6-25-2014

Clinical and Financial Impact of Hospital Readmissions Following Colorectal Resection: Predictors, Outcomes, and Costs: A Thesis

Rachelle N. Damle
University of Massachusetts Medical School

CLINICAL AND FINANCIAL IMPACT OF HOSPITAL READMISSIONS FOLLOWING COLORECTAL RESECTION: PREDICTORS, OUTCOMES, AND COSTS

A Thesis Presented

By

RACHELLE NICOLE DAMLE, MD

Submitted to the Faculty of the

University of Massachusetts Graduate School of Biomedical Sciences,

Worcester, MA 01605

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

JUNE 25, 2014

BIOMEDICAL SCIENCES
HEALTH SERVICES RESEARCH

CLINICAL AND FINANCIAL IMPACT OF HOSPITAL READMISSIONS FOLLOWING COLORECTAL RESECTION: PREDICTORS, OUTCOMES, AND COSTS

A Thesis Presented

By

RACHELLE NICOLE DAMLE, MD

The signatures of the Master's Thesis Committee signify completion and approval as to style and content of the Thesis

_____
Fred Anderson, PhD, Chair of Committee

_____
Karim Alavi, MD, MPH Member of Committee

_____
Heena Santry, MD, Member of Committee

_____
Gordon FitzGerald, PhD, Member of Committee

The signature of the Dean of the Graduate School of Biomedical Sciences signifies that the student has met all master's degree graduation requirements of the school.

_____
Anthony Carruthers, PhD,
Dean of the Graduate School of Biomedical Sciences

Program
Masters of Science in Clinical Investigation

June, 25, 2014

Acknowledgements

I would like to acknowledge my Thesis Mentor, Dr. Karim Alavi, for all of his guidance and mentorship throughout my time in this program; this would not have been possible without the time you took to guide me. Julie Flahive provided invaluable help with the dataset creation and statistical analysis. I would also like to thank the contributors to this project, Nicole Cherng, Dr. Jennifer Davids, Dr. Justin Maykel, Dr. Paul Sturrock, and Dr. W. Brian Sweeney. My Thesis Research Advisory Committee, Dr. Fred Anderson, Dr. Heena Santry, and Dr. Gordon FitzGerald provided support and guidance throughout the process of developing my research topic, proposal, and its completion. Dr. Robert Goldberg and Dr. Kate Lapane were helpful throughout the process of navigating the MSCI program and its requirements. Finally, I'd like to acknowledge the Surgical Research Scholars Program for the opportunity to spend two years studying and carrying out health services research.

Abstract

Background: Following passage of the Affordable Care Act in 2010, 30-day hospital readmissions have come under greater scrutiny. Excess readmissions for certain medical conditions and procedures now result in penalizations on all Medicare reimbursements. We examined the risk factors, outcomes, and costs of 30-day readmissions after colorectal surgery (CRS).

Methods: The University HealthSystem Consortium database was queried for adults (≥ 18 years) who underwent colorectal resection for cancer, diverticular disease, inflammatory bowel disease, or benign tumors between January 2008 and December 2011. Our outcomes of interest were **r**eadmission within 30-days of the patient's index discharge, hospital readmission outcomes, and total direct hospital costs.

Results: A total of 70,484 patients survived the index hospitalization after CRS during the years under study, 13.7% (9,632) of which were readmitted within 30 days of discharge. The strongest independent predictors of readmission were: LOS ≥4 days (OR 1.44; 95% CI 1.32-1.57), stoma (OR 1.53; 95% CI 1.45-1.61), and discharge to skilled nursing (OR 1.63; 95% CI 1.49-1.76) or rehabilitation facility (OR 2.93; 95% CI 2.54-3.40). Of those readmitted, half occurred within 7 days of the index admission, 13% required ICU care, 6% had a reoperation, and 2% died during the readmission stay. The median combined total direct hospital cost was over twice as high ($26,917 v. $13,817) for readmitted than for non-readmitted patients.

Conclusions: Readmissions following colorectal resection occur frequently and incur a significant financial burden on the healthcare system. Future studies aimed at targeted interventions for high-risk patients may reduce readmissions and curb escalating healthcare costs.

Categorization: Outcomes research; Cost analysis; Colon and Rectal Surgery

Table of Contents

List of Tables

Figure List

Preface

Other accomplished works that will not be presented as a part of this thesis:

Damle, RN, Hossein Bagshahi, and Donald T. Baril. "En bloc tibial thrombectomy." *Journal of vascular surgery* 58.2 (2013): 501.

Damle, RN, Macomber, C; Flahive, J; Davids, J; Maykel, J; Sturrock, P; Sweeney, WB; Santry, H; Alavi, K. *Surgeon Volume and Elective Resection for Colon Cancer: An Analysis of Outcomes and Use of Laparoscopy.* Journal of the American College of Surgeons 218.6 (2014): 1223-1230.

Damle, RN, Cherng, N; Flahive, J; Davids, J; Maykel, J; Sturrock, P; Sweeney, WB; Alavi, K. *Clostridium difficile infection following colorectal surgery: A rare but costly complication.* Podium presentation at the American Society of Colon and Rectal Surgeones annual conference. Hollywood, FL, May 17-21 2014.

Damle, RN, Cherng, N; Flahive, J; Davids, J; Maykel, J; Sturrock, P; Sweeney, WB; Alavi, K. Risk factors for 30-day readmission following colorectal surgery: A systematic review. Under review for publication in the Journal of the American College of Surgeons.

