shown to decrease health care utilization after abdominal surgery.(69) Third, there may have been secular trends over time, and especially given the context of the COVID pandemic which may have affected the patient's willingness to stay in hospital. Another study by Borsuk *et al.* published prior to the pandemic did however show similar results, with a reduction in LOS from 4.7 to 2.6 days in the active post-discharge monitoring group.(13)

One of the concerns regarding this mHealth intervention is the time requirement for the healthcare providers, which may be especially limiting in a busy surgical practice(70). Our experience found this time burden to be low, as most responses were very limited in scope and required minimal time commitment, and many days had no patient contact. Patients generally sent appropriate messages that were relevant to their surgical care and recovery. However, we were not able to directly measure the burden on the health care provider team other than the number of messages received.

The results of this study need to be interpreted in light of other limitations. Our institution is a regional referral centre that services a large geographical area. There may have been unplanned visits that occurred outside of our centre, however given our case complexity and practice patterns, patients readmitted elsewhere generally are transferred back to our centre for management. Second, our

satisfaction survey was not built into the app and had to be sent in a follow-up email, but only a minority of patients completed it. Finally, patients who participated in the study were younger than our overall patient population. While we account for this in the matching process, this finding may limit the generalizability of the findings to younger patients able to use mobile apps. In certain situations, the app was installed on the device of a primary caregiver or family member if the patient was unable to operate the app themselves. The presence of strong social support was also a potential bias affecting healthcare utilization, one that we could not reasonably account for in the current study(71). We also did not measure health literacy or patient activation, both of which may affect app usage as well as health resource utilization(72, 73). Furthermore, we did not perform a cost-analysis, a necessary step prior to widespread implementation of such interventions. That said, deriving a generalizable economic evaluation is difficult to achieve as each healthcare system differs significantly with regards to reimbursement methods and cost data. Such evaluations would have to be done on a case by case basis to best assess to assess eco nomic viability within a given system. Finally, this study was also conducted in part during the coronavirus (COVID-19) pandemic. This may have affected patient participation and may have potentially affected ED visits, as well as the case complexity of the operated cases.(74)

Our experience with the app was very positive with high uptake amongst patients and the involved healthcare providers. Future iterations of the app or similar platforms may need to streamline the user experience by limiting the number of surveys and tasks, as this may not be routinely completed by patient. What was clear from our experience was that the most useful feature was the patient-physician communication. Patients benefited from having a dedicated first-line responder that answered questions within thirty minutes of sending. To ensure timely response and satisfaction with patients may require a dedicated person to monitor and respond to questions, either the treating surgeon on an allied health professional trained in the field. Future studies should examine whether other platforms can be used to improve this communication in the post-discharge setting without increasing provider burden.

In conclusion, the use of a mobile app was associated with fewer potentially preventable ED visits and shorter length of stay after major elective colorectal surgery, likely due to enhanced post-discharge monitoring and patient-provider communication. mHealth technology has the potential to increase patient satisfaction and value in colorectal surgery.

