The Clinical and Economic Implications of Same Day Discharge Compared to Enhanced Recovery Protocols Following Minimally Invasive Colectomy and Stoma Reversal

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December 2023

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree Master's in Clinical Epidemiology

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ABSTRACT

Introduction

Enhanced recovery protocols (ERPs) after minimally invasive colorectal surgery are well established in the literature resulting in faster return of gastrointestinal function, shorter lengths of stay, and reduced complications. Same day discharge (SDD) after colorectal surgery represents the next step in the evolution of ERPs. While preliminary evidence suggests that SDD offers benefits to both patients and our healthcare system, including shorter hospital stays and similar postoperative outcomes compared to ERPs, it is important to acknowledge there is a proportion of patients who fail SDD. Importantly, factors predicting SDD failure, and the potential financial consequences of these programs remains unclear.

Objectives

1) To identify predictive factors associated with SDD failure and success and, 2) to identify the cost implications of SDD at the institutional level for patients undergoing minimally invasive colectomy and stoma reversal.

Methods

Ethics approval was obtained under the McGill University Health Centre prior to the initiation of these studies. 1) Adult patients who underwent elective minimally invasive colectomy or ostomy reversal at a tertiary colorectal centre between January 2020 and March 2023 were eligible for SDD with remote post-discharge follow-up. Eligibility criteria included minimal comorbidities, proximity to the hospital, sufficient home support, and ownership of a mobile device. Patients meeting these criteria were discharged on the day of surgery if they met specific discharge

criteria, which included adequate oral analgesia, tolerance of liquids, independent ambulation and urination, and the absence of complications. Data was collected prospectively, and patients successfully discharged on the same day were compared to those who failed in an effort to identify factors associated with SDD success or failure using univariate and regression analyses. 2) A coarsened exact matching was used to create comparable patient groups undergoing SDD versus ERP following laparoscopic colectomy or ostomy reversal. These groups were matched for age, body mass index (BMI), sex, Charlson Comorbidity Index, and procedure. The coarsened exact matching algorithm was adjusted to achieve a state of balance between the two groups without significant differences. The comparative ERP cohort consisted of a retrospective group of patients who underwent minimally invasive colectomy or ostomy reversal at the same hospital centre as the initial study, spanning from August 2017 to March 2022. These patients were subject to the same inclusion criteria as those undergoing SDD. Institutional costs were calculated through a microcosting technique from the time of surgery to 30-days postoperatively and reported in Canadian dollars. Uncertainty was conveyed through 10,000 bootstrapped estimates.

Results

1)A total of 175 (85.3%) achieved successful SDD, while 44 patients (21.5%) experienced SDD failure. The SDD failure group exhibited a higher Charlson Comorbidity Index (3.7, 2.8, p-value=0.03). Notably, mean length of stay (0.8, 3.0, p-value=0.00), 30-day complications (10%, 48%, p-value=0.00) and readmissions (8%, 27%, p-value=0.00) were significantly higher in the SDD failure group. Regression analysis revealed that failed SDD was associated with increased comorbidity burden (OR 0.79, 95% CI 0.66, 0.95) and longer Post Anesthesia Care Unit (PACU)

time (OR 0.99, 95% CI 0.99, 0.99). Conversely, individuals who received a regional nerve block (OR 4.1, 95% CI 1.2, 14) and those who did not require postoperative opioids (OR 4.6, 95% CI 1-21) were more likely to achieve successful SDD. 2) During the study period, a total of 689 patients underwent colectomy or stoma reversal (121 SDD, 568 ERP), with 305 patients included after matching (96 SDD, 209 ERP). Cost analysis revealed savings of $1,817 (95% CI -3021 to -613) per patient for SDD colectomy and 2344$ (95% CI -3838 to 851) for stoma reversal. Majority of cost savings were observed in ward, pharmaceutical, and allied healthcare expenses. Total length of stay was significantly shorter in SDD patients undergoing colectomy with no difference in those undergoing stoma reversal compared to the ERP cohort. Emergency department (ED) visits were higher in SDD patients undergoing stoma reversal, with no significant difference in those undergoing colectomy compared to the ERP cohort.

Conclusion

Overall, SDD is safe, effective, and associated with an institutional cost savings in select patients. Our findings underscore the importance in careful patient selection as those with increased comorbidities and prolonged PACU stays are at increased risk of SDD failure.

RÉSUMÉ

Introduction

Les protocols de rétablissement amélioré (ERPs) après une chirurgie colorectale laparoscopique sont bien établis dans la littérature, entraînant un rétablissement plus rapide de la function gastrointestinale, des durées de séjour plus courtes et des complications réduites. La sortie le jour méme (Same Day Discharge = SDD) après une chirurgie colorectale représente la prochaine étape de l'évolution des ERPs. Bien que des preuves préliminaires suggèrent que la SDD offer des avantages aux patients et à notre système de santé, notamment des séjours plus courts à l'höpital et des résultats postopératoires similaires par rapport aux ERPs, il est important de reconnaître qu'une proportion de patients échoue dans la SDD. Il est également important de noter que les facteurs prédisant l'échec de la SDD et les consequences financières potentielles de ces programmes restent incertains.

Objectifs

1)Identifier les facteurs prédictifs associés à l'échec et à la réussite de la SDD. 2) Identifier les implications financières de la SDD au niceau institutionnel pour les patients subissant une colectomie laparoscopique et une inversion de stomie.

Méthodes

Une approbation éthique a été obtenue auprès du Centre universitaire de santé McGill le début de ces études. 1) Les patients adultes ayant subi une colectomie laparoscopique elective ou une inversion de stomie dans un centre colorectal tertiaire entre Janvier 2020 et mars 2023 étaient éligibles pour la SDD avec un suivi à distance après la sortie. Les critères d'éligibilité

comprenaient des comorbidités minimales, la proximité de l'hôpital, un soutien à domicile suffisant et la possession d'un appareil mobile. Les patients répondant à ces critères étaient renvoyés le jour de la chirurgie s'ils répondaient à des critères de sortie spécifiques, notamment une analgésie orale adequate, la tolerance des liquids, l'ambulation et la miction indépendantes, ainsi que l'absence de complications. Les données ont été collectées de manière prospective, et les patients renvoyés avec succès le même jour ont été compares à ceux qui n'ont pas réussi à identifier les facteurs associés à la réussite ou à l'échec de la SDD à l'aide d'analyses univariées et de regression. 2) Une correspondence exacte grossière a été utilisée pour créer des groups de patients comparables subissant une SDD par rapport à une ERP après colectomie laparoscopique ou inversion de stomie. Ces groups ont été appariés pour l'âge, l'indice de masse corporelle (IMC), le sexe, l'indice de comorbidité et la procedure. L'algorithme de correspondence exacte grossière a été ajusté pour atteindre un équilibre entre les deux groups sans differences significatives. La cohort comparative de la cohort ERP se composait d'un groupe rétrospectif de patients ayant subi une colectomie laparoscopique ou une inversion de stomie dans le même centre medical que l'étude initiale, de août 2017 à mars 2022. Ces patients étaient soumis aux mêmes critères d'inclusion que ceux subissant une SDD. Les coûts institutionnels ont été calculés par microcoûtage depuis le moment de la chirurgie jusqu'à 30 jours après l'opération et ont été rapportés en dollars canadiens. Une correspondence exacte grossière a éré utilisée pour créer des groups similaires de patients. L'incertitude a été transmise grâce à 10,000 estimations bootstrap.

Résultats

Au total, 175 (85.3%) ont réussi la SDD, tandis que 44 patients (21.5%) ont connu un échec de la SDD. Le groupe d'échec de la SDD présentait un indice de comorbidité de Charlson plus élevé (3.7,2.8,p-value=0.03). De manière significative, la durée moyenne du séjour (0.8,3.0,p-value=0.00), les complications à 30 jours (10%,48%,p-value=0.00) et les readmissions (8%,27%,p-value=0.00) étaient nettement plus élevées dans le groupe de la SDD. L'analyse de regression a révélé que l'échec de la SDD était associé à une charge de comorbidités accrue (OR0.79,95%CI0.66,0.95) et à une durée prolongée en PACU (OR0.99,95%CI0.99,0.99). En revanche, les individus ayant reçu un bloc nerveux régional (OR4.1,95%CI 1.2,14) et ceux n'ayant pas eu besoin d'opioïdes postopératoires (OR4.6,95%CI 1-21) étaient plus susceptibles de réussir la SDD. 2) Pendant la période de l'étude, un total de 689 patients ont subi une colectomie ou une inversion de stomie (121 SDD, 568 ERP), avec 305 patients inclus après appariement (96SDD, 209 ERP). L'analyse des coûts a révélé des économies de 1817$ (95% CI-3021, -613) par patient pour la colectomie en SDD et de 2344$ (95% CI -3838, 851) pour l'inversion de stomie en SDD. La majorité des économies de coûts ont été observes dans les dépenses liées aux services hospitaliers, pharmaceutiques et de soins de santé. La duré2 totale du séjour était nettement plus courte chez les patients en SDD subissant une colectomie, sans difference chez ceux subissant une inversion de stomie par rapport à la cohort ERP. Les visites aux services d'urgence étaient plus fréquentes chez les patients en SDD subissant une inversion de stomie, sans difference significative chez ceux subissant une colectomie par rapport à la cohorte ERP.

Conclusion

Dans l’ensemble, la SDD est sûre, efficace et associée à des économies institutionnelles pour certains patients. Nos résultats soulignent l’importance d’une selection minutieuse des patients, car ceux présentant des comorbidités accrues et des séjours prolongés en salle de réveil courent un risqué accru d’échec de la SDD.

THESIS FORMAT

The following thesis is presented in a manuscript-based format including two manuscripts. The manuscript titled “Predictive Factors for Successful Same day discharge following minimally invasive colectomy and stoma reversal was accepted for publication in Diseases of the Colon and Rectum. The second manuscript titled “An Economic Impact of Same Day Discharge Versus Conventional Enhanced Recovery Protocols for Minimally Invasive Colectomy and Stoma Reversal” was submitted to the Central Surgical Association Conference and is pending decision.

ACKNOWLEDGEMENTS

I extend my heartfelt gratitude to my mentors, supervisors, and colleagues, whose unwavering support and guidance made this Master's thesis a reality. I wish to begin by expressing my deep appreciation to Dr. Lawrence Lee, my dedicated supervisor, whose invaluable guidance, and feedback guided me through the entire process, from the inception of the project to its successful execution. I also want to extend my gratitude to Dr. Liane Feldman, my co-supervisor, whose passion for research inspired me to pursue work that contributes to improved patient outcomes. To both of my supervisors, I am sincerely thankful for your patience, for allowing me to learn from my mistakes and for providing me with the essential knowledge to grow as a clinician-researcher.

I would like to extend my sincere acknowledgment to several individuals who have played a pivotal role in the completion of this thesis. Firstly, thank you Dr. Julio F. Fiore, Pepa Kaneva, and Mahalia Olivier for their invaluable support and insightful contributions throughout this research process. To Andre Guigui and the entire finance department at the McGill University Health Centre for their diligent work in data acquisition, which has been instrumental in bringing this thesis to fruition. I am deeply grateful to all the dedicated members of the Steinberg-Bernstein Centre for Minimally Invasive Surgery lab and the entire colorectal team at the Montreal General Hospital for their support and collaborative efforts towards this project.

I wish to express my profound appreciation to my husband, Ryan Hennessey, whose unwavering support, and encouragement have been the cornerstone of my journey towards realizing my dreams. Additionally, I extend my heartfelt appreciation to my parents, Wendy Vardon and Denis

Paradis. Their dedication, relentless work ethic, and the invaluable life lessons they imparted have been instrumental in shaping the determination that drives me today. Their enduring support throughout this endeavor has been a source of strength and inspiration.

I am indebted to the McGill University General Surgery program and the Department of Surgery's Surgeon Scientist Program, which granted me the precious time away from my residency training to pursue a Master's degree. My research training received essential funding support through the Fonds de Recherche du Québec – Santé Master's award and the Canadian Institutes for Health Research.

CONTRIBUTION TO ORIGINAL KNOWLEDGE

The present research has made contributions to the body of original knowledge in the field of enhanced recovery after surgery (ERAS), specifically focusing on same day discharge (SDD) protocols. In our first paper, we conducted a comprehensive investigation of SDD patients undergoing colorectal surgery, delving into their postoperative outcomes, and identifying specific patient-related and perioperative factors associated with SDD success or failure. Notably, this study represents the first and largest examination of a substantial cohort of SDD patients including an in-depth analysis of postoperative outcomes and predictive factors for success and failure. In our second manuscript, we explored new horizons by conducting an economic analysis that directly compared SDD to conventional ERAS protocols. Our study revealed institutional cost savings linked to patients undergoing SDD. These contributions collectively enrich our comprehension of SDD and its implications, providing valuable insights for healthcare practitioners, policymakers, and researchers in the pursuit of optimizing perioperative care in colorectal surgery.

CONTRIBUTION OF AUTHORS

Tiffany Paradis (TP) served as the principal author for this thesis and the accompanying two manuscripts. TP was responsible for conducting the background literature review, collecting data, performing data analysis, interpreting the results, and composition of the thesis. Dr. Lawrence Lee (LL) contributed significantly to all facets of this project, encompassing study design, thorough review of statistical analysis, and the written components. LL also acted as the principal investigator for both manuscripts included in this thesis. Dr. Liane Feldman (LF) made substantial contributions to study design and provided valuable input during the final thesis review process.