Chapter I: Introduction

Scrutiny of 30-day Readmissions

In 2007, the Medicare Payment Advisory Commission made a report to Congress that outlined a total reimbursement for hospital readmissions of $15 billion for the year 2005. [1] Upon further analysis of the Medicare hospitalizations that year, it was noted that 18% were readmissions that occurred within the first 30 days of the patient's index discharge, resulting in this staggering cost. Additionally,, only half of the readmitted patients were seen by a provider between the time of discharge and readmission. The most common conditions associated with hospital readmissions were myocardial infarction, chronic obstructive pulmonary disease, and pneumonia. Based on these findings, the commission deemed 80% of these readmission hospitalizations to be "potentially avoidable."

In response to this, as a part of the Patient Protection and Affordable Care Act, the Hospital Readmissions Reduction Program (HRRP) was formed [2]. In an effort to reduce potentially avoidable readmissions, the HRRP penalizes hospitals for readmissions for certain conditions, in excess of their risk-adjusted expected rates. This puts the burden of reducing readmissions on the hospital [3]. Beginning in 2012, the Centers for Medicare and Medicaid Services began penalizing hospitals for patients with a diagnosis of myocardial infarction, chronic obstructive pulmonary disease, and pneumonia. These penalties are levied on all Medicare reimbursements for the hospital, regardless

of the condition or procedure, making the disincentive quite large. The maximum penalty began at 1% of all Medicare reimbursements for the hospital but has increased to 3%, and may continue to rise in future. This list of covered conditions in the HRRP expanded to total knee and hip arthroplasty in October 2013, and is expected to expand further to include cardiovascular procedures in 2014.[4] The HRRP allows for expansion to additional conditions and surgical procedures at anytime.

Colorectal Surgery Readmissions

Of the 600,000 patients who annually undergo colorectal surgery (CRS), up to 1 in every 4 will be readmitted within the first 30 days of initial discharge.[5] This represents a significant burden on the healthcare system, with readmissions following colon cancer operations accounting for $300 million annually.[6] With the current healthcare climate of increasing costs and the scrutiny of readmissions by the HRRP, CRS may provide an ideal target for future penalties, prompting clinicians to examine readmissions and reduce their occurrence.

Readmissions following CRS has been extensively studied in the literature.[6-22] However, objective evidence of the most important risk factors for hospital readmission does not exist as the studies that have been performed to date have yielded conflicting results. Furthermore, only a minority of studies have assessed readmission risk with multivariable regression models.[6-22] Many of these studies have been limited by being single institution chart reviews with relatively small study size[7, 11, 13, 15, 19, 22], data from national cancer

registries from countries with national healthcare systems[8], or Medicare data specific to cancer diagnoses[10, 12], [20]. To date, factors found to be independently associated with readmission risk vary from sociodemographic to psychosocial, clinical, and perioperative.[7-18] In addition to the limitations of prior studies in this area, their focus has been on the risk factors for readmission. The outcomes and costs of readmission hospitalizations among CRS patients have been infrequently examined.{Greenblatt et al., 2010, #69810} {Collins et al., 1999, #27898}

National Surgical Quality Improvement Project

A more promising database for addressing the problem of hospital readmissions among surgical patients is the National Surgical Quality Improvement Project (NSQIP). [23] Each hospital has dedicated abstractors that collect data on patients undergoing specific surgical procedures every 1 in 8 days, representing a sample of surgical patients from each hospital. The data collected are rich in clinical information, from preoperative vital signs and lab values, to intraoperative blood loss, transfusion requirements, and to post-operative complications and discharge information. This database provides distinct advantages over many of the other large scale, multicenter databases available for analysis such as the Nationwide Inpatient Sample and Medicare. NSQIP also collects information on readmissions within 30 days of the index discharge and the reason(s) for readmission.

A recent report on readmissions after colorectal procedures using data from NSQIP found the strongest risk factor for readmission was post-operative complications. [24] However, this study only represents a sample of the total patients undergoing colorectal surgery procedures. Additionally, Wick et al, examined readmissions in a single institution study, comparing the readmissions captured for CRS patients in NSQIP, the University HealthSystem Consortium (UHC) Clinical Database, and by physician medical record review. The authors found NSQIP to be less comprehensive, missing readmissions that were captured by UHC or physician review.[11] Therefore, NSQIP, at this time, does not provide the best data with which to analyze hospital readmissions.

University HealthSystem Consortium Clinical Database

The UHC Clinical Database collects inpatient data from 120 participating academic medical centers and 300 of their affiliates, comprising nearly 95% of U.S. non-profit medical centers. Variables collected include *International Classification of Diseases, 9th edition* (ICD-9) codes for diagnoses and procedures, physician specialty, length of stay, risk-adjusted severity of illness scores, and hospital associated costs. The UHC converts hospital charges into cost-estimates based on federal-wage data for each hospital location, allowing for meaningful cost comparisons between centers, regardless of hospital location. They also capture both the occurrence of 30-day readmissions as well as the complete encounter information for the readmission hospitalization. Although patients admitted to non-UHC hospitals are not included in the

database, it does provide for a thorough examination of the reasons for readmission, outcomes from the readmission hospitalization, as well as the associated total direct hospital costs.[25]

Specific Aims

The primary aim of this study was to identify patient-related risk factors for 30-day readmission among adult patients following colorectal surgery procedures. Secondary study aims included a description of the rehospitalization outcomes among these patients and assessment of the total direct hospital costs associated with readmission. To meet these aims, we utilized the University HealthSystem Consortium Clinical Database to examine these outcomes among adult patients (≥ 18 years) who underwent colorectal surgery for both benign and malignant conditions between 2008 and 2011.