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**FIGURES**

| | Unmatched Cohort | | | Matched Cohort | | |
|---|---|---|---|---|---|---|
| **Patient demographics** | **APP+ (n = 114)** | **APP- (n = 608)** | **p** | **APP+ (n=94)** | **APP- (n=256)** | **p** |
| Age mean (SD), years | 56.1 (13.1) | 60.9 (14.9) | 0.0016 | 54.7 (13.2) | 56.4 (14.9) | 0.3529 |
| Male n (%) | 73 (64%) | 343 (56%) | 0.131 | 60 (64%) | 139(54%) | 0.1105 |
| CCI mean (95%CI) | 3.5 (3.0 – 4.0) | 3.8 (3.6 – 4.0) | 0.3126 | 3.0 (2.6 – 3.4) | 3.1 (2.8 – 3.3) | 0.7940 |
| Indication for OR n (%) | | | 0.022 | | | 0.877 |
| Neoplastic | 83 (72.8%) | 371 (61.0%) | | 66 (70.2%) | 177 (69.1%) | - |
| IBD | 17 (14.9%) | 95 (15.6%) | | 16 (17.0%) | 41 (16.0%) | - |
| Other (Diverticular Disease, Stoma, Other) | 14 (12.3%) | 142 (23.4%) | | 12 (12.8%) | 38 (14.8%) | - |
| Surgical Procedure n (%) | | | 0.107 | | | 0.896 |
| Right/Transverse Colectomy | 37 (32.5%) | 177 (29.1%) | | 30 (31.9%) | 76 (29.7%) | - |
| Left/Sigmoid Colectomy | 28 (24.6%) | 154 (25.3%) | | 21 (22.3%) | 70 (27.3%) | - |
| Rectal | 29 (25.4%) | 132 (21.7%) | | 25 (26.6%) | 65 (25.4%) | - |
| Subtotal/TAC/TPC | 9 (7.9%) | 29 (4.8%) | | 7 (7.5%) | 15 (5.9%) | - |
| Other (ie. Stoma closure, SB) | 11 (9.7%) | 116 (19.1%) | | 11 (11.7%) | 30 (11.7%) | - |
| Operative Approach | | | <0.001 | | | 0.562 |
| Laparoscopic | 95 (83.3%) | 404 (66.5%) | | 82 (87.2%) | 217 (84.8%) | - |
| Open | 19 (16.7%) | 204 (33.6%) | | 12 (12.8%) | 39 (15.2%) | - |
| Stoma n (%) | 27 (23.7%) | 135 (22.2%) | 0.728 | 19 (20.2%) | 43 (16.8%) | 0.458 |

**Table 1: Patient demographics, clinical, and surgical details for matched and unmatched cohorts.**

| Reason | APP+ (n=4) | APP- (n=23) |
|---|---|---|
| Wound complications | 1 (25%) | 6 (26%) |
| Minor Bleeding | 0 | 5 (22%) |
| Pain | 0 | 3 (13%) |
| Non-infectious GI issues | 1 (25%) | 3 (13%) |
| Other | 0 | 3 (13%) |
| Genitourinary | 0 | 2 (9%) |
| Stoma appliance & Drain issues | 2 (50%) | 1 (4%) |

**Table 2: Common reasons for potentially preventable visits in APP+ and APP- matched cohorts.**

| | **APP+ (n = 94)** | **APP- (n=256)** | **Statistic 95% CI p-value** |
|---|---|---|---|
| *Main Outcome* | | | |
| Total number of preventable ED visits | 4 | 23 | Incidence Rate Ratio: 0.34 (95% CI 0.12 – 0.97) **p = 0.043** |
| | | | |
| *Secondary Outcomes* | | | |
| Mean length of stay, days (95%CI) | 3.2 (2.2 – 4.2) | 4.6 (4.1 – 5.2) | Mean difference: -1.62 days (95%CI -2.88 – -0.38) **p = 0.011** |
| 30-day complications, n (%) | 21 (22%) | 68 (27%) | Odds ratio: 0.68 (95%CI 0.39 – 1.19) p = 0.175 |
| 30-day ED visits, n (%) | 14 (15%) | 38 (15%) | Odds ratio: 0.84 (95%CI 0.44 – 1.61) p = 0.592 |
| Total number of ED visits | 15 | 41 | Incidence Rate Ratio: 0.85 (95% CI 0.48 – 1.53) p = 0.594 |
| Readmissions, n (%) | 7 (7%) | 16 (6%) | Odds ratio: 1.58 (95%CI 0.61 – 4.13) p = 0.348 |

**Table 3: Primary and secondary outcomes in matched APP+ and APP- cohorts.**

| Reason | APP+ (n=15) | APP- (n=41) |
|---|---|---|
| Wound complications | 1 (6.7%) | 8 (19.5%) |
| Bleeding | 1 (6.7%) | 8 (19.5%) |
| Genitourinary | 1 (6.7%) | 5 (12.2%) |
| Pain | 0 | 5 (12.2%) |
| Other | 1 (6.7%) | 5 (12.2%) |
| SBO/Ileus | 3 (20.0%) | 4 (9.8%) |
| Noninfectious GI Issues | 2 (13.3%) | 3 (7.3%) |
| Organ Space Infection/Anastomotic Leak | 3 (20.0%) | 3 (7.3%) |
| Stoma appliance & Drain issues | 2 (13.3%) | 0 |
| Cardiopulmonary | 1 (6.7%) | 0 |