Manuscript 1: Predictive Factors For Successful Same Day Discharge Following Minimally Invasive Colectomy and Stoma Reversal

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Study Conceptualization: TP, LSF, LL

Data Collection: TP, SR, AW, CG

Data Analysis: TP, LL

Writing: TP, LL

Revision: TP, SR, AW, CG, SL, PC, BLS, JFF, LSF, LL

Manuscript 2: An Economic Analysis of Same Day Discharge Versus Conventional Enhanced Recovery Protocols for Minimally Invasive Colectomy and Stoma Reversal

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Study Conceptualization: TP, LSF, LL

Data Collection: TP, SR, NB

Data Analysis: TP, LL

Writing: TP, LL

Revision: TP, SR, NB, SL, PC, BLS, JFF, LSF, LL

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LIST OF ABBREVIATION

ERP – Enhanced Recovery Protocols
ERAS – Enhanced Recovery After Surgery
SDD – Same Day Discharge
BMI – Body Mass Index
PACU – Post Anesthesia Care Unit
IBD – Inflammatory Bowel Disease
MIS – Minimally Invasive Surgery
LOS – Length of Stay
GI – Gastrointestinal
NSAIDs – Non-Steroidal Anti-inflammatory Drugs
POD – Postoperative Day
ED – Emergency Department
GDP – Gross Domestic Product
HIPAA - Health Insurance Portability and Accountability Act
CCI - Comprehensive Complication Index
TAP – Transversus Abdominis Plane
ASA – American Society of Anesthesiologists
CAD – Canadian Dollars
USD – United States Dollar
CHF – Congestive Heart Failure
SBO – Small Bowel Obstruction
Km – Kilometers
CEM – Coarsened Exact Matching
PSM - Propensity Score Matching
PA – Patient Activation
PAM – Patient Activation Measure
GHG – Greenhouse Gas

CHAPTER 1: INTRODUCTION

1.1 The Evolution of Colorectal Surgery

Colorectal cancer continues to be a significant public health concern in Canada, ranking as the third most prevalent cancer and the second leading cause of cancer-related mortality [1]. The gold standard treatment for colorectal cancer remains surgical resection of the mass and its surrounding lymph node basin. Rectal cancer poses its own unique challenges due to its close proximity to important pelvic neurovascular bundles, and the genitourinary system. Colorectal surgery is not exclusively reserved for patients with an underlying malignancy. A proportion of patients will undergo colorectal surgery for non-malignant reasons including inflammatory bowel disease (IBD) and diverticulitis. Regardless of the indication for surgery the location of the mass or diseased colon will dictate the resection margins (Figure 1). Patients with an ascending or descending colon mass will undergo a right or left hemicolectomy with extension to include transverse colon masses. In terms of diverticulitis and high rectal cancers patients may undergo removal of the sigmoid and upper rectum through a low anterior resection. Low rectal cancers are close to the anal sphincters making oncologic resection difficult. As a result, these patients may undergo restorative proctectomy or total mesorectal excision with permanent stoma referred to as abdominoperineal resection. In many of these circumstances' bowel continuity can be restored through an anastomosis with either small bowel to colon, colon to colon, or colon to rectum. Anastomoses can be technically challenging such as in cases of low rectal cancer or poor tissue quality and as a result they pose a high risk of leak. In these cases, patients may be diverted with a stoma pulled through the abdominal wall which can eventually be reversed. The evolution of surgical training and infrastructure has resulted in the majority of these cases being performed laparoscopically also referred to as minimally invasive surgery (MIS). Minimally

invasive colorectal surgery has been well documented in the literature as a safe alternative to open surgery resulting in faster patient recovery, improved pain tolerance, and shorter lengths of stay (LOS) [2, 3]. Currently the MIS approach is the preferred method of colorectal surgery where applicable.

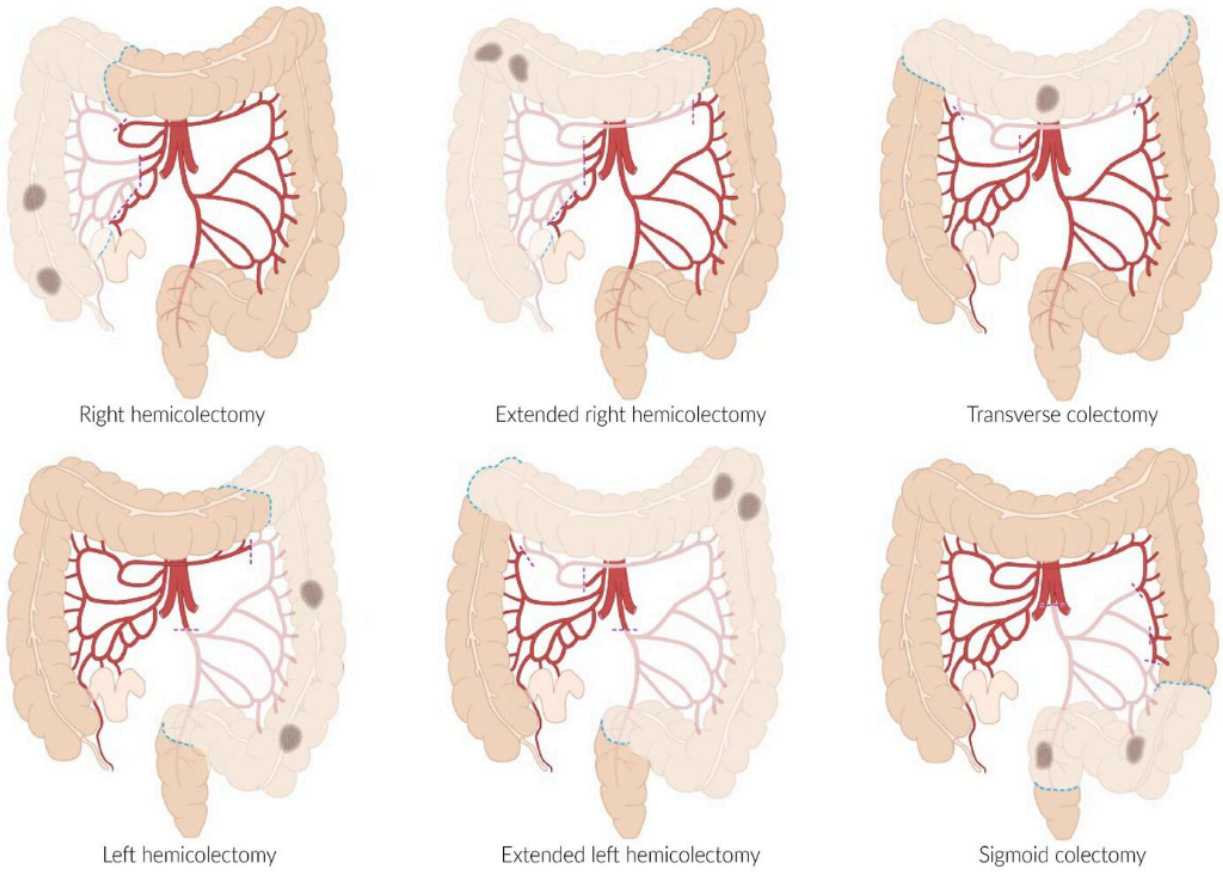

Figure 1: *Resection margins are depicted along the dotted line based on the location of the suspected colonic malignancy depicted as a dark circle. (https://www.amboss.com/us/knowledge/colorectal-cancer)*

1.2 Enhanced Recovery Pathways

Despite improvements in quality and outcomes over the past decades, gastrointestinal (GI) surgical interventions such as colorectal surgery are still associated with a degree of morbidity and mortality. An American study examining general surgery procedures from 2005-2006 found

colorectal surgery to be associated with a 30% risk of postoperative complications and a major contributor to excess hospital stay [4]. Prior to the implementation of enhanced recovery protocols (ERPs), GI surgery would be followed by a lengthy hospital admission. Standard of care included nasogastric decompression and resumption of oral intake only after the return of GI function was established which would take several days. Prior to the introduction of laparoscopic surgery patients underwent open surgery through a large midline abdominal incision. As a result, pain was significant and management relied on epidural thoracic analgesia and opioid medication. These practices also contributed to delayed return of GI function and diet initiation, decreased mobilization and prolonged hospital stay [5].

Surgery is a complex intervention. Surgical patients' trajectory through the healthcare system includes multiple domains such as outpatient clinics, the operating room, Post Anesthesia Care Unit (PACU), and the surgical ward. While challenging this does provide various avenues of potential intervention and optimization. ERPs are standardized perioperative care pathways that were created with a multidisciplinary approach to incorporate up to 25 evidence-based interventions to decrease the physiologic stress response, shorten recovery time and improve patient outcomes. This approach was first described as "Fast Track"surgery in the mid-1990's and was associated with accelerated postoperative recovery [6-8]. Since then, the pathways have been further refined to include a multitude of elements along the perioperative timeline and are now referred to as enhanced recovery after surgery (ERAS) protocols (Figure 2) [9].

ERAS targets four main domains along the surgical trajectory including the preadmission, preoperative, intraoperative, and postoperative periods. The preadmission period includes

identification of action areas that can be targeted in the outpatient clinical setting. This time can be used to educate patients and set expectations regarding the surgical process, which has been shown to reduce anxiety and increase patient satisfaction [10, 11]. Other methods of preoperative patient optimization include risk assessment tools, management of chronic disease, smoking cessation, refining nutritional status, treating hyperglycemia and anemia prior to surgery [12, 13]. Reduced preoperative functional capacity is also associated with poor postoperative outcomes [14]. Prehabilitation programs have been developed to address this issue through exercise and nutritional interventions [15]. While initial studies showed mixed results in terms of postoperative outcomes, a recent randomized controlled trial demonstrated that multimodal prehabilitation programs prior to surgery were associated with a reduction in severe postoperative medical complications [16].

Prior to ERP implementation patients were fasted for 12 hours preceding their surgery in an effort to reduce the risk of aspiration during anesthetic induction. However, prolonged fasting has been associated with hypoglycemia and hypovolemia [17]. Recent studies have established that clear fluids 2 hours prior to surgery, more specifically carbohydrate rich fluids, have a beneficial effect through attenuation of the catabolic response [18]. Additionally, efforts have been made to standardize intraoperative pathways through inclusion of short acting general anesthetics and opioid sparing analgesia in an effort to ensure rapid wakening, multimodal pain control, and a reduction in postoperative nausea and vomiting [13]. Lastly, fluids should be administered judiciously to maintain normovolemia and temperature control should be maintained throughout the surgical procedure in an effort to maintain hemostasis. In terms of

surgical technique, where applicable, laparoscopic surgery with minimal pneumoperitoneum is recommended.

Standardization of postoperative care requires participation from all stakeholders including the patient. Pain control is a major concern following surgery, as poorly controlled pain can lead to reduced patient mobilization and nausea or vomiting. However, pain control that relies solely on opioid administration has been linked to delayed GI function [19]. Multimodal pain control through the use of non-steroidal anti-inflammatory drugs (NSAIDs), acetaminophen and regional nerve blocks reduce postoperative opioid consumption [20, 21]. Promoting early mobilization and oral diet is essential within ERPs, eliminating the need for nasogastric decompression.

The implementation of ERPs in conjunction with minimally invasive colorectal surgery has resulted in a significant decrease in LOS, from the traditional 6-10 days to 3 days, without an increase in readmissions [22]. The literature has also demonstrated an approximate 50% reduction in postoperative complications following MIS colorectal surgery when adhering to ERP principles [23]. Moreover, high adherence to ERP following colorectal surgery have also been associated with a reduction in 5-year cancer related mortality [9]. Since the initial adoption of ERPs, there is now a plethora of literature supporting its efficacy in reducing morbidity and extending its application beyond colorectal surgery to encompass hepatobiliary and cardiothoracic procedures[24-26].

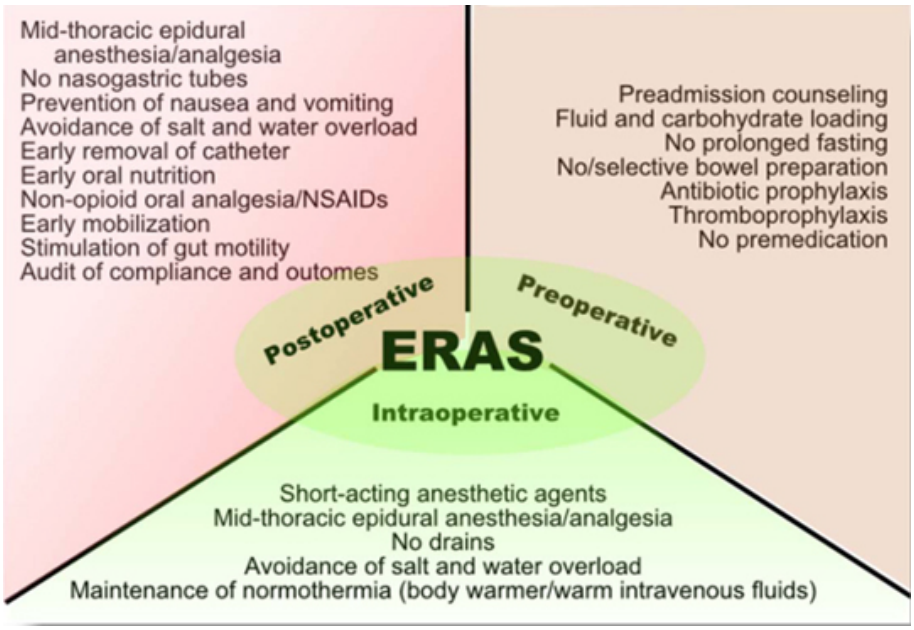

Figure 2: *The preoperative, postoperative, and intraoperative elements of an Enhanced Recovery After Surgery (ERAS) Pathway. Abbreviations: nonsteroidal anti-inflammatory drugs. https://erassociety.org/*

1.3 Same Day Discharge Program

The practice of discharging patients on the same day as their surgical procedure is not a novel concept within the field of general surgery. Several surgical procedures, such as inguinal hernia repair and laparoscopic cholecystectomy have been successfully transitioned to day surgery for most patients since the 1990's. The introduction of MIS has been a catalyst for advancing elective surgical care, leading to the expansion of day surgical practice in various other domains such as gynecology, urology, and thoracic surgery. Day surgery procedures are associated with increased patient satisfaction and reduced consumption of healthcare resources. The Canadian healthcare system is facing a critical situation, with hospitals consistently operating beyond their capacity due to a reduced workforce [27]. The coronavirus disease of 2019 (COVID-19) pandemic exacerbated this through increased demand. Surgical procedures were significantly reduced in an effort to free hospital and intensive care beds for patients with COVID-19

infections. As a result, only emergency and oncologic procedures were offered across Canada [28]. The pandemic as well as preliminary results demonstrating the safety of same day discharge (SDD) in select patients were motivating factors in establishing a same SDD colorectal surgery program at our centre [29].