Chapter II: Study Methodology

Patient Selection

Following exemption status by the University of Massachusetts Medical Center Institutional Review Board, the UHC database was queried for adult patients, 18 years or older, with procedure codes for several colorectal resection ICD-9 codes (17.33-36, 17.39, 45.7, 45.73-76, 45.79, 45.8, 45.81-82, 48.42, 48.51-52, 48.62-63) performed between 2008 and 2011. The cohort was limited to those with either a primary or secondary ICD-9 diagnosis of malignancy (153.X, 154.0-3, 154.48), diverticular disease (562.10-11, 562.12-13), inflammatory bowel disease (555.0-2, 555.9, 556.X) or benign neoplasm (211.3-4). These years were studied since they allowed for analysis of surgeon-volume, as the unique surgeon identification numbers changed in 2012. Patients that died during their index hospitalization were excluded from this study since our primary outcome, readmission, required survival beyond the index stay.

Outcome Measures

The primary outcome of interest was all-cause 30-day hospital readmissions, as classified in the UHC database. Secondary endpoints were: readmission diagnosis (categorized by primary ICD-9 diagnosis at readmission), reoperation during readmission stay (exploratory surgery, stoma creation/revision, resection), intensive care unit (ICU) stay during the readmission, readmission length of stay (LOS), total direct hospital costs at readmission (as reported by UHC), and combined total direct hospital costs

(index hospitalization direct costs + readmission total direct costs), death during readmission, and readmission discharge disposition (home vs. non-home).

Factors Associated with 30-Day Hospital Readmission Rates

The covariates examined in relation to our primary study endpoint included age, gender, race, insurance status, comorbid diagnoses (based on ICD-9 diagnosis codes), 3M © APR-DRG Admission Severity of Illness Score (3M Health Information Systems, Salt Lake City, UT) recoded into low (minor and moderate) and high (major and extreme) for ease of analysis, inpatient post-operative complications (e.g., stroke, pneumonia, hemorrhage/hematoma, reopening of surgical wound, cellulitis, urinary tract infection, myocardial infarction, venous thromboembolism, sepsis), ICU admission rate after the initial procedure, index hospitalization LOS, index hospitalization discharge status (home vs. non-home), indication for procedure (diagnosis type), laparoscopy use (vs. open surgery) and ostomy creation. Surgeon and hospital volume was categorized based on quartiles of annual colorectal procedure volume.

Data Analysis

Univariate analysis was used to assess the demographic, clinical, and perioperative risk factors for 30-day hospital readmissions. Selected continuous variables were analyzed by student's t-test, while differences in categorical variables were examined by use of the chi-square test. Multivariable logistic regression was used to assess independent predictors of readmission. Variables included in the adjusted analysis included those deemed important based on a priori knowledge and those found to be significantly different

between those who were readmitted vs. those who were not on univariate analysis. All analyses were conducted with the use of Stata© IC version 12.1.

Chapter III: Study Results

Over the study period, 71,279 patients underwent colorectal resection for malignancy (n = 34,383), diverticular disease (n = 17,845), inflammatory bowel disease (n = 11,048), or benign tumor (n = 7,208), 795 of whom died during the index hospitalization, leaving 70,484 persons at risk for 30-day hospital readmissions. The mean age of the study population was 59 years, half were male, 76% were white, and nearly half (49%) were privately insured. The all-cause 30-day readmission rate was 13.7%.

Characteristics of readmitted vs. non-readmitted pts

In examining differences between those readmitted (RD) during the 30 days following CRS with those who were not (NRD), RD patients were likely to be slightly younger, male, black, and have public insurance (**Table 1**). Comorbid conditions were more prevalent in the readmitted group, and 13% of RD patients were of high severity of illness, compared to 8% of NRD pts ($p<0.001$). Patients who were readmitted were more likely to have a rectal resection, and less likely to have the procedure performed laparoscopically, than patients who were NRD (**Table 2**). NRD patients were more likely to be operated on by very-high volumes surgeons at very-high volume hospitals, though the absolute between group differences were quite small.

Outcomes of index hospitalization

During the index hospitalization, patients who were readmitted had higher rates of post-operative complications, ICU admission, and non-home discharges, and longer LOS(**Table 3**). Reoperation or percutaneous drain

placement occurred in 4% of the RD group, and only 2% of the NRD group. Median total direct costs for the index hospitalization were significantly higher in the RD group ($13,175 vs. $10,507,(p<0.001, data not shown). The factors with the highest odds of readmission were non-home discharge (skilled nursing facility OR 1.63; 95% CI 1.49-1.76; rehabilitation facility OR 2.93; 95% CI 2.54-3.40), stoma (OR 1.53; 95% CI 1.45-1.61), and LOS 4 days or longer (OR 1.44; 95% CI 1.32-1.57) (**Table 4**).

Outcomes of readmission hospitalization

Evaluation of primary readmission diagnoses revealed gastrointestinal disorders (29%) and surgical site infections (28%) as the most common reasons for readmission (**Table 5**). When the reasons for readmission were assessed in pts with the strongest risk factors identified (stoma creation, LOS ≥ 4 days, and non-home discharge), the readmission diagnoses were similar, although stoma patients had higher rates of readmission for fluid & electrolyte imbalance/failure to thrive, and organ space infection (**Table 5**).

The median time to readmission was 7 days (**Figure 1**). Patients readmitted within 7 days of discharge (early readmissions [ER]) compared with those readmitted 8-30 days after discharge (late readmissions [LR]) were more likely to undergo reoperation (**Table 6**). Intensive care unit rates and readmission LOS were higher among ER patients. The readmission mortality rate of 2% was no different between ER and LR patients. Median readmission total direct costs were slightly higher for ER patients compared with LR patients ($4,489 vs. $4,396, p<0.001). These readmission costs resulted in a combined

cost of $9,148 higher for RD than NRD patients (median costs $19,655 vs. $10,507, $p<0.001$).