**Table 4: Common reasons for all 30-day ED visits in APP+ and APP- matched cohorts.**

## CHAPTER 4 – DISCUSSION

### 4.1 General Findings

This thesis investigated the effect of postoperative telemedicine interventions on healthcare utilization after elective abdominopelvic colorectal surgery. A systematic literature review reported limited efficacy of telemedicine in reducing ED visits across surgical specialties, but this may have been due to significant heterogeneity. In colorectal surgery specifically, we provided evidence that half of ED visits at our center were potentially preventable and were likely the product of a lack of patient access to specialized care in the postoperative period. Based on this, we implemented a mobile phone app that promoted patient-surgeon communication in the postoperative period and found a significant reduction in the rate of potentially preventable ED visits.

Emergency department visits for conditions that could be treated in outpatient settings represent a stunning $38 billion in wasteful expenditures in the North American healthcare system, highlighting a target for quality improvement in our global delivery of care(1). In Chapter 2, we found that 17.6% of patients presented to the emergency room, with only 43.6% requiring readmission. We went one step further and identified the reasons for which patients presented, as well as the resources that were required for each visit. Reasons such as concerns related to wound healing, gastrointestinal issues such as high output stoma, and minor bleeding dominated, accounting for over 50% of preventable visits. These issues are either part of the normal recovery process or expected postoperative complications, which highlights a lack of clear expectations conveyed to the patient during their recovery. Beyond this, these complications are often self-limited or require minimal resources to be addressed successfully in an outpatient setting. These indications were likely to be minimized with better outpatient post-discharge monitoring and communication.

Access to specialized care during the outpatient recovery period is limited in the current Canadian system. Jones *et al.* highlighted this in a qualitative study, finding that most patients were advised to present to the emergency room in the event of concerns regarding their recovery(6). This highlights a communication breakdown that exists between patient and physician following discharge from the surgical ward, one that can be easily addressed in the modern era of mobile health technology. Mobile phone ownership in the adult North American population is nearly universal, and only expected to rise with time, representing a platform through which to improve access to information in surgical patient populations(7). In Chapter 1, we highlighted that several subspecialties have developed novel tools to enhance patient-physician communication, with varying effects on unplanned healthcare utilization. Indeed, our systematic review

found that not all specialties are likely to benefit from such interventions. This is likely to be in part mediated by low return rates in certain specialties or high proportion of non-preventable visits. As such, specialties like colorectal surgery which have a high return rate, of which nearly half are preventable, represent a prime target for telemedicine-based postoperative interventions.

In Chapter 3, we tested this hypothesis and indeed found that implementation of a mobile app that allowed for patient-physician communication resulted in a statistically significant reduction in preventable emergency department visits at 30 days following surgery. Several studies have assessed similar interventions, with similar positive outcomes to our own(13, 28, 56). However, positive findings alone are insufficient to support widespread implementation of such interventions, as the question regarding cost effectiveness remains unanswered. While Iqbal *et al.* estimated that their intervention had a significant cost-reduction impact, neither our study nor Borsuk *et al.* assessed the cost of implementing such an intervention or the effect it had on resource consumption or costs (13, 28).