Guidelines for ERPs following colorectal surgery suggest a targeted LOS of 3 days [13]. However, as perioperative care is increasingly refined, one may question the necessity for any inpatient admission at all, as the purpose for uncomplicated patients seems to mostly consist of clinical observation. For example, a retrospective study performed at our centre prior to the implementation of same day discharge (SDD) found that majority of patients managed through ERPs post colorectal surgery are discharged prior to the targeted 3 day LOS. [30]. In fact, the main reason keeping patients in hospital after elective laparoscopic surgery was to await return of GI function [30]. We further demonstrated that tolerating fluids on postoperative day 0 (POD) was predictive of full return of GI function [31]. The lack of hospital interventions for the majority of patients following MIS colectomy and stoma reversal question the need for any postoperative admission at all.

SDD pathways represent the evolution of ERPs by optimizing the elements of perioperative care that keep patients hospitalized after colorectal surgery [32, 33]. The implementation of SDD protocols following colectomy requires a multifaceted approach including advanced surgical techniques, opioid sparing analgesia to promote return of bowel function, early remote follow-up methods, and risk prediction based on patient related factors. An initial case series in France including 157 patients demonstrated the safety of ambulatory colectomy [29]. Since then, the

term has now been re-coined as SDD and its feasibility has been demonstrated in other studies from Canada and the United States with different modalities of post-discharge care [29, 34, 35].

The objective of SDD is for patients to be discharged on the same calendar day as their surgery with an uneventful early postoperative course. The apprehension with regards to SDD is that patients may develop a complication at home that could have been identified early in the postoperative period if they were admitted to the hospital. However, most studies have demonstrated similar postoperative morbidity and mortality rates to those observed with standardized ERPs [34-36]. Nevertheless, a proportion of intended SDD patients are unable to be discharged on the day of surgery or require an early post-discharge emergency department (ED) visit or readmission [33]. Despite these promising preliminary results SDD has not been widely adopted. Much of the barriers to SDD implementation focus on the potential for SDD failure and/or early readmission, which may have negative clinical and economic outcomes [32].

1.4 Economic Analysis in Postoperative Management of Surgical Patients

Healthcare expenditure in Canada has reached over $300 billion dollars annually representing approximately 13% of our gross domestic product (GDP) in 2020 [37]. Surgical patients pose a unique economic demand on healthcare systems as prolonged hospital stays and postoperative complications are significant cost drivers [38, 39]. Approximately 20% of patients will present to the ED within 30-days of major colorectal surgery with the majority not requiring readmission [40]. While surgical patients can be taxing on our healthcare system it is unlikely that the surgical demand will decrease. The COVID-19 pandemic resulted in a large proportion of elective surgeries being postponed due to reallocation of hospital resources, increasing the

surgical backlogs [37]. Moreover, the aging population and advances in surgical safety will further increase demand for services and increase waitlists[41].

Extensive hospital stays following colorectal surgery were common prior to the introduction of laparoscopic surgery. Once surgeons became accustomed to MIS colorectal surgery the overall length of stay plummeted from 8 to 5 days with lower associated costs [42] [43]. Standardization of perioperative care through ERPs following colorectal surgery further reduced the average length of stay following MIS colorectal surgery to an average of 3 days [44]. It can be hypothesized that ERAS following MIS colectomy would be associated with an overall reduction in economic impact on the healthcare system due to the decreased overall LOS. However, studies have demonstrated that the tail-end of a surgical admission is not resource intensive and the majority of costs incurred occur within the first three postoperative days [45]. In addition to hospital acquired costs, there is an associated fee with implementation and maintenance of these ERPs. Nevertheless, a cost-effectiveness study identified that ERPs were associated with overall reduced costs at the societal level despite the requirement for program development and maintenance [46]. The promising results surrounding improved patient outcomes and cost-effectiveness of ERPs supported their broad implementation, which is currently the standard of practice today.

As SDD patients return home on the same calendar day as their surgery it can be hypothesized that this would be associated with an economic benefit resulting from the reduced resources associated with hospitalization. However, this may not be the case given that patients might stay longer in the PACU or increased unplanned healthcare visits and complications compared to

those managed with ERPs. Therefore, while SDD is associated with favourable outcomes in select patients there remains an element of failure and the cost implications of these programs is unknown.

1.5 Thesis Objectives

The primary goals of this thesis were twofold: first, to identify predictive factors linked to the success of SDD and, second, to assess the economic implications of SDD in comparison to conventional ERAS protocols following minimally invasive colectomy and stoma reversal procedures. These objectives were addressed through a comprehensive approach, including a prospective single-center cohort study of SDD patients who underwent minimally invasive colectomy or stoma reversal. This study examined various aspects such as complication rates, unplanned ED visits, and factors predictive of failed SDD. Furthermore, an economic analysis was conducted to investigate the institutional costs associated with SDD compared to standard care. This analysis involved a matched cohort study to provide insights into the financial implications of SDD implementation.

The thesis is structed as follows: Chapter 1 provides background about the evolution of colorectal surgery, enhanced recovery protocols after surgery, same day discharge following colorectal surgery, and economic analysis on the postoperative management of patients. Chapter 2 includes a prospective cohort study of SDD patients undergoing MIS colorectal surgery, followed by Chapter 3 connecting the first manuscript to the second. An institutional economic analysis of SDD versus conventional care comprises Chapter 4. Chapter 5 includes a discussion

of both manuscripts methodology and results. Each manuscript contains its own reference list and associated figures, with the master reference list at the end for the entire thesis.

CHAPTER 2 – PREDICTIVE FACTORS FOR SUCCESSFUL SAME DAY DISCHARGE FOLLOWING MINIMALLY INVASIVE COLECTOMY AND STOMA REVERSAL

2.1 Preamble

SDD is defined as patients returning home on the same calendar day as their surgical procedure. This concept is well-established as numerous surgical procedures are routinely conducted as outpatient or day cases. The extension of SDD to the field of colorectal surgery was recently introduced via a small cohort study conducted in France, where 30% of patients underwent ambulatory colectomy [29]. Further implementation of SDD programs have been done through identification and optimization of factors that traditionally necessitate a prolonged hospitalization. This approach focuses on enhancing various aspects of perioperative care to facilitate safe discharge on the same day as their surgical procedure. Before the introduction of SDD at our center, we reported that a significant number of patients were discharged before the recommended 3-day LOS as per ERP guidelines, and this early discharge did not result in a higher rate of ED visits or complications [30]. This observation is notable, especially in light of existing literature suggesting that tolerating fluids on POD 0 is associated with return of GI function [31]. These findings, coupled with incorporation of multimodal pain management, were integrated into our existing ERP program, aiming to transition into a SDD program for select patients[34].

One of the concerns hindering the adoption of SDD is the fear that patients might experience a complication at home, which could have been promptly identified and managed if they were hospitalized, potentially with better outcomes. Consequently, vigilant postoperative monitoring becomes crucial for this patient cohort. In response to this concern, we introduced a mobile health application as a means of closely tracking patients during the early postoperative period [47]. Following the initial study done in France in 2019, SDD programs have now been implemented at other North American centres with varying methods of postoperative follow-up [34, 35, 48, 49]. Importantly, these studies have demonstrated that patients undergoing SDD have similar ED visits and complication rates as those managed through standard ERP. However, there is a proportion of patients who fail SDD either due to immediate postoperative complications, social reasons, or ED visits early in the postoperative period. The following manuscript titled "Predictive Factors for Successful Same Day Discharge Following Minimally Invasive Colectomy and Stoma Reversal" aimed to address this issue through identification of factors associated with SDD success and failure. This manuscript was presented at the American Society of Colon and Rectal Surgeons conference in Seattle Washington 2023 and has been accepted for publication in the journal "Diseases of the Colon and Rectum".

2.2- PREDICTIVE FACTORS FOR SUCCESSFUL SAME DAY DISCHARGE FOLLOWING MINIMALLY INVASIVE COLECTOMY AND STOMA REVERSAL

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ABSTRACT

Same-day-discharge following minimally invasive colectomy may further improve efficiency of enhanced recovery pathways. We have previously demonstrated the feasibility of same-day discharge, however, there is still a failure rate. Therefore, we sought to describe our experience with SDD for MIS colectomy and identify predictors for SDD failure.

Adult patients undergoing elective minimally invasive colectomy or ostomy reversal at a tertiary colorectal centre from 01/2020 – 03/2023 were included for same-day-discharge with remote post-discharge follow-up if they had few comorbidities, lived near the hospital, had adequate home support, and owned a mobile device. Patients were discharged on the day of surgery if the following criteria were met: adequate oral analgesia, tolerated liquids, independent ambulation, urination, and absence of complications. Data was collected in a prospective manner comparing the patients who successfully underwent same-day-discharge to those who failed. Successful same-day-discharge was defined as discharge on the day of surgery without unplanned visits in the first 72hrs.

A total of 175(85.3%) patients were discharged on the day of surgery with 14(8%) patients having an unplanned visit within 72hrs. Overall 161(78.5%) patients were categorized as same-day-discharge success and 44(21.5%) patients as same-day-discharge failure. The same-day-discharge failure group had a higher Charlson Comorbidity Index(3.7,2.8,p-value=0.03). Mean length of stay(0.8,3.0,p-value=0.00), 30-day complications(10%,48%,p-value=0.00) and readmissions (8%,27%,p-value=0.00) were higher in the same-day-discharge failure group. Regression analysis showed that failed same-day-discharge was associated with higher

comorbidities(OR0.79,95%CI0.66,0.95) and prolonged post-anesthesia-care-unit time(OR0.99,95%CI0.99,0.99). Individuals who received a regional-nerve-block (OR4.1,95%CI 1.2,14) and those who did not consume postoperative opioids(OR4.6,95%CI1-21) were more likely to have successful same-day-discharge.

Our study suggests that significant comorbidities, prolonged post-anesthesia-care-unit time were associated with same-day-discharge failure. While regional-nerve-block and no early postoperative opioids were associated with same-day-discharge success. These factors may provide further areas of research in hopes to improve current enhanced recovery protocols after colorectal surgery.

INTRODUCTION

Enhanced recovery protocols (ERP) are well supported in the literature and result in faster gastrointestinal (GI) recovery, decreased length of stay (LOS), and fewer postoperative complications following colorectal surgery [25]. Same day discharge (SDD) pathways represent the evolution of ERPs by optimizing the elements of perioperative care that keep patients hospitalized after colorectal surgery [32, 33]. After an initial series from France, studies from Canada and the United States have demonstrated its feasibility in different settings and with different modalities of post-discharge care [29, 34, 35].

The implementation of SDD protocols following colectomy requires a multifaceted approach including advanced surgical techniques, opioid sparing analgesia to promote return of bowel function, early remote follow-up methods, and patient related factors. The objective of SDD is for patients to be discharged on the same calendar day as their surgery with an uneventful early postoperative course. The apprehension with regards SDD is that patients may develop a complication at home that could have been identified early in the postoperative period were they admitted to the hospital. However, most studies have demonstrated similar postoperative morbidity and mortality rates to those observed with standardized ERPs [34-36]. Nevertheless, a proportion of intended SDD patients are unable to be discharged on the day of surgery, or require an early post-discharge emergency department (ED) visit [33]. Much of the barriers to SDD implementation focus on the potential for SDD failure and/or early readmission, which may result negative clinical and economics outcomes [32]. Identification of factors predictive of SDD success or failure may provide early ‘warning signs’ for providers to keep patients hospitalized instead of discharged on the day of surgery, and thus decrease several of the barriers to SDD

implementation by increasing the chances of success. Therefore, the primary objective of this study was to identify patient related or perioperative factors that impact SDD success and failure.

MATERIALS AND METHODS

Setting: This is a prospective study performed at a single university-affiliated colorectal specialty referral centre from 01/2020 – 03/2023. Approval was obtained by the McGill University Health Centre institutional research ethics board.

***Patients*:** All adult patients undergoing elective minimally invasive colectomy or loop colostomy/ileostomy closure by a fellowship-trained colorectal surgeon at our institution were eligible for recruitment. Patients undergoing stoma creation, open procedures, multivisceral resection, or anorectal procedures without an abdominal component were not eligible. Patients with significant comorbidities including insulin-dependent diabetes, chronic renal failure precluding nonsteroidal anti-inflammatory (NSAID) usage, need for dialysis, and respiratory or cardiac comorbidities that require prolonged postoperative monitoring were excluded. Individuals with chronic pain requiring daily opioid consumption were also excluded. Patients were considered eligible if they had adequate home support during the immediate postoperative period, defined as a live-in support for at least 72 hours. Individuals who lived more than a 50 kilometer drive to the Montreal General Hospital were not eligible. All patients were required to understand verbal and written English or French, own a smartphone and be comfortable downloading and using mobile applications. Patients meeting all inclusion criteria were approached in the colorectal surgery clinic for participation in the SDD program. For those

eligible, SDD was offered from Monday to Friday and patients were discharged directly home from the post-anesthesia care unit (PACU).