Chapter IV: Discussion

In this large observational cohort study of adult men and women who underwent colorectal surgery for benign and malignant conditions over the period from January 2008 to December 201, we found a readmission rate of 13.7%. Several risk factors for 30-day readmission were identified including: index LOS 4 days or longer, stoma, and non-home discharge. The majority of 30-day readmissions occurred within one week of index admission; the most common reasons were gastrointestinal and surgical site infection related. Outcomes from the readmission hospitalization were poor, with one in five patients requiring reoperation or percutaneous drain placement, 13% requiring ICU admission, a median LOS of 4 days, and a 2% mortality rate.

Length of hospital stay

The relationship between shorter length of stay and increased readmission rates has been a debated topic in colorectal surgery, which was prompted by the introduction of enhanced recovery pathways (ERAS). The concept of ERAS, was first introduced for CRS in 1995.[26] Since then, numerous randomized controlled trials have indicated the safety and feasibility of shorter length of stay for CRS patients with no significant differences in readmission rates.[27] We found that LOS was higher, on average, for patients readmitted after surviving the hospital stay than those who were not readmitted. Length of stay 4 days or longer translated into a 40% higher readmission risk, after adjusting for relevant confounders. The contribution by ERAS or other process/patient specific factors to shorter hospital stays and lower readmission

rates is unclear given the lack of granularity in the UHC database. What is evident, based on our findings as well as that of previous studies, is the safety of early discharge of patients who meet pre-determined clinical criteria.

Stoma

In the present study, approximately 40% of readmitted patients had a stoma creation during the index hospitalization which was identified as a significant independent risk factor for readmission. While clearly indicated in certain clinical scenarios,[7, 28] the impact of stomas on quality of life and on the health care system is unquestioned.[29]

Well known to clinicians, a frequently encountered complication of stomas is high output, resulting in derangement of fluid and electrolyte balance, a common reason for readmission. [19] In our study, 12% of stoma patients were readmitted with fluid & electrolyte imbalance/failure to thrive, which was higher than the overall rate of 7% for all readmitted patients. Paquette and colleagues performed a study evaluating the readmission rates for dehydration or acute kidney injury among pateints receiving new ileostomates from a single institution over the period 2007 to 2011. [19] Out of the 201 patients eligible for readmission, 17% were readmitted within 30-days for dehydration or renal failure, which is slightly higher than was found in our study.

While creation of temporary or permanent stomas remains a mainstay and important tool in the armamentarium of the surgeon, its creation is clearly associated with increased costs. Strategies such as earlier clinic follow-up, more frequent home nurse visits, and perhaps even weekly phone-calls by

physician-extenders may need to be investigated further in an effort to reduce unnecessary and costly readmissions.

Non-home discharge

Several prior studies have identified non-home discharge status as a risk factor for readmission.[6, 10, 14] We found up to 3 times increase risk for readmissions for non-home discharge, which has been corroborated by the findings from prior studies ([6, 10, 14]). While our analysis adjusted for several factors related to the need for skilled nursing or inpatient rehabilitation, such as older age and occurrence of post-operative complications, we cannot determine whether the readmission risk was related to patient-factors that could not be adjusted for in our regression models, or if there is a risk inherent in non-home discharge itself. Potential sources for increased readmission include additional exposure to healthcare associated infections, lower thresholds for sending patients back to the hospital, poor communication between the transferring institution and the accepting facility, or perhaps a diminished quality of care.[30, 31] A study of Medicare beneficiaries requiring skilled nursing care following an acute care hospitalization suggested an inverse facility volume-outcome relationship with rehospitalization.[31] An evaluation of the association between facility volume and readmission rates among non-Medicare surgical patients is required to further examine this relationship.

Readmission prevention

Not all readmissions are preventable. Twenty percent of the readmitted patients in our study required a return to the operating room or percutaneous

abdominal drainage, and about one in five required ICU level care. It's unclear, however, given the nature of our database, whether some of the remaining readmissions could have been identified and treated prior to initial discharge. We are further limited by the lack of available data on the levels of care and resources in the outpatient setting, which, if appropriately utilized, could prevent unnecessary readmissions. Patients requiring readmission for less urgent concerns may be treated appropriately in the outpatient setting.

For example, a New York hospital performed a trial comparing readmission rates for adult patients following coronary artery bypass graft between those who had standard visiting nurse care, and those who had a cardiothoracic trained physician assistant (PA) make home visits on post-operative days 2 and 5.[32] Readmissions were reduced by 25% among patients receiving PA home visits. The most significant drop in readmission rates occurred in wound-related complications, in which the readmission rates decreased from 44% to 19%. This highlights a possible readmission reduction strategy in the CRS population, since 30% of readmissions in our study were due to surgical-site infections. The costs of implementation of this strategy have to be balanced against the overall costs of readmission and its burden on the healthcare system.

Another promising readmission prevention strategy that has recently received some press is by a startup company called Noora Health. Their program works through an iPad app, which allows patients and their families to view a combination of videos, quizzes, and interactive content that teaches them

skills that will aid in their recovery once discharged. [33] While hospitalized, patients and families are given 24-hour access to the app, and actually practice some of the skills they may need, such as changing a bandage, or assisting the family member out of bed to avoid falls. The clinicians and nurses get reports on the progress so they may intervene and emphasize the skills they are struggling with. This program is being tested in the United States, but has proven to be effective in India at a chain of low-cost hospitals run by Narayana Health.