**4.2 Discussion of Methodology**

In Chapter 1, we presented a systematic review of telemedicine interventions in postoperative patients, in which we found significant heterogeneity in both the patient populations and the type of interventions delivered. Systematic reviews represent the highest quality in terms of literature reviews as the systematic and explicit methods used to identify publications minimize the risk of missing key publications in the domain. However, our search is limited by the lack of a commonly accepted definition for "telemedicine." Indeed, a 2007 study found 104 distinct definitions for the term, leading the World Health Organization to define it as:

> "*The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment, and prevention of disease and injuries […]"(75, 76)*

Information and communication technologies is a broad definition the encompasses a breadth of platforms such as the internet, cell phones, computers, telephones, and many others. We attempted to encompass all these possibilities in our search strategy. Here we found a multitude of different interventions, ranging from once a week telephone calls, to email services, and finally mobile app messaging features. With such breadth and diversity of telemedical interventions, the risk of missing certain key publications is present and its effect difficult to characterize. Furthermore, a significant number of studies were deemed to be at significant risk of bias, predominantly driven by the lack of

control for confounding domains that may affect usage of mobile health technologies such as patient education level, age, socioeconomic status, and user satisfaction with a given intervention. This level of bias inherently weakens the conclusions we can draw from overall pooled estimates. To account for this, we performed subgroup analyses by risk of bias, which did not show significant differences from our overall pooled effect size estimates.

In Chapter 2, we performed a retrospective review to assess the rate and reasons why patients presented to the emergency department following elective colorectal surgery. We further assessed the proportion of visits that were deemed potentially preventable by applying the NYU ED algorithm to this patient population. The NYU ED algorithm was developed using a panel of physicians who reviewed thousands of charts and assessed resource utilization of each visit, determining if these resources were ED-specific. They then attributed one of four gradings, with only the last category being considered completely non-preventable. This algorithm has since been validated in several large follow-up studies assessing ED-visits in different populations. However, while the algorithm is validated in the broad population of emergency department patients, it has not been validated in the context of post-operative patients(65). We adapted this model to fit the colorectal patient population. Each visit was reviewed by two independent reviewers, with a Cohen's weighted Kappa score calculated to assess inter-rater reliability (IRR). Use of a Kappa score is appropriate in this context as it is considered a more robust assessment of IRR in that it accounts for chance agreement(77). Cohen's Kappa represents a weighted variation on this statistic best applied to rating schemes with more than two possibilities, in that it incorporates the degree of disagreement between raters. In our report, we reached a Kappa of 0.58, which suggests moderate inter-rater reliability(77). This highlights a certain level of heterogeneity in which the adapted preventability rating system was applied, suggesting that a more thorough and consistent grading scheme is necessary. Nevertheless, we hope that the current suggested system encourages others to apply and adapt this system to their surgical subspecialty with the intent of finding a consistent way of assessing preventability of emergency department resource utilization.

The retrospective nature of Chapter 2 imposes certain limitations on our conclusions. First, retrospective studies rely on the completeness of medical records for accuracy, which is highly dependent on the individual user who submits clinical information and notes. This may result in our inability to capture the full extent of what occurred during each ED visit and thus exert a bias on the grading preventability. Second, patients that were assessed in this cohort were never directly contacted and did not have access to our app platform and thus it is very likely that certain patients may have not presented to our

emergency department for complications at home, opting to “tough it out” at home. Our inability to capture these complications is likely to underestimate the true rate of ED visits and complications. This is compounded by the fact that patients may not necessarily present to an ED affiliated with our institution. Given that the McGill University Health Centre is a referral center for colorectal surgery, patients often present from several neighboring cities that do not share their medical records with us. As such, patients may have at times presented to other hospitals, leading to a further underestimation of the true rate of postoperative complications and healthcare utilization. A more optimal assessment of the true healthcare needs of postoperative colorectal patients would have been to perform a prospective cohort study in which patients were followed in the perioperative period, thus capturing more accurately clinically relevant events. However, such a study is often costly and resource-intensive, a primary reason for which it was not executed in this manner.

In Chapter 3, we assessed the effect of a mobile app-based intervention on reducing unplanned healthcare utilization after elective colorectal surgery. Our study used a prospective cohort design with coarsened exact matching to a retrospective cohort, a format that is inherently at risk of bias. Indeed, assessment of a given intervention is usually best achieved through a randomized-controlled trial. In our setting however, a randomized controlled trial would have required greater resources and a longer accrual period, one not amenable to reasonable completion within a 1-year time frame of the current thesis. While coarsened-exact matching helps to address baseline imbalances, it only accounts for the specified set of variables that are used for matching, ignoring the potential effect of unknown confounders. Short of a randomized controlled trial however, it represents an appropriate method to establish a reasonable comparison.