Intervention: At the time of study enrollment, participants were offered a digital health smart phone application (Caresense, MedTrak Inc., Conshohocken, PA) as a method of post discharge follow-up – a commercially available customizable smart phone application compliant with the Health Insurance Portability and Accountability Act of 1996 (HIPAA). The application included educational material, daily health check questionnaires, and postdischarge direct communication with the healthcare team. Health check questionnaires occurred until postoperative day (POD) 7, any concerning answers would be directly notified to the treating surgical team. Patients were able to communicate with the surgical team through a chat function that was monitored from 7am to 5pm, 7 days a week, from a member of the surgical team (either the treating colorectal surgeon or a resident physician). Communications sent outside of these hours were addressed the following day through the chat function, a telephone call or requested in-person clinic visit. Patients were instructed to present to the ED if worrisome symptoms arose or they were unable to contact the surgical team.

Patients who qualified as a SDD candidates were approached during their preoperative clinic visit. The program was discussed with patients including discharge criteria, preference for opioid sparing analgesia as first line pain control, and postoperative monitoring through the Caresense application. Those enrolled in the program were scheduled as the first case of the day. The anesthetic regimen used followed a standardized institutional protocol and ERP guidelines. Surgical procedures were performed according to each surgeon's technique. All ileocolic

anastomoses were performed intracorporeally. The distal transection was performed intracorporeally for colorectal anastomosis and a small Pfannenstiel was made (to extract the specimen and insert the anvil), pneumoperitoneum was re-established, and the anastomosis was done under laparoscopic guidance. A bilateral transversus abdominis block with 40mL of 0.25% bupivacaine and 10mg of dexamethasone was administered by the surgical (non-image guided) or anesthesia team (ultrasound-guided technique) to all patients undergoing colectomy. Patients were monitored postoperatively in the PACU until discharge. Patients were discharged from PACU, directly home, if they tolerated a clear fluid diet, pain controlled with oral analgesia, and the ability to ambulate and urinate independently. Patients who had more extensive surgery than anticipated, those with intraoperative/postoperative complications were admitted and no longer eligible for the SDD program. All patients were evaluated by the colorectal team (colorectal surgeon or resident physician) to ensure they satisfied the aforementioned discharge criteria.

Outcomes: Our primary outcome measure was successful or failed SDD. Failed SDD occurred when patients were not discharged from PACU on the day of their surgery or presented to the ED, or unplanned clinic visit within the first three postoperative days. Three days was selected as it is the targeted LOS according to ERPs used at our centre and the fact that previous research has demonstrated early GI dysfunction occurs between POD1 and 2 [50]. Early postoperative complications were defined as those that were experienced in the PACU prior to SDD. We excluded patients who experienced intra-operative complications (unplanned stoma, conversion to open, greater extent of surgery, multivisceral resection, etc.) from the SDD cohort as these 'SDD failures' were not attributable to patient-dependent factors. Secondary outcomes included differences in baseline patient characteristics, complications, reoperations, readmission, and 30-

day ED visits. The Clavien Dindo Classification and the Comprehensive Complication Index (CCI) were used as a method to classify postoperative complications [51, 52].

Statistical analysis: Data was analysed using Stata 17.1 (StataCorp, College Station, TX) and statistical significance was defined as $P < 0.05$. Categorical variables were reported as frequency and percentage, while continuous variables were expressed as mean and standard deviation. When indicated Univariate analysis of categorical variables was performed using X^2 or Fisher exact test, and Student t- or Kruskall-Wallis test for continuous variables. A multiple logistic regression was performed to identify predictive factors of successful SDD after controlling for important confounders (age, comorbidities, sex, and procedure). No subgroup analysis were performed.

RESULTS

A total of 670 elective colorectal resections were performed during the study time period. 456 patients would not have been eligible for SDD as they did not fit the aforementioned inclusion criteria, underwent a planned open procedure or new stoma, and those who refused to participate. 214 patients were recruited for SDD, 9 patients were excluded due to intraoperative complications, extensive surgical intervention, or unplanned stoma creation (figure 1). Among the 205 patients included in the final cohort, 13 (6.3%) experienced early postoperative complications and 17 (8.3%) failed SDD criteria for a total of 30 (14.6%) patients requiring an unplanned admission (figure 1). The most common reasons for SDD failure from PACU were inadequate pain control, and patient/caregiver refusal (figure 1). A total of 175 (85.3%) patients were discharged on the same day as their surgery with 14 (8.0%) presenting to the ED within

three postoperative days (figure 1). Therefore, a total of 161 (78.5%) patients were categorized as SDD success, and 44 (21.5%) as SDD failure.

A comparison of the patient and operative characteristics of the SDD success and failures are shown in Table 1. SDD failure patients were more likely to have increased comorbidities than the SDD success cohort. There were no differences in baseline characteristics, procedures performed or indication for surgical intervention between groups (table 1). There was no difference in overall operative time between both groups, however, time spent in PACU was significantly longer for the SDD failure group. Mean morphine milliequivalents in PACU were also similar between groups with a small subset of patients requiring no opioids in PACU (table 1). Almost all patients received NSAIDS intraoperatively or in the PACU with no difference between groups (table 1). A proportion of patients (26%, 55/205) did not receive a TAP block including those undergoing colectomy (14/55) and stoma reversal (41/55).

30 Day ED visits, complication rates, readmissions and mean LOS were significantly higher in the SDD failure group (table 1). The most common cause of SDD failure from PACU was inadequate pain control or patient refusal (table 2). Patients who failed SDD from PACU spent on average two days in hospital. Patients who were discharged on POD 0, however, failed SDD secondary to ED visits within 72 hours majority were for anastomotic bleeding, GI dysfunction, and urinary retention (table 2). All patients presenting with GI dysfunction required readmission (n=4) with two of those patients having undergone stoma reversal surgery. Among patients readmitted one required surgical intervention due to wound dehiscence and one patient died secondary to cardiac complications.

On multiple regression analysis, after controlling for important covariates (age, comorbidities, sex, and procedure) SDD failure was associated with a higher Charlson Comorbidity Index (OR 0.79, 95% CI 0.66, 0.95) and prolonged PACU stay (OR 0.99, 95% CI 0.99, 0.99). Individuals who received a TAP block (OR 4.1, 95% CI 1.2, 14) and those who did not consume opioids (OR 4.6, 95% CI 1, 21) in PACU were more likely to have SDD success.

DISCUSSION

There is increasing evidence to support the feasibility and safety of SDD for elective colorectal surgery. SDD has demonstrated similar postoperative complications, readmissions, and reoperation rates as standardized ERPs [33]. The benefit of SDD is not solely patient-related – shorter hospital stays have the dual advantage of reduced cost and carbon footprint through decreased resource consumption [46, 53]. With this incentive, we sought to determine factors that may impact successful SDD as an area of potential intervention.

Our results show that comorbidity status, duration of time in the PACU, TAP block administration, and use of early opioids for pain control were predictive of success or failure of SDD. This is not surprising considering that significant comorbidities have been associated with prolonged LOS above the average three-day target for ERPs after colorectal surgery [54, 55]. The success of SDD depends on many factors, with opioid sparing postoperative pain control as a major pillar to its success. The literature has shown that routine TAP block, and minimal postoperative opioid consumption, in patients undergoing abdominal surgery results in adequate pain control and reduced postoperative ileus [20, 56, 57]. Our study supports these findings as

patients receiving TAP blocks and those who did not require postoperative opioids in PACU were more likely to have successful SDD. While the majority of patients who did not receive a TAP block were stoma closures, a proportion of patients undergoing colectomy did not receive a TAP block. However, when controlling for both procedure and TAP block in our multivariate analysis only TAP block was found to be significant in predicting successful SDD.

In addition to the importance of postoperative pain control, our results show that time spent in PACU may also impact SDD success – patients with prolonged PACU time after surgery were more likely to fail SDD. It is unlikely that the prolonged PACU time was solely related to patients being enrolled in our SDD program given that a previous study comparing SDD to ERP demonstrated similar PACU times [34]. However, the negative impacts of prolonged PACU time are documented in the literature as being associated with clinical deterioration and longer LOS after surgery [58]. While prolonged PACU time may be related to a variety of factors including reduced hospital capacity, in certain circumstances it may also be considered a surrogate for time to achieve discharge criteria among SDD patients. Therefore, it is likely that patients with prolonged PACU stay either took longer to meet discharge criteria or eventually failed and required admission. There is likely a PACU stay cut-off at which point patients are unlikely to meet discharge criteria and will require admission. This would be an interesting future targeted area of research, however, is likely influenced by each centre's unique institutional recovery process [48]. These results suggest that minimal comorbidities, opioid sparing analgesia, use of regional nerve blocks, and reduced PACU stay are associated with SDD success. Therefore, it is recommended to consider these factors when selecting SDD candidates.

While select patients required admission from PACU secondary to unavoidable early postoperative complications, a proportion of individuals fail SDD for potentially preventable causes. Among the 17 (8.2%) patients who failed SDD from PACU, most were for inadequate pain control. This is unexpected as there were no differences in the amount of postoperative morphine equivalents or NSAIDs between failed or SDD success groups. As pain is subjective, not all patients respond to acute postoperative pain uniformly, which may explain these findings. However, our results are limited as we did not use a multimodal approach to better classify postoperative pain [59]. In keeping with the current literature, our findings indicate that the second leading cause for SDD failure from PACU was patient or caregiver refusal [29, 36].

Our experience suggests that there is a myriad of factors that can potentially lead to SDD refusal, including fear of adverse outcomes, anxiety, suboptimal preoperative education and/or preparation. This occurred despite our use of a smart phone application that included a patient-physician communication feature, which in previous studies was shown to enhance patients' sense of security and relive anxiety post-discharge [34]. Future studies should investigate how patient/caregiver personality characteristics, baseline anxiety, health literacy, and engagement levels interact with willingness to undergo SDD.

The literature has demonstrated that patient related outcomes are similar between SDD and ERPs, however, there are no reports comparing successful and failed SDD cohorts. Our data suggests that patients who failed SDD had a higher 30-day complication rate, ED visits and readmissions. It is important to note that among patients who failed SDD due to postoperative complications, only two patients required reoperation with only one anastomotic leak (Table 2).

Moreover, only one patient failed SDD secondary to an unplanned clinic visit for a blocked foley catheter (Table 2). These findings may be related to the fact that our SDD failure group had more comorbidities than those undergoing successful SDD. This is in keeping with other studies that have shown an association between increased post-discharge unplanned visits and increased comorbidities [60]. While malignancy may contribute to increased CCI score for a subset of our cohort, many patients underwent surgery for diverticulitis, inflammatory bowel disease or stoma reversal. Therefore, it is likely that select patients have an elevated CCI due to other underlying comorbidities. Currently little is published in terms of why those with SDD failure have worse postoperative outcomes and remains an area of potential investigation. In particular, there may be a potential role for pre-operative prehabilitation programs to 'convert' patients into SDD candidates and broaden the inclusion criteria. In other studies, prehabiltiation interventions have significantly increased functional capacity and decreased postoperative complications for patients undergoing colorectal surgery [16]. However, no patients were included in the present study.

The findings of this study should be interpreted in the setting of other limitations. Patient activation (PA) was not measured in this study. The literature has demonstrated that low PA, a patient's ability to manage their own health, is associated with increased postoperative complications and unplanned healthcare utilization following major abdominal surgery [61]. Therefore, the higher complication rates and emergency department visits in our SDD failed cohort may be related to PA. Another potential limitation is we did not actively collect information in terms of patient interaction with the Caresense application. However, our previous study describing the initial implementation of SDD at our centre reported a 76% usage rate with

on average 21 direct messages from patients during their recovery process [34]. Additionally, our study included patients that were highly selected which may affect generalizability. All patients required a smartphone device and familiarity with its utilization in order to download the follow-up application. Older patients may not have access to a smart phone or be as familiar with technology as younger patients. However, smart phone technology is increasing among the older population and colorectal cancer is also increasing among younger patients therefore it is likely this levels out to a certain degree [62, 63]. Lastly, we did not use pain scores or recovery metrics making it difficult to classify the degree pain control in patients who failed SDD secondary to inadequate analgesia.

CONCLUSION:

In summary, our study suggests that significant comorbidities and prolonged PACU time were associated with SDD failure. In addition to this TAP blocks and no postoperative opioids in PACU were associated with SDD success. Our findings also suggest that discharge on POD 0 was associated with lower overall complications, ED visits, and readmissions in the first 30-days after surgery compared to individuals who were unable to be discharged on POD 0 despite a small proportion of patients discharged on POD 0 requiring an early unplanned hospital visit. Ultimately our findings demonstrate that those who fail SDD have worse postoperative outcomes than those with SDD success. These results provide preliminary evidence on factors associated with successful and failed SDD, which may provide areas of further research in hopes to improve current ERPs following colorectal surgery.