Future Areas of Research

At our institution, we plan to implement the use of a readmission risk prediction calculator. We plan to prospectively collect the predicted readmission risk for patients who meet the inclusion criteria used in the present study and compare to observed readmission rates. This will serve as a validation measure of the risk predictor. When the risk predictor is validated, we can begin to implement interventions to assess for reduction in readmission risk. As we collect this data, it will alert us to high-risk patients. For these patients, we plan to implement earlier clinic follow-up, and increased communication with any post-discharge care facilities the patients may go. With these interventions we hope to reduce the readmission rates at our institution and expand to additional surgical patients and perhaps other institutions.

Study Strengths/Limitations

In this study we were able to describe the outcomes of the readmission hospitalization. Though prior reports have identified the readmission itself, there is a paucity of information on what actually occurs during the readmission.

Knowledge of this information allows for identification of potentially preventable readmissions. We also highlighted the additional costs attributed to readmission stays, which are critical for planning resource allocation for readmission reduction strategies.

We acknowledge several important limitations of this paper. Given the limitations of the database, we were unable to follow patients for longer than 30 days. However, the 30-day time point is used as a quality metric by CMS and is what penalizations are currently based on. The database may have missed patients readmitted to non-UHC hospitals, or those that died in the non-hospital setting. We believe this occurrence is low, given the similar readmission rates seen in other studies.[11, 12, 17] Patients evaluated in the emergency department and discharged home are not captured in the data. Lastly, this database lacks true clinical data, including laboratory values, vital signs, inpatient/outpatient medications and other more specific clinical information which may aid in decision making with regards to early discharge and/or readmission. Despite these limitations, we believe this study provides a scaffold on which to build and develop readmission prevention strategies.

Conclusion

In summary, readmissions within 30-days of the index discharge occur in about 1 in 8 adults following colorectal surgery for benign or malignant conditions. Predictive factors are clear and easily identified prior to hospital discharge, including LOS ≥4 days, ostomy, and non-home discharge. The significant risk of non-home discharge highlights a potential target for future

prevention strategies. Certainly, the clinical and financial burden of readmissions warrant a closer look in an effort to improve care quality and reduce costs in a climate of excess healthcare spending.

Bibliography

1. Medicare Payment Advisory Commission. *Report to the Congress: promoting greater;* 2007.
2. Medicare Payment Advisory Commission. Public Meeting. 2011
3. Kocher R, Emanuel EJ, DeParle NA. The Affordable Care Act and the future of clinical medicine: the opportunities and challenges. *Ann Intern Med*. 2010;153:536-539.
4. FY2013 Final rule. Federal Register: Inpatient Prosecptive Payment Systems. 2012; 77:170.
5. Guinier D, Mantion GA, Alves A, Kwiatkowski F, Slim K, Panis Y. Risk factors of unplanned readmission after colorectal surgery: a prospective, multicenter study. *Dis Colon Rectum*. 2007;50:1316-1323.
6. Wick EC, Shore AD, Hirose K, Ibrahim AM, Gearhart SL, Efron J, Weiner JP, Makary MA. Readmission rates and cost following colorectal surgery. *Dis Colon Rectum*. 2011;54:1475-1479.
7. Appau KA, Fazio VW, Shen B, Church JM, Lashner B, Remzi F, Brzezinski A, Strong SA, Hammel J, Kiran RP. Use of infliximab within 3 months of ileocolonic resection is associated with adverse postoperative outcomes in Crohn's patients. *J Gastrointest Surg*. 2008;12:1738-1744.
8. Devon KM, Urbach DR, McLeod RS. Postoperative disposition and health services use in elderly patients undergoing colorectal cancer surgery: a population-based study. *Surgery*. 2011;149:705-712.
9. Faiz O, Haji A, Burns E, Bottle A, Kennedy R, Aylin P. Hospital stay amongst patients undergoing major elective colorectal surgery: predicting prolonged stay and readmissions in NHS hospitals. *Colorectal Dis*. 2011;13:816-822.
10. Greenblatt DY, Weber SM, O'Connor ES, LoConte NK, Liou JI, Smith MA. Readmission after colectomy for cancer predicts one-year mortality. *Ann Surg*. 2010;251:659-669.
11. Hechenbleikner EM, Makary MA, Samarov DV, Bennett JL, Gearhart SL, Efron JE, Wick EC. Hospital readmission by method of data collection. *J Am Coll Surg*. 2013;216:1150-1158.
12. Hendren S, Morris AM, Zhang W, Dimick J. Early discharge and hospital readmission after colectomy for cancer. *Dis Colon Rectum*. 2011;54:1362-1367.
13. Kariv Y, Wang W, Senagore AJ, Hammel JP, Fazio VW, Delaney CP. Multivariable analysis of factors associated with hospital readmission after intestinal surgery. *Am J Surg*. 2006;191:364-371.
14. Kelly M, Sharp L, Dwane F, Kelleher T, Comber H. Factors predicting hospital length-of-stay and readmission after colorectal resection: a population-based study of elective and emergency admissions. *BMC Health Serv Res*. 2012;12:77.
15. Kennedy ED, Rothwell DM, Cohen Z, McLeod RS. Increased experience