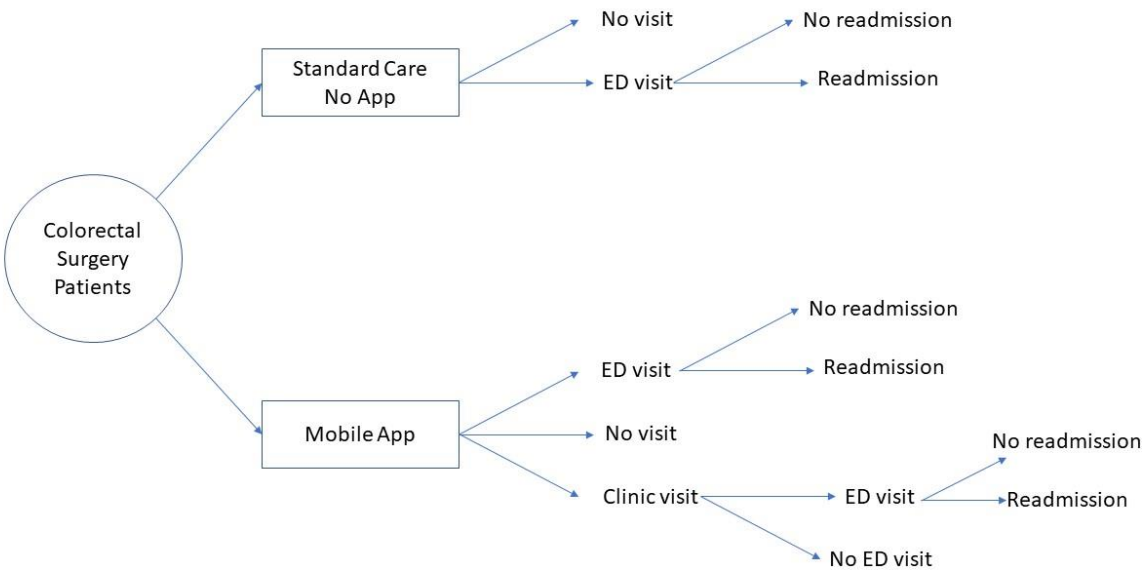
Beyond this however, several known confounders that affect patient outcomes and use of novel health technologies were not accounted for, such as patient health literacy and patient activation with the novel intervention. It is hypothesized that patients who are not ‘activated’ or ‘engaged’ are not as involved in their care and may take a more passive approach to seeking out medical care. In the case of ED visits after surgery, these patients may not seek out other means of communicating with their physician and simply present to the ED for any issues, whether they be minor or major. Similarly, patients with low health literacy may not understand the information that is provided to them and may seek out unnecessary medical care. Low health literacy has previously been demonstrated to be associated with poor health outcomes in the management of chronic disease(72). However, few studies have assessed whether this is true in surgical populations, despite it being demonstrated that low health literacy is present in over a

third of surgical patients(72). Similarly, low patient activation and adherence to treatment protocols is associated with poorer surgical outcomes(60). While the app we implemented had reminders for patients with regards to certain postoperative elements, we did not measure whether this translated to improved adherence. Furthermore, our group previously demonstrated no significant benefit in adherence with the use of mobile apps in postoperative patients (60). Not accounting for both factors weakens our ability to conclude a causative link between our intervention and the observed benefits, at most allowing us only to highlight an association between the two. As such, it would be reasonable to suggest that patients who used the app could have been more proactive patients with higher patient activation and literacy, predisposing them to seek out medical assistance earlier than others which in turn may explain the observed improvement in their outcomes.