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Table 1. Patient characteristics and outcomes between cohorts			
	Successful SDD (n=161)	**Failed SDD (n=44)**	**p-value**
Mean age, years (SD)	56 (15.7)	59 (12)	0.23
Male, No (%)	84 (54%)	20 (40%)	0.12
Mean BMI, kg/m^2 (SD)	27.3 (6)	25.7 (5)	0.12
Mean Charlson Comorbidity Index, points (SD)	2.8 (2)	3.7 (2.7)	0.03*
ASA Physical Status, No (%)			0.58
1	20 (13%)	4 (8%)	
2	103 (63%)	27 (61%)	
3+	36 (22%)	13 (29%)	
Indication for Surgery, No (%)			0.96
Colon and Rectal Cancer	85 (52%)	26 (59%)	
Diverticulitis	11 (7%)	3 (7%)	
Inflammatory Bowel Disease	10 (6%)	3 (7%)	
Stoma	52 (32%)	11 (25%)	
Other	3 (2%)	1 (2%)	
Procedures, No (%)			0.45
Right Hemicolectomy/Ileocecectomy	51 (32%)	14 (31%)	
Left hemicolectomy/Sigmoidectomy	38 (23%)	10 (22%)	
Low Anterior Resection**	19 (12%)	9 (20%)	
Stoma Reversal	53 (32%)	11 (25%)	
Approach, No (%)			
Laparoscopic	111 (68%)	33 (75%)	0.43
Open (local stoma reversal)	50 (31%)	11 (25%)	
Mean Operative Duration, min (SD)	135.3 (88)	124 (65)	0.41
Transversus abdominis plane block, No (%)	120 (74%)	30 (69%)	0.40
Mean Post Anesthesia Care Unit Duration, min (SD)	271 (111)	408 (296)	0.008*
Mean Morphine Milligram Equivalents in PACU (SD)	67 (117)	76 (118)	0.67
No Opioids in PACU, No (%)	40 (24%)	7 (16%)	0.21
Non-Steroidal Anti-inflammatories in PACU, No (%)	107 (69%)	29 (59%)	0.18
Mean Length of Stay, Days (SD)	0.8 (5)	3 (6.4)	0.01*
30-Day Complications, No (%)	15 (10%)	24 (48%)	0.003*
30-day ED Visits, No (%)	18 (11%)	19 (43%)	0.001*
30-day Readmission, No (%)	12 (8%)	12 (27%)	0.001*
Reoperation Rates, No (%)	2 (1%)	2 (5%)	0.21
Comprehensive Complication Index (SD)	18.4 (10)	22.3(9)	0.44

**Clinically significant findings (P-value < 0.05)*

***Low anterior resection is defined by extraperitoneal colorectal anastomosis*

Abbreviations: SDD (Same Day Discharge), ASA (American Society of Anesthesia), BMI (Body mass index), PACU (Postoperative Anesthesia Care Unit), ED (Emergency department)

Table 2. Reasons for SDD Failure	
Reasons for Failure to Discharge on POD 0	**n = 30**
Early Postoperative Complications	
Anastomotic Bleed	3
Rectus Sheath Hematoma	1
Traumatic Foley Insertion	1
Cardiac Monitoring/Workup	2
Hemodynamic Instability	3
Oxygen Requirements	1
Urinary Retention	1
Delirium	1
Recommended Prolonged PACU Stay	4
Spinal Anesthesia Complication	1
Inadequate Pain Control	6
Patient/Caregiver Refusal	5
Significant Postoperative Nausea	1
Reasons for Failure of SDD Secondary to ED Within 72 Hours	**n = 14**
Anastomotic Bleeding	4
Anastomotic leak	1
Small Bowel Obstruction (Anastomotic Hematoma)	1
Urinary Retention	3
Gastrointestinal Dysfunction	4
Fever without Etiology	1

Abbreviations: SDD (Same Day Discharge), PACU (Postoperative Anesthesia Care Unit), ED (Emergency department), POD (postoperative day)

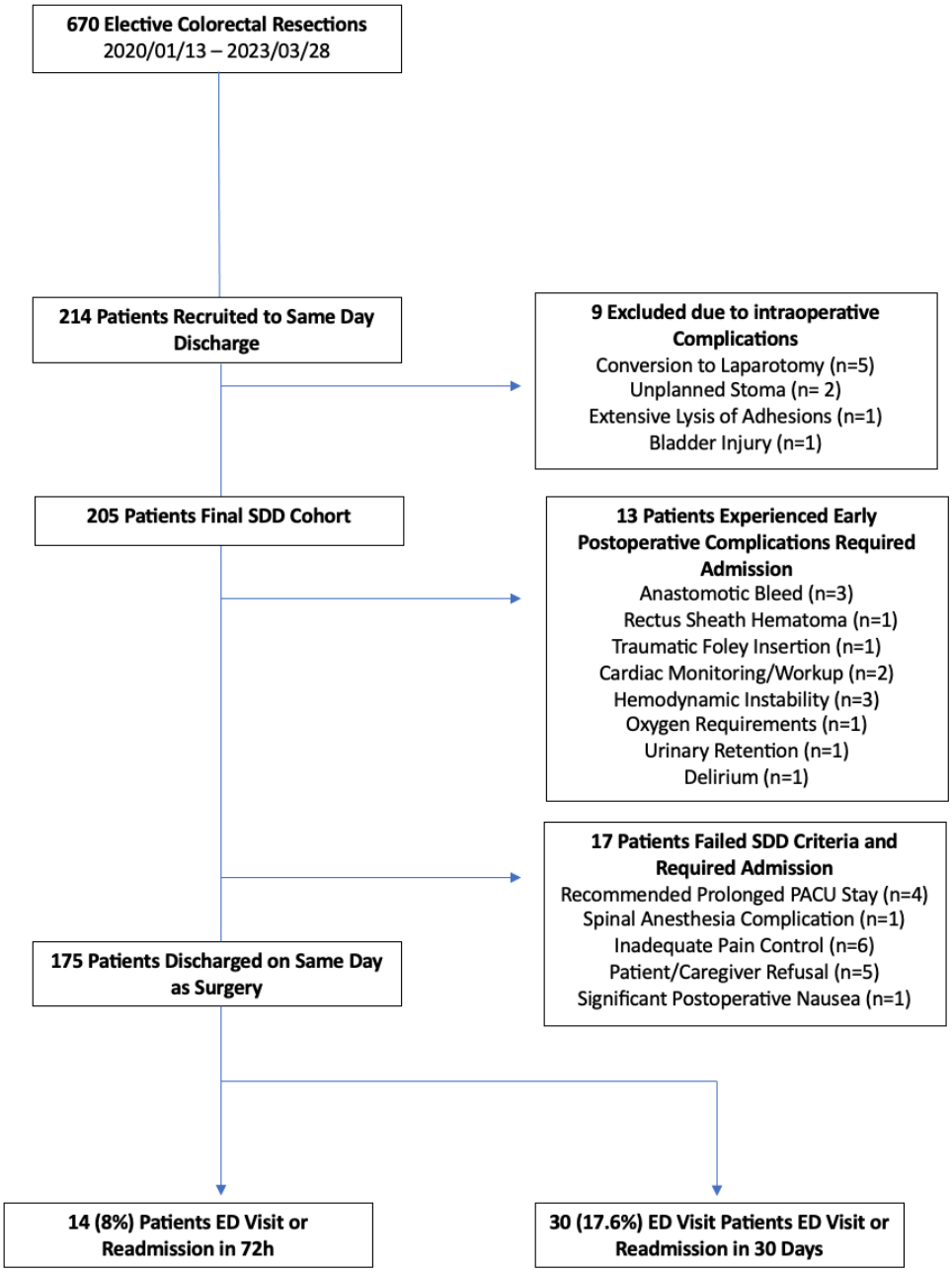

Figure 1. Flow diagram of patients enrolled in SDD
Abbreviations: SDD (Same Day Discharge), PACU (Postoperative Anesthesia Care Unit), ED (Emergency department)

CHAPTER 3: AN ECONOMIC ANALYSIS OF SAME DAY DISCHARGE VERSUS CONVENTIONAL ENHANCED RECOVERY PROTOCOLS FOR MINIMALLY INVASIVE COLECTOMY AND STOMA REVERSAL

3.1 Preamble

The previous chapter discusses a prospective study of patients undergoing SDD following minimally invasive colectomy or stoma reversal. Among the entire cohort 14.6% of patients failed discharge on the same calendar day as their surgery with approximately 7% failing SDD due to unplanned ED visit within 72hrs. In total we identified a SDD failure rate of 21.5%. The principal findings were that significant comorbidities and prolonged PACU time were associated with SDD failure. In contrast receiving a regional nerve block and not consuming opioids in PACU were factors associated with SDD success. Moreover, this study identified that patients who were not discharged on postoperative day (POD) 0 had higher complication rates, ED visits, and readmissions within 30-days of their surgery compared to individuals who were discharged on POD 0.

The knowledge obtained from this initial study brought to our attention predictive factors associated with failed SDD. Although a small number of patients were not discharged on POD 0 this cohort had a higher proportion of complications and ED visits. We initially hypothesized that a SDD program would have a lower economic impact compared to conventional ERPs due to reduced hospital stay, however, our initial study puts this into question. Given that patients who failed SDD have a prolonged PACU stay and more complications and unplanned health care visits we decided to perform an institutional economic analysis to compare costs acquired by patients managed through SDD versus conventional ERPs. Through collaboration with the

McGill University Health Centre financial department, all institutional costs acquired for patients undergoing SDD and a matched cohort managed through ERPs were extracted. This information was used to determine the financial implications of a SDD program including primary and secondary admission costs at the institutional level. This abstract has been submitted to the Central Surgical Association and is pending decision.

3.2: AN ECONOMIC ANALYSIS OF SAME DAY DISCHARGE VERSUS CONVENTIONAL ENHANCED RECOVERY PROTOCOLS FOR MINIMALLY INVASIVE COLECTOMY AND STOMA REVERSAL

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ABSTRACT

Same day discharge (SDD) has been shown to be safe and effective with similar outcomes to patients managed with standardized enhanced recovery protocols (ERPs), however, their economic advantage from the healthcare perspective is unknown.

Adult patients undergoing minimally invasive colectomy or ostomy reversal at a colorectal centre from 08/2017-03/2022 were eligible. A prospective cohort of SDD patients were compared to a historic cohort of patients managed through ERPs. Institutional costs were calculated through a microcosting technique from the time of surgery to 30-days postoperatively and reported as 2023 Canadian dollars. Coarsened exact matching was used to create similar groups of patients undergoing laparoscopic colectomy or stoma reversal. Uncertainty was conveyed through 10,000 bootstrapped estimates.

A total of 534 patients were included in this study with 121 undergoing SDD and 413 patients managed through an ERP. A total cost savings of 1817$ (95% CI -3021 to -613) for SDD colectomy and 2344$ (95% CI -3838 to 851) for SDD stoma reversal per patient was identified. Majority of the expenditure savings occurred in hotel, pharmaceutical and allied healthcare costs. Length of stay was significantly shorter in SDD patients undergoing colectomy with no difference in those undergoing stoma reversal compared to the ERP cohort. Emergency department visits were higher in SDD patients undergoing stoma reversal with no difference in those undergoing SDD colectomy compared to the ERP cohort.

SDD following colorectal surgery is associated with favourable clinical outcomes resulting in lower overall institutional costs compared to those managed with ERPs.

INTRODUCTION

Enhanced recovery protocols (ERPs) following colorectal surgery have transformed perioperative management through improved postoperative outcomes, shorter hospitalizations, and rapid return of gastrointestinal (GI) function [25]. These protocols have now been broadly implemented as standardized practice. Further optimization of ERPs has resulted in the inception of same day discharge (SDD) after minimally invasive colorectal surgery. Preliminary studies in the European and North American settings provide preliminary evidence supporting the feasibility and safety of SDD [29, 34, 64]. SDD has been associated with decreased LOS without increasing complications or readmissions[65]. However, there are no studies demonstrating an economic advantage.

Total health care expenditure in Canada has reached over $300 billion annually representing approximately 13% of gross domestic product (GDP) in 2020 [37]. Surgical patients pose a unique economic demand on our healthcare system as prolonged hospital stays and postoperative complications can be a significant cost driver [38, 39]. The advantages of ERPs extend beyond the patient, with economic analyses demonstrating a cost benefit to the healthcare system [46, 66, 67].

While SDD has been shown to be safe and effective with similar postoperative outcomes as patients managed with ERPs, the cost implications have not been investigated [34]. Given that SDD patients go home the same calendar day as their surgery it is thought that there may be an economic benefit in terms of reduced hospitalization. However, this may not be true as the final days of a surgical admission are less resource consumptive than the first days [45] and would

also be negated if SDD patients require increased unplanned healthcare visits in clinics or emergency departments. Therefore, whether SDD has an economic benefit compared to standard ERPs is not known. The primary objective of study was to examine whether there is a cost benefit to SDD compared to ERPs for patients undergoing elective minimally invasive colectomy or stoma reversal. Secondary outcomes include specific costs and patient related outcomes.

METHODS

Setting: This is a single centre study performed at a university-affiliated colorectal specialty centre from 08/2017-03/2022 comparing a prospective cohort of SDD patients with a historic cohort of admitted patients managed through ERPs. Approval was obtained prior to initiation of the study by the McGill University Health Centre's institutional research ethics board.

SDD Cohort: Adult patients undergoing elective loop colostomy/ileostomy closure or minimally invasive colectomy by a fellowship-trained colorectal surgeon at our centre were eligible for recruitment. All individuals undergoing open procedures, anorectal procedures without an abdominal component, multivisceral resections, planned stoma creation, or intraoperative complications were not eligible. Patients with cognitive impairment, cardiac or respiratory comorbidities requiring prolonged post-anesthesia care unit (PACU) stay, insulin dependent diabetes, chronic renal failure, or other medical conditions precluding the use of nonsteroidal anti-inflammatory usage (NSAIDS) were also excluded. Individuals were required to live within 50km from our hospital centre, have the ability to use a mobile smart phone, and have an in-person caregiver for the first 72 hours following their surgical intervention (table 1). Patients

meeting our inclusion criteria were approached at the time of their colorectal clinic visit for participation in the SDD program. Individuals were offered SDD from Monday to Friday and discharged home directly from the PACU on the same calendar day as their surgery if they met our pre-defined discharge criteria. All patients were discharged with access to a digital health smart phone application (Caresense, MedTrak Inc., Conshohocken, PA) as an adjunct to postoperative follow-up. The application is customizable, commercially available, and compliant with the Health Insurance Portability and Accountability Act of 1996 (HIPAA). The application included educational material, daily questionnaires regarding postoperative recovery, and the ability to contact a member of the surgical team through a direct chat function. All messages were addressed from 7am to 5pm 7 days a week by a treating colorectal surgeon or resident physician. Messages occurring outside of these hours were addressed the following day. All patients were advised to present to the ED if urgent issues arose.