and surgical technique lead to improved outcome after ileal pouch-anal anastomosis: a population-based study. *Dis Colon Rectum*. 2006;49:958-965.
16. Lidor AO, Schneider E, Segal J, Yu Q, Feinberg R, Wu AW. Elective surgery for diverticulitis is associated with high risk of intestinal diversion and hospital readmission in older adults. *J Gastrointest Surg*. 2010;14:1867-1873.
17. Manilich E, Vogel JD, Kiran RP, Church JM, Seyidova-Khoshknabi D, Remzi FH. Key factors associated with postoperative complications in patients undergoing colorectal surgery. *Dis Colon Rectum*. 2013;56:64-71.
18. Ozturk E, Kiran RP, Remzi F, Fazio VW. Early readmission after ileoanal pouch surgery. *Dis Colon Rectum*. 2009;52:1848-1853.
19. Paquette IM, Solan P, Rafferty JF, Ferguson MA, Davis BR. Readmission for Dehydration or Renal Failure After Ileostomy Creation. *Dis Colon Rectum*. 2013;56:974-979.
20. Schneider EB, Hyder O, Brooke BS, Efron J, Cameron JL, Edil BH, Schulick RD, Choti MA, Wolfgang CL, Pawlik TM. Patient readmission and mortality after colorectal surgery for colon cancer: impact of length of stay relative to other clinical factors. *J Am Coll Surg*. 2012;214:390-8; discussion 398.
21. Toneva GD, Deierhoi RJ, Morris M, Richman J, Cannon JA, Altom LK, Hawn MT. Oral antibiotic bowel preparation reduces length of stay and readmissions after colorectal surgery. *J Am Coll Surg*. 2013;216:756-62; discussion 762.
22. Turina M, Remzi FH, Dietz DW, Kiran RP, Seyidova-Khoshknabi D, Hammel JP, Vogel JD. Quantification of Risk for Early Unplanned Readmission after Rectal Resection: A Single-Center Study. *J Am Coll Surg*. 2013;217:200-208.
23. Fink AS, Campbell Jr DA, Mentzer Jr RM, Henderson WG, Daley J, Bannister J, Hur K, Khuri SF. The National Surgical Quality Improvement Program in non-veterans administration hospitals: initial demonstration of feasibility. *Annals of surgery*. 2002;236:344.
24. Lawson EH, Hall BL, Louie R, Zingmond DS, Ko CY. Identification of modifiable factors for reducing readmission after colectomy: A national analysis. *Surgery*. 2014;155:754-766.
25. University HealthSystem Consortium Clinical Database. May 2014. (https://www.uhc.edu/docs/45015488_CRMUserManual.pdf)
26. Bardram L, Funch-Jensen P, Jensen P, Crawford ME, Kehlet H. Recovery after laparoscopic colonic surgery with epidural analgesia, and early oral nutrition and mobilisation. *Lancet*. 1995;345:763-764.
27. Varadhan KK, Neal KR, Dejong CH, Fearon KC, Ljungqvist O, Lobo DN. The enhanced recovery after surgery (ERAS) pathway for patients undergoing major elective open colorectal surgery: a meta-analysis of randomized controlled trials. *Clin Nutr*. 2010;29:434-440.
28. Weston-Petrides GK, Lovegrove RE, Tilney HS, Heriot AG, Nicholls RJ, Mortensen NJM, Fazio VW, Tekkis PP. Comparison of outcomes after

restorative proctocolectomy with or without defunctioning ileostomy. *Archives of Surgery*. 2008;143:406-412.
29. Nugent KP, Daniels P, Stewart B, Patankar R, Johnson CD. Quality of life in stoma patients. *Diseases of the colon & rectum*. 1999;42:1569-1574.
30. Unroe KT, Greiner MA, Colon-Emeric C, Peterson ED, Curtis LH. Associations between published quality ratings of skilled nursing facilities and outcomes of medicare beneficiaries with heart failure. *J Am Med Dir Assoc*. 2012;13:188.e1-188.e6.
31. Li Y, Cai X, Yin J, Glance LG, Mukamel DB. Is higher volume of postacute care patients associated with a lower rehospitalization rate in skilled nursing facilities? *Med Care Res Rev*. 2012;69:103-118.
32. Nabagiez JP, Shariff MA, Khan MA, Molloy WJ, McGinn JTJ. Physician assistant home visit program to reduce hospital readmissions. *J Thorac Cardiovasc Surg*. 2013;145:225-31, 233; discussion 232.
33. Rao L. Noora Health's training program for patietns and caregivers improves recovery and reduces readmission rates. TechCrunch. 2014 (http://techcrunch.com/2014/03/23/noora-healths-training-program-for-patients-and-caregivers-improves-recovery-and-reduces-readmission-rates/)

Tables

TABLE 1. Sociodemographic and baseline characteristics by 30-day readmission status for patients that survived index hospitalization for colorectal resection for cancer, diverticular disease, inflammatory bowel disease, or benign tumors from the UHC database between 2008-2011 (n = 70,484).

	Readmitted (N =9,632)	**Not-Readmitted (N = 60,852)**	***P*-value**
Age, y, mean (SD)	58 (17)	59 (16)	0.003
Male	4,940 (51)	30,523 (50)	0.05
Race			<0.001
White	7,157 (74)	46,316 (76)	
Black	1,320 (14)	6,824 (11)	
Hispanic	69 (1)	391 (1)	
Asian	194 (2)	1,263 (2)	
Other	892 (9)	6,058 (10)	
Insurance Status			<0.001
Private	4,118 (43)	30,178 (50)	
Public	4,970 (52)	27,532 (45)	
Self-pay	74 (1)	509 (1)	
Other	470 (5)	3,633 (4)	
Comorbidities			
Hypertension	4,648 (48)	27,196 (45)	<0.001
Diabetes	1,805 (19)	8,882 (15)	<0.001
Anemia	1,724 (18)	8,641 (14)	<0.001
Chronic obstructive pulmonary disease	1,379 (14)	7,186 (12)	<0.001
Obesity	1,150 (12)	6,225 (10)	<0.001
Congestive heart failure	560 (6)	2,022 (3)	<0.001
Depression	914 (9)	4,549 (7)	<0.001
Renal disease	622 (6)	2,352 (4)	<0.001
Peripheral vascular disease	350 (4)	1,639 (3)	<0.001
Liver disease	298 (3)	1,228 (2)	<0.001

SD = standard deviation

"Other" Race = native american/eskimo, hawaiian/pacific-islander, multi-racial, other, unavailable, and declined; "Other" insurance status = military, auto, worker's compensation, research, charity, and other.