In terms of analysis, Chapter 3 assessed the rate of preventable ED visits in both matched cohorts using a Poisson regression. Poisson was deemed appropriate in the sense that ED visits represent count data with each patient presenting for an ED visit independent from the next. Visit data may be prone to overdispersion which reduces the validity of the Poisson model, however in our data the mean number of preventable visits was equal to the variance. Furthermore, we found that a significant number of patients never presented to ED and thus we were concerned that our Poisson model may be prone to zero-inflation. To address this, we performed sensitivity analyses in which we compared the Poisson model to a zero-inflated Poisson model. Both models showed nearly identical results (IRR: 0.34 vs. 0.35), suggesting that our data did not over-represent a zero count and thus a standard Poisson was an appropriate model. Secondly, we assessed mean difference in length of stay using a linear regression model. However, length-of-stay distributions are often prone to right skew and thus a linear regression model may not be appropriate. To assess whether our normality assumptions were met we plotted the distribution on a histogram, finding the data to be reasonably normal but with a small right-sided tail. To assess whether the skew affected the linear regression output we performed a sensitivity analysis applying a generalized linear model (GLM) of a gamma distribution, which is more robust to skewed data. Here again, we found our GLM results to be essentially identical (34% vs. 31% reduction in length of stay), suggesting that our initial data set was not significantly skewed to begin with and thus a linear regression model was appropriate.

### 4.3 Future Directions

This thesis demonstrates a benefit for telemedicine interventions in reducing preventable ED visits after elective colorectal surgery. Furthermore, we demonstrated that use of a telemedicine app was associated




with a significant reduction in hospital length-of-stay. Together, these suggest a potential economic benefit to such intervention, which future studies should explore. Designing a cost-effectiveness assessment (CEA) would likely have to be done on a case-by-case basis, as each healthcare system has different costs, resources, and payment systems.

**Figure 1. Cost-effectiveness assessment decision tree diagram.**

Based on our results, it is likely that the main effects of mHealth for post-discharge follow-up are on the healthcare resource utilization post-discharge. In this setting, patients may not necessary seek medical attention at the same hospital as their surgery, depending on the acuity of their medical issue. Therefore, a CEA should be performed from the healthcare system perspective. It would also be necessary to use a societal perspective to determine if this intervention has any effect on caregiver burden or productivity losses. Second, certain broad categories of cost would have to be determined and defined appropriately: (1) cost of the primary hospital admission based on length of stay, (2) cost associated to developing, implementing, and maintaining a mobile app intervention, (3) social costs of increased caregiver support associated with potentially earlier discharges, and (4) an estimate of the mean cost of ED visits, clinic visits, and readmission costs, or a combination of these that could occur in the postoperative period.

Second, we noted that our inability to control for patient activation or health literacy limits our ability to demonstrate a causative benefit between mHealth interventions and health outcomes. To truly assess the effect of health literacy and patient activation, future studies in the form of a 4-arm randomized

controlled trial comparing app patients to non-app users in high and low literacy/activation groups would be necessary. Such studies would provide greater insight into the true benefit of mHealth interventions, and a great confidence in our ability to suggest a causative benefit. This study design may also further inform where additional interventions may be necessary to improve patient activation and health literacy.

## CHAPTER 5 – CONCLUSION

This thesis assessed the benefit of telemedicine interventions in reducing emergency department visits after elective colorectal surgery. In Manuscript 1, we found that telemedicine in surgery overall has mixed effects, suggesting that surgical specialties with a moderate-high return rate and a significant proportion of potentially preventable visits were likely to benefit most from telemedicine-based interventions. In Manuscript 2, we highlighted that colorectal surgery represented such a specialty, in that it had both a high return rate, half of which were preventable. Lastly, in Manuscript 3, we implemented a mobile app intervention with a patient-physician communication feature and found that it resulted in a significant reduction in preventable emergency department visits, as well as shorter hospital length-of-stay. Furthermore, patient demonstrated high levels of satisfaction with the intervention. Overall, telemedicine represents a promising avenue to improve the quality of care delivered and patient outcomes in the postoperative period. Future directions should assess the cost implications of such interventions.

**CHAPTER 6 – REFERENCES**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