ERP Cohort: Two independent reviewers (TP, NB) screened a historic cohort of patients undergoing minimally invasive colectomy or loop ileostomy/colostomy reversal according to predetermined inclusion/exclusion criteria (table 1). A mapping application was used to determine the distance between the patient's residence and the hospital with those beyond a 50km radius excluded. Disagreements were discussed between reviewers and residual differences were addressed by the senior author (LL). All individuals undergoing planned open procedures, stoma creation, or multivisceral resections were excluded. Patients with intraoperative complications that would have precluded SDD, those with significant comorbidities including chronic renal failure, insulin dependent diabetes, contraindication to

NSAID usage, and respiratory or cardiac comorbidities requiring an extended PACU stay were excluded.

Intervention

Patients underwent an anesthetic regimen according to a standardized institutional protocol in conjunction with ERP guidelines. All surgical procedures were performed by a fellowship trained colorectal surgeon according to their own specific technique. Ileocolic anastomoses were performed intracorporeally. For colorectal anastomoses the distal transection margin was performed intracorporeally, a Pfannenstiel incision was made to extract the specimen and insert the anvil, pneumoperitoneum was re-established, and the anastomosis was performed under laparoscopic guidance. A proportion of patients underwent bilateral transversus abdominis (TAP) block by the surgical (non-image guided) or anesthesia (ultrasound-guided) team with 40mL of a mixture including 0.25% bupivacaine with epinephrine and 10mg of dexamethasone. Patients enrolled in the SDD program were discharged home directly from PACU after meeting the following discharge criteria: ability to tolerate a clear fluid diet, pain controlled with oral analgesia, ambulating, and urinating independently. All SDD patients were evaluated in the PACU by the surgical team (staff surgeon or resident physician) prior to discharge. Patients with intraoperative or immediate postoperative complications and those not meeting the discharge criteria were admitted. Individuals in the historic cohort were transferred from the PACU directly to the surgical ward for further management. All patients in our historic cohort were managed postoperatively with a well-established ERP with a targeted length of stay (LOS) of three days (https://www.sages.org/enhanced-recovery/mcgill-colorectal-pathway/).

Outcomes

Our primary outcome measure was total institutional costs (including both direct and indirect costs) acquired per patient from the time of their surgery to 30-days postoperatively represented in Canadian dollars (CAD$). All medical costs were estimated through a micro-costing technique. The rate of resource consumption was multiplied to its specific unit cost. Unit costs were supplied by the Montreal General Hospital McGill University Health Centre's finance department or provincial health ministry records. Institutional perspective costs were calculated comprising all medical costs incurred by the hospital including operating room, ward, pharmacy, laboratory, diagnostic, procedural, allied health, and emergency department costs. Total costs are expressed in 2023 Canadian dollars (USD $1 = CAN $1.2, using purchasing power parity) [68]. Secondary outcomes included differences in patient characteristics, postoperative complications, defined as a patient that did not leave the hospital on the same calendar day as their surgery or who presented to the ED or clinic within 72 hours of their discharge from the hospital. Three days was selected as a cut off given that it is the target length of stay for patients managed through ERPs [13]. Clavien Dindo Classification and the Comprehensive Complication Index (CCI) were used to classify postoperative complications [51, 52].

Statistical Analysis

Descriptive variables were reported as frequency percentage for categorical variables whereas continuous variables were expressed as mean and standard deviation. Cost data confidence intervals were obtained from the 2.5^{th} and 97.5^{th} percentile values from 10,000 bootstrap replications[69]. Where indicated a Student t- or Kruskall-Wallis test for continuous variables was performed, and univariate analysis of categorical variables was performed using X^2 or

Fisher exact test. Coarsened exact matching was used to create similar groups (SDD and ERP) for patients undergoing laparoscopic colectomy or stoma reversal. SDD and ERP groups were matched for age, body mass index (BMI), sex, Charlson Comorbidity Index (CCI), and procedure (colectomy versus stoma reversal). The coarsened exact matching algorithm was adjusted until both groups were balanced without significant differences. Stata 17.1 (StataCorp, College Station, TX) was used to analyze all data and statistical significance was defined as $P < 0.05$.

RESULTS

A total of 689 patients underwent elective laparoscopic colectomy or stoma reversal during the study time period. There were 121 patients managed by SDD with 16 patients failing discharge on postoperative day (POD) 0 and 5 patients presenting to the ED within 72 hours, for a final of 100 successful SDD and 21 failed SDD patients (figure 1). A total of 568 patients managed through an ERP were screened for eligibility, 155 patients were excluded as they did not fit our predetermined inclusion criteria, for a final cohort of 413 patients (figure 1). There were no differences in patient characteristics, operative indication, or procedure in matched cohorts for patients undergoing colectomy or stoma reversal (table 2,3). SDD patients undergoing colectomy had a longer PACU stay and more TAP blocks compared to the ERP cohort (table 2). In contrast, SDD patients undergoing stoma reversal had a longer mean operative time than the ERP cohort with no significant difference in PACU time or TAP block administration (table 3).

Overall LOS was significantly shorter in SDD patients undergoing colectomy while there was no difference in those undergoing stoma reversal compared to the ERP cohort (table 2,3). ED visits

at 30-days were significantly higher in SDD patients undergoing stoma reversal with no difference in those undergoing SDD colectomy (table 2,3). In addition, both colectomy and stoma reversal patients undergoing SDD had a higher rate of readmission compared to their matched ERP cohort (table 2,3). A total of 18 patients within the SDD cohort presented to the ED department within 30-days (figure 1). Only two SDD patients required reoperation due to evisceration (1) and anastomotic leak (1) (figure 1, table 2-3). Among the 13 patients requiring readmission three presented with ileus following stoma reversal, with an average LOS of 2-3 days (table 2-3). A total of 21 patients in the matched ERP cohort presented to the ED within 30 days with the two most common reasons being poor pain control and wound complications (including seroma, infection, and bleeding at the surgical site) (figure 1). Three patients required reintervention for bleeding (2) and anastomotic leak (1).

Compared to the matched ERP cohort, SDD colectomy was associated with a significant overall cost savings of 1817$ (95% CI -3021 to -613) per patient (table 4). Major differences were observed in the primary admission only with no difference in secondary admission costs (table 4). Upon cost breakdown a large proportion of these cost savings occurred in hotel costs while other significant differences in expenditure were found in pharmaceutical, allied healthcare, laboratory, and procedure costs (table 4). Similarly, patients undergoing SDD stoma reversal were found to have an overall cost savings of 2344$ (95% CI -3837 to 851) per patient, with most of the savings occurring in the primary admission (table 5). The majority of expenditure savings originated from hotel, pharmaceutical, and allied healthcare costs (table 5). In contrast, secondary admission costs and ED costs were found to be higher in the SDD stoma reversal

patients compared to the matched ERP cohort with no significant difference in patients undergoing SDD colectomy (table 5).

DISCUSSION

The safety and feasibility of SDD following minimally invasive colorectal surgery has been demonstrated in the literature with varying methods of postoperative follow-up [32-34, 48]. We sought to determine the economic impact of SDD on the healthcare system as this may impact broader implementation. This study is the first to perform an economic analysis from the institutional perspective comparing SDD with conventional ERPs in patients undergoing MIS colectomy or stoma reversal in a North American setting. The results demonstrate that SDD was associated with shorter hospitalizations and a significant reduction in overall hospital expenditure compared to ERPs.

Patients undergoing SDD return home on the same calendar day as their surgical procedure. It is a common assumption that patients managed through a SDD protocol will result in reduced hospital-based expenditure given the shorter LOS. In fact, the literature has demonstrated that approximately 40% of costs occur during the first three days of admission making the final days of an admissions less resource intensive [45]. A retrospective study performed at our centre prior to the implementation of SDD identified that the majority of patients managed through an ERP following colorectal surgery are discharged within the targeted 2-3 day LOS with only 34% requiring prolonged admission [30]. Given our mean LOS for patients managed through an ERP was 3 days, it is not surprising that we identified a significant reduction in hotel costs among patients undergoing MIS colectomy or stoma reversal managed through a postoperative SDD

program. Interestingly cost savings were also observed in other areas of hospital expenditure. SDD patients had lower pharmaceutical costs compared to those managed through an ERP. Given that TAP blocks are associated with less postoperative opioid consumption, it was thought that the larger proportion of TAP blocks in the SDD cohort would be the main driver of reduced pharmaceutical costs [21]. However, there were no observed differences in mean morphine equivalents obtained in the PACU between SDD and ERP patients regardless of the procedure. Thus, the difference in pharmaceutical cost is likely multifactorial including the fact that patients admitted to the hospital will not only take pain medication but also have their home medication represcribed for the duration of their admission. These findings are limited as the data regarding home medication consumption for SDD patients is unavailable. It is not surprising that allied health care and laboratory costs were also higher in ERP patients compared to those enrolled in the SDD program regardless of the procedure as patients must be admitted to hospital for these services.

The majority of cost differences occurred during the primary admission for patients enrolled in the SDD program irrespective of the procedure. However, patients undergoing SDD stoma reversal had a significantly more costly secondary admission and emergency department visit compared to their matched ERP cohort. Among the 5 patients readmitted following stoma reversal 3 were for ileus with one patient requiring surgical intervention for evisceration. This increase in secondary admission and ED expenditure was not observed within the SDD colectomy cohort despite there being a significantly higher proportion of readmissions compared to the matched ERP group. Among the 8 patients readmitted following SDD colectomy no patients were admitted for ileus and one required surgical intervention for anastomotic leak. This

discrepancy may be associated with the fact that postoperative ileus can be a major financial burden to our healthcare system and has been shown to increase median costs by approximately 71% [70]. These patients often need hospital admission with nasogastric decompression, nursing care, laboratory work, diagnostic imaging and in severe cases total parenteral nutrition [71]. Given that these complications occurred beyond the recommended 72-hour period, the recommended LOS by ERP, it is challenging to ascertain whether they would have been detected during the initial admission or if patients would have been discharged only to return to the ED for an unplanned visit.

A major hesitation to the implementation of SDD is that patients may potentially develop a postoperative complication at home that may have otherwise been detected during their index admission. Unplanned ED visits are associated with a significant cost burden with approximately 20% of colorectal patients presenting to the ED within 30 days of surgery [40]. While previous studies have shown similar emergency department visits and readmissions between patients managed through SDD compared to ERPs, our study demonstrated a significantly higher proportion of 30 day ED visits for stoma reversal patients and higher readmissions for SDD patients [32]. These findings are likely multifactorial and may be related to the addition of patients outside the inclusion criteria as our institution became more comfortable with the SDD program. Another potential reason for these findings is the timing of our program initiation. SDD was implemented at our centre in the midst of the COVID-19 pandemic, as a result many patients would avoid hospitals in fear of becoming infected [72, 73].

Our study should be interpreted in the context of several limitations. First, this study was performed at a single Canadian institution with significant differences compared to other healthcare systems which may affect generalizability. For example, the United States (US) expenses per inpatient day is estimated to be US 2883$, whereas in Canada it is approximately CAD 1083$ [37, 74]. Moreover, there may be discrepancies in the method of hospital remuneration between Canada and other countries. There are also important differences in the overall case volume between Canada and other countries such as the US. SDD eliminates the need for a surgical bed, which in turn provides the opportunity to reallocate these unused resources to other surgical patients undergoing procedures that require inpatient postoperative observation. This is not only beneficial to the healthcare system but also to patients who required surgery during the COVID-19 pandemic when access to in-patient beds was severely curtailed [75, 76]. It is also important to note that the cost of SDD implementation at the institutional level was not evaluated in this study. However, given that many aspects of SDD protocols are similar to those enforced in ERPs – such as TAP block, early ambulation, and feeding – it is unlikely that the cost of implementing a SDD program would be significant in facilities that have ERPs in place. Furthermore, our investigation focused specifically on unscheduled visits occurring within a singular institutional context, encompassing clinics and ED visits. This scope did not include unplanned visits occurring outside this setting, such as different hospitals or to a general practitioner. Another limitation to our study is the potential risk for selection bias. The efficacy and safety of SDD has been demonstrated in a relatively healthy patient population and therefore may not be the same for those with significant comorbidities. Moreover, in terms of screening our retrospective cohort according to whether or not they would have been a SDD candidate we were unable to determine smartphone device ownership or if they would have agreed to

participate in the program at the time of their surgery. While our study has demonstrated a cost benefit to SDD on the healthcare system it is unknown whether this benefit extends beyond the hospital. For example, previous studies have demonstrated that earlier discharge through ERPs after colorectal surgery is associated with in improved disease survival, yet these findings have not been investigated in SDD patients [77]. Lastly, little is known in terms of the patient perspective surrounding SDD after colorectal surgery. A recent survey-based study identified that approximately 85% of patients undergoing SDD would do so again if given the opportunity [49, 64]. Although these findings are promising additional qualitative studies are needed to further elucidate the impact of SDD on patients to ensure the burden is not being shifted from the hospital to home.

CONCLUSION

Same day discharge following colorectal surgery is associated with favourable clinical outcomes and lower overall institutional costs compared to those managed with ERPs following colorectal surgery. Majority of cost savings were associated with reduced hotel, pharmaceutical, allied health professional consultation, and laboratory costs. Studies evaluating the societal costs and patient perspective surrounding SDD are needed in hopes to close this gap and further support SDD implementation.