TABLE 2. Procedure characteristics by 30-day readmission status for patients that survived index hospitalization for colorectal resection for cancer, diverticular disease, inflammatory bowel disease, or benign tumors from the UHC database between 2008-2011 (n = 70,484).

	Readmitted (N =9,632)	**Not-Readmitted (N = 60,852)**	***P*-value**
Admission Status			<0.001
Elective	7,075 (73)	48,229 (80)	
Urgent	878 (9)	4,832 (8)	
Emergent	1,671 (17)	7,736 (13)	
Diagnosis			<0.001
Colon cancer	3,261 (34)	22,663 (37)	
Rectal cancer	1,566 (16)	6,893 (11)	
Diverticular disease	2,048 (21)	15,797 (26)	
Ulcerative Colitis	1,052 (11)	3,943 (7)	
Crohn's disease	958 (10)	5,095 (8)	
Benign tumor	747 (8)	6,461 (11)	
Procedure			<0.001
Colectomy	7,073 (73)	48,605 (80)	
Right	2,454 (25)	18,180 (30)	
Transverse	184 (2)	1,241 (2)	
Left	728 (8)	4,652 (8)	
Sigmoid	2,104 (22)	17,620 (29)	
Total	1,251 (13)	4,774 (8)	
Other	672 (7)	3,327 (5)	
Low anterior resection	1,384 (14)	7,438 (12)	
Abdominoperineal resection	831 (9)	3,481 (6)	
Colon & rectal resection	344 (4)	1,328 (2)	
Stoma creation	3,793 (39)	14,714 (24)	<0.001
Surgical approach			<0.001
Open	6,853 (71)	36,055 (59)	
Laparoscopic-assisted	2,660 (28)	24,021 (40)	
Robotic-assisted	119 (1)	776 (1)	
Surgeon volume category			<0.001
Very High	14,608 (48)	30,008 (50)	
High	2,329 (24)	14,773 (24)	
Medium	1,556 (16)	9,655 (16)	
Low	1,139 (12)	6,416 (11)	
Hospital volume category			<0.001
Very High	5,452 (57)	35,850 (59)	
High	2,419 (25)	14,535 (24)	
Medium	1,309 (14)	7,487 (12)	
Low	452 (5)	2,980 (5)	

TABLE 3. Index hospitalization outcomes by 30-day readmission status for patients that survived index hospitalization for colorectal resection for cancer, diverticular disease, inflammatory bowel disease, or benign tumor from the UHC database between 2008-2011 (n = 70,484).

	Readmitted (N =9,632)	**Not-Readmitted (N = 61,647)**	***P*-value**
Post-operative complication	1,249 (13)	4,788 (8)	<0.001
Wound related	842 (9)	3,326 (5)	<0.001
Other infectious (Urinary tract infection, pneumonia, sepsis)	293 (3)	1,018 (2)	<0.001
Cardiovascular (Myocardial infarction, stroke, venous thromboembolism)	148 (2)	453 (1)	<0.001
ICU admission	2,571 (27)	9,847 (16)	<0.001
ICU length of stay, d, median (SD)	3 (8)	2 (7)	<0.001
Reoperation	375 (4)	1,152 (2)	<0.001
Re-exploration	173 (2)	573 (1)	<0.001
Bowel resection	125 (1)	321 (1)	<0.001
Stoma creation/revision	213 (2)	573 (1)	<0.001
Anastomotic revision	39 (<1)	107 (<1)	<0.001
Percutaneous abdominal drain placement	380 (4)	1,109 (2)	<0.001
Inpatient length of stay, *days*, median (SD)	8 (10)	5 (7)	<0.001
Discharge status			<0.001
Home	7,991 (83)	55,585 (91)	
Skilled nursing facility	1,065 (11)	3,752 (6)	
Rehabilitation facility	329 (3)	572 (<1)	
Other non-home facility	247 (3)	943 (2)	

ICU = intensive care unit

TABLE 4. Univariate and multivariable analysis assessing risk factors for 30-day readmission (n = 9,632) for patients that survived index hospitalization for colorectal resection for cancer, diverticular disease, inflammatory bowel disease, or benign tumors from the UHC database between 2008-2011 (n = 70,484)

	Unadjusted Odds Ratio (95% Confidence Interval)	**Adjusted Odds Ratio (95% Confidence Interval)**
Age, per 10-year increase	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
Female (vs. Male)	0.96 (0.92, 1.00)	0.99 (0.96, 1.04)
Non-white[a] (vs. White)	1.25 (1.17, 1.34)	1.09 (1.03, 1.14)
Non-private insurance (vs. Private)	1.32 (1.27, 1.38)	1.28 (1.22, 1.35)
High Severity of Illness (vs. Low)	1.71 (1.61, 1.83)	1.15 (1.07, 1.24)
Urgent/Emergent Admission (vs. Elective)	1.38 (1.31, 1.45)	0.96 (0.90, 1.02)
Diagnosis (vs. Benign tumor)		
Diverticular disease	1.12 (1.03, 1.23)	0.89 (0.82, 0.98)
Inflammatory bowel disease	1.92 (1.76, 2.10)	1.32 (1.19, 1.46)
Cancer	1.41 (1.30, 1.53)	1.00 (0.92, 1.10)
Colectomy (vs. Proctectomy)	1.44 (1.37, 1.51)	1.27 (1.21, 1.35)
Stoma creation	2.03 (1.95, 2.13)	1.53 (1.45, 1.61)
Open (vs. Laparoscopic/Robotic)	1.70 (1.63, 1.79)	1.24 (1.17, 1.31)
Surgical complication	1.74 (1.63, 1.86)	1.13 (1.05, 1.22)
Reoperation	2.10 (1.97, 2.37)	1.05 (0.91, 1.20)
Percutaneous drain placement	2.12 (1.97, 2.49)	1.32 (1.16, 1.50)
ICU admission	1.89 (1.79, 1.98)	1.36 (1.28, 1.44)
Index length of stay ≥4 days (vs. <4 days)	2.19 (2.01, 2.38)	1.44 (1.32, 1.57)
Discharge status (vs. Home)		
Skilled nursing facility	1.97 (1.83, 2.12)	1.63 (1.49, 1.76)
Rehabilitation facility	4.00 (3.49, 4.59)	2.93 (2.54, 3.40)
Other non-home facility	1.82 (1.58, 2.10)	1.23 (1.06, 1.43)
Hospital volume category (vs. Low)		
Medium	1.15 (1.03, 1.29)	1.20 (1.07, 1.35)
High	1.10 (0.99, 1.22)	1.17 (1.05, 1.31)
Very High	1.00 (0.90, 1.11)	1.11 (1.00, 1.24)

[a]Non-white = Black, Asian, or Other
[b]Non-private insurance = public, self-pay, other
Multivariable model adjusted for all variables in the table.

TABLE 5. Reasons for 30-day readmission for all readmitted patients, those with index length of stay ≥ 4 days, stoma creation, or non-home discharge (n = 9,632).

	All patients (N = 9,632)	**Stoma creation (N = 3,793)**	**Length of stay ≥4 days (N = 8,995)**	**Non-home discharge (N = 7,991)**
	No. (%)			
Gastrointestinal	2797 (29)	1029 (27)	2508 (28)	2511 (31)
Surgical site related	2676 (28)	951 (25)	2515 (28)	2383 (30)
Organ space abscess	353 (13)	157 (17)	335 (13)	311 (13)
Deep wound infection	73 (3)	21 (2)	72 (3)	56 (2)
Superficial infection	2140 (80)	746 (78)	2007 (80)	1923 (81)
Hematoma/seroma	110 (4)	27 (3)	101 (4)	93 (4)
Cardiovascular	173 (2)	48 (1)	164 (2)	108 (1)
Bleeding	115 (1)	28 (1)	102 (1)	91 (1)
Respiratory	183 (2)	61 (2)	175 (2)	127 (2)
Genitourinary	454 (5)	279 (7)	447 (5)	354 (4)
Deep vein thrombosis/pulmonary embolism	192 (2)	60 (2)	183 (2)	148 (2)
Neurological	69 (1)	24 (1)	68 (1)	40 (1)
Fluid & electrolyte imbalance/failure to thrive	681 (7)	450 (12)	664 (7)	587 (7)
Other infectious	414 (4)	172 (5)	396 (4)	284 (4)
Other	1878 (20)	691 (18)	1773 (20)	1358 (17)

Groups are not mutually exclusive, therefore the number of patients with length of stay ≥ 4 days, stoma creation, and non-home discharge add up to >9,632

TABLE 6. Reasons for 30-day readmission and outcomes of readmission encounter between early (≤7 days) and late (>7 days) readmission following colorectal resection for cancer, diverticular disease, inflammatory bowel disease, or benign tumors from the UHC database between 2008-2011 (n=9,632).

	Early readmission (N = 4,923)	**Late readmission (N = 4,709)**	***P***
Readmission diagnosis			<0.001
Gastrointestinal	1,709 (35)	1,088 (23)	
Surgical site related	1,306 (27)	1,370 (29)	
Organ space	157 (12)	196 (14)	
Deep	34 (3)	39 (3)	
Superficial	1040 (80)	1100 (80)	
Non-infectious	75 (5)	35 (3)	
Cardiovascular	76 (2)	97 (2)	
Bleeding	83 (2)	32 (1)	
Respiratory	99 (2)	84 (2)	
Genitourinary	139 (3)	315 (7)	
Venous thromboembolism	88 (2)	104 (2)	
Neurological	33 (1)	36 (1)	
Fluid & Electrolyte/Malnutrition	322 (7)	359 (8)	
Other infectious	172 (3)	172 (5)	
Other	896 (18)	982 (21)	
Reoperation during readmission encounter	395 (8)	181 (4)	<0.001
Abdominal exploration	100 (25)	47 (26)	
Stoma creation/revision	274 (69)	105 (58)	
Bowel resection	21 (5)	29 (16)	
Percutaneous abdominal drain	800 (17)	668 (14)	<0.001
ICU admission during readmission encounter	705 (14)	543 (12)	<0.001
Readmission length of stay, d, median (SD)	5 (8)	4 (7)	<0.001
Non-home readmission discharge	649 (14)	584 (13)	NS
Death during readmission stay	91 (2)	72 (2)	NS
Readmission total direct cost, $, median (SD)	$4,489 ($22,120)	$4,396 ($8,196)	<0.001
Combined total direct cost*	$19,739 ($29,264)	$19,654 ($28,902)	<0.001

ICU = intensive care unit, SSI= surgical site infection, DVT = deep vein thrombosis, PE = pulmonary embolism
*index encounter + readmission encounter

Figures

Figure 1. Distribution of time to readmission (median = 7 days)