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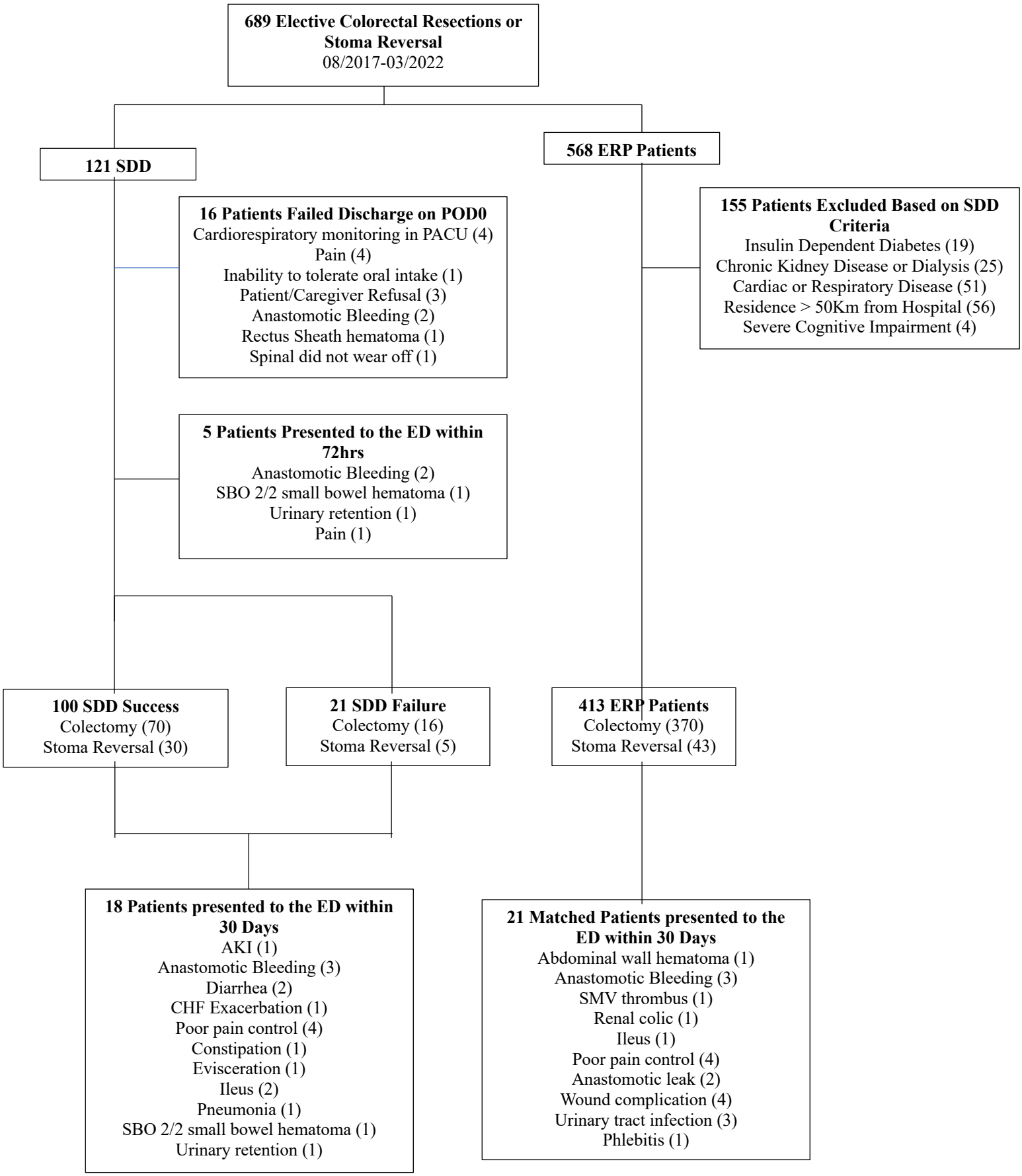

Figure 1. *Flow diagram of SDD and ERP cohort*
Abbreviations: SDD (Same Day Discharge), ERP (Enhanced Recovery Protocol), ED (Emergency Department), PACU (Post Anesthesia Care Unit), SBO (small bowel obstruction), CHF (Congestive Heart Failure, SMV (superior mesenteric vein)

Table 1. Full Study Inclusion and Exclusion Criteria	
Inclusion Criteria	**Exclusion Criteria**
-Adult patients undergoing elective minimally invasive colectomy or stoma reversal -Owned and capable of using a smart phone -Lives within 50km to the Montreal General Hospital -Adequate support system at home*	-Insulin dependent diabetes -Chronic kidney disease, dialysis requirements or any other contraindication to NSAIDs -Cardiac or respiratory disease requiring prolonged PACU monitoring -Creation of new stoma -Severe cognitive impairment -Intraoperative complication or conversion to open

**Adequate home support was described as another live-in caregiver for the first 72hrs after surgery*
Abbreviations: km (kilometers), NSAIDs (non-steroidal anti-inflammatories), PACU (Postoperative Anesthesia Care Unit)

Table 2. Patient Characteristics and outcomes between cohorts for colectomy only						
	Unmatched			Matched		
	SDD (n=85)	ERP (n=370)	p-value	SDD (n=71)	ERP (n=181)	p-value
Mean age, years (SD)	57 (14)	63 (15)	0.00*	57 (14)	59 (11)	0.21
Male, No (%)	49 (57%)	193 (52%)	0.65	33 (46%)	101 (55%)	0.20
Mean BMI, kg/m^2 (SD)	27 (5)	26 (5)	0.37	26 (4)	25 (4)	0.08
Mean CCI, points (SD)	3.3 (2)	4 (2)	0.01*	3.5 (2)	3 (1)	0.33
ASA Physical Status, No (%)			0.01*			0.18
I	13 (15%)	25 (7%)		12 (17%)	16 (9%)	
II	50 (59%)	206 (55%)		41 (58%)	117 (64%)	
III	21 (24%)	138 (37%)		18 (25%)	48 (26%)	
Indication for Surgery, No (%)			0.14			0.68
Colon & Rectal Cancer	72(85%)	313 (85%)		61 (86%)	145 (80%)	
Diverticulitis	8 (9%)	30 (8%)		5 (7%)	20 (11%)	
Inflammatory Bowel Disease	5 (6%)	27 (7%)		5 (7%)	16 (9%)	
Procedures, No (%)						
Right Hemicolectomy/Ileocecectomy	36 (42%)	177 (47%)	0.65	31 (43%)	83 (46%)	0.87
Left Hemicolectomy/Sigmoidectomy	33 (38%)	130 (35%)		28 (39%)	72 (39%)	
*Low Anterior Resection***	16 (18%)	63 (17%)		12 (17%)	26 (14%)	
Mean Operative Time (min), (SD)	161 (96)	187 (61)	0.00*	163 (102)	181 (62)	0.10
Mean Post Anesthesia Care Unit Duration, min (SD)	301 (180)	222 (182)	0.00*	300 (190)	211 (181)	0.00*
Mean Morphine Equivalents in PACU (SD)	47 (30)	28 (32)	0.15	31 (67)	29 (30)	0.76
Transversus Abdominis Plane Block, No (%)	77 (90%)	145 (39%)	0.00*	63 (89%)	60 (33%)	0.00*
Mean Length of Stay, Days (SD)	0.7 (3)	3.4 (4)	0.00*	0.9 (3)	3 (3.3)	0.00*
Median Length of Stay, Days (IQR)	0 (0)	2 (1)	0.00*	0 (0)	3 (1)	0.00*
30-Day Complications, No (%)	12 (14%)	84 (23%)	0.10	11 (15%)	40 (22%)	0.24
Comprehensive Complication Index (SD)	3 (8)	4 (9)	0.13	3 (8)	4(9)	0.34
30-Day ED Visits, No (%)	10 (12%)	40 (10%)	0.80	10 (14%)	18 (9%)	0.34
30-Day Readmissions, No (%)	8 (9%)	18 (5%)	0.10	8 (11%)	7 (3%)	0.03*
Reoperation Rates, No (%)	1 (1%)	4 (1%)	0.01*	1 (1%)	2 (1%)	0.57

**Clinically significant findings (P-value < 0.05)*

***Low anterior resection is defined by extraperitoneal colorectal anastomosis*

Abbreviations: SDD (Same Day Discharge), ERP (Enhanced Recovery Protocol), CCI (Charlson comorbidity index), ASA (American Society of Anesthesia), BMI (Body mass index), PACU (Postoperative Anesthesia Care Unit), ED (Emergency department)

Table 3. Patient Characteristics and outcomes between cohorts for stoma reversal only						
	Unmatched			Matched		
	SDD (36)	ERP (43)	p-value	SDD (25)	ERP (28)	p-value
Mean age, years (SD)	56 (14)	60 (16)	0.29	54 (14)	56 (15)	0.63
Male, No (%)	18 (50%)	28 (65%)	0.18	13 (52%)	17 (60%)	0.52
Mean BMI, kg/m^2 (SD)	27 (9)	25 (4)	0.17	26 (7)	25 (4)	0.61
Mean CCI, points (SD)	2.3 (2)	4.6 (3)	0.00*	2.5 (2)	4 (2)	0.10
ASA Physical Status, No (%)			0.61			0.37
I	4 (11%)	3 (7%)		2 (8%)	2 (8%)	
II	22 (61%)	30 (70%)		16 (64%)	23 (82%)	
III	9 (25%)	10 (23%)		6 (24%)	3 (10%)	
Mean Operative Time (min), (SD)	71 (47)	54 (39)	0.10	73 (48)	51 (21)	0.03*
Mean Post Anesthesia Care Unit Duration, min (SD)	236 (107)	208 (113)	0.30	223 (72)	223 (128)	0.98
Mean Morphine Equivalents in PACU (SD)	45 (56)	32 (21)	0.45	36 (105)	43 (40)	0.72
Transversus Abdominis Plane Block, No (%)	8 (22%)	5 (11%)	0.21	6 (24%)	4 (14%)	0.36
Mean Length of Stay, Days (SD)	1.4 (5)	3 (2)	0.10	1.8 (6)	3.3 (2.5)	0.27
Median Length of Stay, Days (IQR)	0 (0)	2 (0)	0.10	0 (0)	3 (0)	0.27
30-Day Complications, No (%)	7 (19%)	9 (21%)	0.87	7 (28%)	5 (17%)	0.40
Comprehensive Complication Index (SD)	4 (8)	3 (7)	0.70	5 (10)	3(8)	0.36
30-Day ED Visits, No (%)	8 (19%)	6 (13%)	0.51	8 (28%)	3 (7.5%)	0.04*
30-Day Readmissions, No (%)	5 (13%)	1 (2%)	0.05*	5 (20%)	0	0.01*
Reoperation Rates, no (%)	1 (3%)	1 (2%)	0.01	1 (4%)	1 (3%)	0.01*

**Clinically significant findings (P-value < 0.05)*
Abbreviations: SDD (Same Day Discharge), ERP (Enhanced Recovery Protocol), CCI (Charlson comorbidity index), ASA (American Society of Anesthesia), BMI (Body mass index), PACU (Postoperative Anesthesia Care Unit), ED (Emergency department)

Table 4. Comparison of Institutional Costs Between SDD and ERP for Colectomy				
	SDD (n=85), $ (95% CI*)	**ERP (n=370), $ (95% CI*)**	**Mean Difference Unmatched, $ (95% CI*)**	**Mean Difference Matched, $ (95% CI*)**
Overall Institutional Costs	6788 (6071 to 7506)	8890 (8393 to 9387)	-2101 (-2919 to -1284)	-1817 (-3021 to -613)
Primary Admission Costs	6320 (5892 to 6748)	8710 (8225 to 9195)	-2390 (-3046 to -1733)	-2258 (-3189 to -1326)
Secondary Admission Costs	468 (-93 to 1030)	179 (68 to 290)	288 (-273 to 850)	441 (-230 to 1131)
Operative Room Costs	6121 (5773 to 6468)	6060 (5874 to 6245)	60 (-322 to 444)	183 (-289 to 654)
Hotel Costs	373 (57 to 690)	2094 (1808 to 2379)	-1720 (-2130 to -1309)	-1630 (-2188 to -1072)
Pharmacy Costs	134 (4 to 264)	335 (274 to 396)	-201 (-343 to -60)	-180 (-363 to -2.5)
Allied Health Professional Costs	34 (-10 to 79)	146 (109 to 183)	-111 (-170 to -52)	-70 (-137 to -3.3)
Diagnostic Costs †	25 (-2 to 53)	55 (32 to 78)	-29 (-64 to 5.7)	-27 (-75 to 22)
Laboratory Costs	61 (11 to 112)	137 (92 to 183)	-75 (-142 to -9)	-95 (-198 to 9.4)
Procedure Costs ††	0 (0.00 to 0.00)	18 (8 to 27)	-18 (-27 to -8)	-10 (-21 to -0.3)
Emergency Department Costs	37 (-2 to 76)	43 (19 to 67)	-6 (-52 to 40)	12 (-37 to 63)

**Derived from the 2.5th and 97.5th percentiles of 10,000 bootstrap replications.*
†Diagnostic costs include radiographic imaging including x-rays, computed tomography, and contrast related studies.
†† Procedural costs include drainage through ultrasound, computed tomography, or interventional radiology, and endoscopic procedures

Table 5. Comparison of Institutional Costs Between SDD and ERP for Stoma Reversal				
	SDD (n=85), $ (95% CI*)	**ERP (n=370), $ (95% CI*)**	**Mean Difference Unmatched, $ (95% CI*)**	**Mean Difference Matched, $ (95% CI*)**
Overall Institutional Costs	2898 (2523 to 3272)	5015 (3988 to 6041)	-2117 (-3177 to -1057)	-2344 (-3837 to 851)
Primary Admission Costs	2662 (2347 to 2978)	4891 (3872 to 5909)	-2228 (-3257 to -1198)	-2654 (-4120 to -1189)
Secondary Admission Costs	235 (9 to 460)	123 (-48 to 296)	111 (-159 to 381)	310 (6.32 to 613)
Operative Room Costs	2539 (2297 to 2782)	2607 (2160 to 3054)	-67 (-543 to 407)	-94 (-765 to 577)
Hotel Costs	107 (-17 to 231)	1970 (1399 to 2542)	-1834 (-2399 to -1270)	-2107 (-2953 to -1259)
Pharmacy Costs	41 (22 to 60)	229 (163 to 294)	-189 (-108 to -38)	-202 (-272 to -133)
Allied Health Professional Costs	8 (-2 to 18)	81 (45 to 116)	-73 (-96 to -38)	-95 (-145 to -46)
Diagnostic Costs †	23 (3 to 44)	25 (4 to 46)	-2 (-30 to 27)	6.49 (-33 to 46)
Laboratory Costs	16 (-4 to 37)	62 (21 to 104)	-46 (-91 to -1.6)	-55(-118 to -7)
Procedure Costs ††	2 (-2 to 6)	3 (-3 to 10)	-1(-9.8 to 6.9)	3 (-1 to 7)
Emergency Department Costs	159 (8 to 311)	34 (7 to 62)	-124 (-29 to 279)	208 (-4 to 421)

**Derived from the 2.5th and 97.5th percentiles of 10,000 bootstrap replications.*
†Diagnostic costs include radiographic imaging including x-rays, computed tomography, and contrast related studies.
†† Procedural costs include drainage through ultrasound, computed tomography, or interventional radiology, and endoscopic procedures

CHAPTER 4 – DISCUSSION

4.1 General Findings

The objectives of this thesis were as follows: (a) to identify patient related or perioperative factors that impact SDD success and failure; and (b) to determine if there is a cost benefit to SDD versus ERPs for patients undergoing elective minimally invasive colectomy or stoma reversal.

Preliminary results in SDD patients are promising, however, there is a proportion who fail SDD on the same calendar day as their surgery or have an unplanned ED visit early in the postoperative period [32, 34, 64]. In this study, a SDD failure rate of 21.5% (44 of 205) was identified. Among those failing SDD, 14.5% (30 of 205) required an unplanned admission from PACU and 8% (14 of 205) required an ED visit within 72 hours of discharge. The most common reason for failed discharge from the PACU was inadequate pain control despite 73% of patients undergoing a transabdominal plane block. Among the patients having an unplanned ED visit all were medically indicated. This was expected given that patients had access to a mobile application as an adjunct to postoperative follow-up which has been previously shown to reduce the number of unnecessary ED visits [47]. Additionally, the occurrence of SDD failure was more pronounced among patients with a higher burden of comorbidities and those who experienced prolonged PACU stays. This observation aligns with the existing evidence, as significant comorbidities have consistently been linked to extended LOS surpassing the typical 3-day benchmark set by ERPs following colorectal surgery. In terms of PACU stay, the probability of failed SDD was notably higher among patients who experienced extended PACU stay following surgery. It is unlikely that these findings were solely attributable to our SDD program as previous

studies comparing SDD to ERPs had similar PACU times [32]. Nevertheless, the adverse consequences associated with prolonged PACU stays have been well-documented in the literature, with links to clinical deterioration and prolonged lengths of stay [58]. While various factors may contribute to prolonged PACU time it may serve as a surrogate marker for the time required to meet discharge criteria among SDD patients. It is also plausible that prolonged PACU stays among patients may be indicative of either an extended period required to meet the discharge criteria or an eventual inability to meet these criteria, necessitating hospital admission. Conversely our findings indicate that the administration of a TAP block and the avoidance of early opioid use for pain management were associated with a higher likelihood of achieving successful SDD.

It is important not to assume that SDD will reduce the cost burden solely due to a shortened hospital stay as a proportion of patients will have an unplanned emergency department or require readmission. Our primary study has demonstrated that a subset of patients fail to achieve successful SDD. This subgroup experiences a higher incidence of ED visits and postoperative complications, all of which result in substantial healthcare system costs. Our institutional cost analysis revealed a substantial decrease in ward-related expenses for patients undergoing minimally invasive colectomy or stoma reversal when managed through a postoperative SDD program. This observation aligns with existing literature, which has established that a large proportion of costs are incurred during the initial three days of hospital admission [45]. Although the bulk of cost savings were noted during the initial admission, stoma reversal patients specifically exhibited a higher cost associated with subsequent admissions and ED visits when compared to a matched cohort. Interestingly, these findings were not seen in the SDD colectomy

cohort despite the proportion of readmissions being notably higher than their matched ERAS cohort. The primary source of cost savings identified in this study were in ward expenses, pharmaceutical costs, allied health professional, and laboratory expenditures.

Our research has added to the current body of literature by emphasizing the significance of patient selection, the implementation of effective pain management strategies, and the necessity for additional investigations for PACU threshold times in patients undergoing SDD. Furthermore, our findings indicate that SDD is linked to substantial cost savings at the institutional level.

4.2 Discussion of Methodology – Selection Bias

The primary manuscript in this thesis included a prospective cohort study of patients undergoing SDD following minimally invasive colectomy or stoma reversal. As outlined in the primary manuscript, it is recommended that patients are carefully selected for participation in a SDD program. Our study introduced strict inclusion criteria, requiring minimal comorbidities, specific procedural considerations, smartphone ownership and geographic proximity to the hospital. As a result, this creates a highly refined cohort, which may introduce an element of selection bias. Moreover, patients were extended the opportunity to participate in the SDD program and were required to provide their consent for enrollment. This raises a significant methodological question regarding whether patients meeting the criteria and consenting to participate in the SDD program accurately represent the broader population of individuals undergoing minimally invasive colorectal surgery. Addressing potential selection bias is critical as it has the potential to yield misleading conclusions regarding the generalizability of a study [78]. In our initial

manuscript, which was observational, this consideration did not significantly impact our findings. However, in our subsequent study, we undertook a comparative analysis, contrasting SDD patients with a cohort managed under conventional ERAS protocols. Consequently, we found it necessary to address the potential issue of selection bias. To mitigate this potential bias, we employed a matched cohort analysis.

To establish a historical cohort that closely resembled the SDD cohort, we conducted a thorough screening of our conventional cohort. This screening process involved applying the SDD inclusion/exclusion criteria to assess whether individuals from the conventional cohort, if they were to undergo surgery today, would meet the eligibility criteria for SDD candidacy. Nevertheless, it remains uncertain whether these patients would have consented to participate in the program had it been offered to them. Another strategy employed to mitigate bias involved the implementation of a Coarsened Exact Matching, a statistical method utilized to reduce bias and enhance comparability between two distinct groups within a cohort study [79]. Our study matched for variables that have been reported in the literature to affect postoperative outcomes including age, sex, body mass index, Charlson Comorbidity Index, and procedure [80, 81]. Our reasoning for a procedure-based matching approach was due to the marked dissimilarity between stoma reversal and laparoscopic colectomy. For instance, stoma reversal typically has a shorter operative time with a localized incision surrounding the previous stoma site compared to laparoscopic colectomy. However, stoma reversal is associated with a higher rate of postoperative ileus compared to laparoscopic colectomy alone [82, 83].

In the context of our matched analyses, the primary objective was to achieve a balance between the treatment and control groups in observational studies, all while striving to maximize the retention of patients within the study. Coarsened exact matching (CEM) was selected as the method of choice due to its unique ability to create exact matches on categorical covariates, thereby ensuring a meticulous balance within cohorts. Nevertheless, it's important to acknowledge the limitations of CEM, notably its relative inability to handle high-dimensional data and missing data as proficiently as Propensity Score Matching (PSM). In this particular study, the emphasis was placed on attaining a higher degree of precision matching, which prompted the selection of CEM over PSM [84]. Furthermore, the decision to employ a matching algorithm, as opposed to regression analyses, stemmed from the recognition that the latter, while providing greater flexibility for covariate adjustment, does not inherently guarantee the achievement of balance between the treatment groups [85].

4.3 Discussion of Methodology – Unmeasured Confounding

To identify factors that could predict the success or failure of SDD, we conducted a multiple logistic regression analysis in our primary manuscript. Although we controlled for anticipated

Figure 3 – The different activation levels assigned to patients based on the results of the patient activation measure. www.insigniahealth.com

confounding variables including age, sex, comorbidity status, and procedure, it is important to acknowledge the presence of unmeasured confounders remains beyond our control that may have influenced the observed outcomes in both the above manuscripts. For example, patient activation (PA) is an inherent characteristic that all patients have which has been defined as a patient's skills, knowledge, beliefs, and confidence in managing their own health [86]. PA can be measured using a 13-item questionnaire, the Patient Activation Measure (PAM), dichotomizing patients into low activation (level 1, 2) and high activation (level 3,4) (Figure 3). Low patient activation has been linked to poor postoperative outcomes in patients undergoing major abdominal and thoracic surgery [61]. Consequently, if there were to be a discrepancy in PA level among those who failed SDD versus those who had successful SDD this may impact the conclusions drawn from our study. It could be hypothesized that individuals who agree to participate in SDD programs may score higher on the activation scale compared to those who refuse. Prior to the above manuscripts an additional cohort study was performed including patients undergoing MIS colorectal surgery, with a subset of SDD patients, to determine the impact of PA on the use of a digital health application as an adjunct to follow-up. In this study we observed no difference in PA levels between individuals enrolling in SDD and those who did not. Nonetheless, our analysis did reveal that patients with low PA levels exhibited a higher incidence of complications and emergency department visits overall, consistent with previous studies in other populations [61]. This study was presented at the Society of American Gastrointestinal and Endoscopic Surgeons and was submitted to the journal Surgical Endoscopy.

4.4 Discussion of Methodology – Societal Costs

Economic analyses play a pivotal role in driving comprehensive change within the clinical setting. Although our study demonstrated a large economic benefit to the implementation of a SDD program, it is important to note that we did not calculate costs from a societal perspective. Societal analyses offer a more comprehensive view examining the costs associated with a new intervention not only at the institutional level, but also the economic impact on a wider level including lost work productivity and caregiver burden [87]. SDD patients may return home on the same day as their surgery, but this does not signify an immediate return to their preoperative level of function. In practice, most patients are unable to promptly resume work and require a designated period of recovery leave. Previous research investigating the societal advantages of ERPs compared to conventional care reported that ERAS was actually associated with faster return to work and reduced caregiver burden, despite the earlier discharge from hospital [46]. Therefore, while our analysis has demonstrated an institutional cost benefit associated with SDD compared to patients managed through ERAS, additional analyses form the societal perspective would be required to fully encompass the economic costs of SDD.

4.5 – Future Directions

While this study offers insights into the predictors of SDD success and failure and their associated economic implications, it serves as a foundational stepping stone for further investigations. Specifically, our research has shed light on the association between prolonged PACU stays and SDD failure. This association warrants more in-depth exploration to ascertain whether PACU duration can serve as a reliable surrogate marker for predicting a patient's likelihood of meeting SDD criteria. Future studies should aim to collect detailed PACU trajectory data for SDD patients, with the objective of pinpointing a specific threshold beyond

which it becomes improbable for patients to meet the discharge criteria, necessitating hospital admission.

The economic implications of SDD at the institutional level are promising, as our study has demonstrated a reduction in hospital resource utilization. Nevertheless, this represents just one facet of the comprehensive assessment required to gauge the cost-effectiveness of SDD programs. While it is improbable that the implementation costs of such programs would significantly deviate from those of ERPs, given their shared components, it is imperative to explore the broader societal costs associated with SDD. The effects of SDD on patients' postoperative home experiences and their ability to resume work promptly remains unclear. Additionally, participants in these programs require a period of postoperative recovery at home, often with the assistance of a designated caregiver in the early stages. The impact of caregiver responsibilities and potential burden in this context is not well-understood. To gain a comprehensive understanding of the full cost-effectiveness of SDD programs and provide valuable insights for informed decision-making regarding their implementation, future economic analyses should prioritize the societal perspective.

The introduction of novel perioperative programs should include a comprehensive assessment of both patient outcomes and economic implications. In light of the imminent threats posed by climate change, it is equally imperative to extend this evaluation to encompass the environmental footprint and associated impacts. The healthcare industry represents a carbon-intensive supply chain characterized by substantial energy consumption, transportation requirements, and resource utilization. Hospitals engage in a multitude of energy-intensive operations encompassing

sophisticated heating and cooling systems, laboratory procedures, sanitation practices, and surgical interventions under continuous operation. As a result, hospitals are substantial contributors to greenhouse gas (GHG) production, directly and indirectly [88]. Considering these adverse environmental outcomes, the United Kingdom Health Service coalition has proposed guidelines to mitigate GHG emissions within healthcare. While the majority of these efforts focus on the operating theatre, new targeted avenues such as enhancing patient recovery and reducing time to discharge are recommended [89]. Clinical care pathways represent an ideal method to deliver high-quality care while minimizing unwarranted resource consumption [90]. Therefore, it is essential to evaluate the environmental impacts of SDD compared to standardized patient care following elective colorectal surgery.

The outcomes of SDD have yielded promising results from both the clinical and economic standpoints. However, it is also crucial to consider the patient's perspective. The successful implementation of these programs should involve engagement with all relevant stakeholders. A solitary survey-based study attempted to explore the patient's viewpoint regarding SDD programs, reporting that over 80% of patients would willingly opt for SDD following laparoscopic colectomy if the situation were to arise in the future [49]. To gain a more profound understanding of the patient's perspective, it is imperative that future investigations employ a more sophisticated qualitative research methodologies. These qualitative studies would provide invaluable insights into the patient experience and further inform the development and optimization of SDD programs.

CHAPTER 5 – CONCLUSION

In conclusion, the research presented in this thesis provide evidence supporting the safety and efficacy of SDD following minimally invasive colectomy and stoma reversal in carefully selected patients. It is imperative to recognize that patients with substantial comorbidities are at higher risk for unfavorable postoperative outcomes, necessitating cautious consideration when identifying candidates for the program. Moreover, extended PACU duration could potentially serve as an indicator of SDD failure. Importantly, we determined that SDD is associated with an overall institutional cost benefit. Decision-makers should consider the above findings when implementing a SDD program.

CHAPTER 6 – REFERENCES THESIS

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