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Increased Healthcare Utilization for Medical Comorbidities Prior to Surgery Improves Postoperative Outcomes

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Abstract

Objective: The purpose of this study was to evaluate the impact of optimization of preoperative comorbidities by nonsurgical clinicians on short-term postoperative outcomes.

Summary background data: Preoperative comorbidities can have substantial effects on operative risk and outcomes. The modifiability of these comorbidity-associated surgical risks remains poorly understood.

Methods: We identified patients with a major comorbidity (eg, diabetes, heart failure) undergoing an elective colectomy in a multipayer national administrative database (2010–2014). Patients were included if they could be matched to a preoperative surgical clinic visit within 90 days of an operative intervention by the same surgeon. The explanatory variable of interest (“preoperative optimization”) was defined by whether the patient was seen by an appropriate nonsurgical clinician between surgical consultation and subsequent surgery. We assessed the impact of an optimization visit on postoperative complications with use of propensity score matching and multilevel, multivariable logistic regression.

Results: We identified 4531 colectomy patients with a major potentially modifiable comorbidity (propensity weighted and matched effective sample size: 6037). After matching, the group without an optimization visit had a higher rate of complications (34.6% versus 29.7%, $P = 0.001$). An optimization visit conferred a 31% reduction in the odds of a complication ($P < 0.001$) in an adjusted analysis. Median preoperative costs increased by \$684 ($P < 0.001$) in the optimized group, and a complication increased total costs of care by \$14,724 ($P < 0.001$).

Conclusions and relevance: We demonstrated an association between use of nonsurgical clinician visits by comorbid patients prior to surgery and a significantly lower rate of complications. These findings support the prospective study of preoperative optimization as a potential mechanism for improving postoperative outcomes.

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Keywords

colectomy; comorbidity; mixed effects regression; outcomes; preoperative care; preoperative period; propensity score; surgery

The time interval between the initial surgical consultation, decision to operate, and the patient's operative date can extend for months for elective operations. Various preoperative interventions such as "prehabilitation" and the "perioperative home" have been proposed to take advantage of this time period to address modifiable risk factors for a patient's upcoming surgery.^{1–3} These early efforts in a number of surgical specialties have suggested that preoperatively improving functional status,^{3,4} improving nutrition,⁵ and reducing nicotine use^{6–8} may improve postoperative outcomes. These proactive measures occur over weeks to months and are distinct from the more routine and increasingly maligned preoperative testing and "clearance" paradigm.^{9,10}

The major assumptions behind these interventions include that patients in their natural state are not fully medically optimized and that increased attention is needed prior to surgery since procedural risks are compounded by underlying comorbidity-related risks. Increased efforts to optimize patients preoperatively demand evidence that such healthcare resource allocation is beneficial and justifiable. It is well known that certain preoperative risk factors such as diabetes, functional status, and malnutrition place patients at increased risk for perioperative complications.^{11–13} However, it is less clear whether patients with medical comorbidities that appear biologically correctable are realistically "modifiable" in the preoperative period. Evidence supporting this belief remains anecdotal.³

We believe that foundational work relating preoperative optimization efforts to postoperative outcomes is critical at the present time. Specifically, the surgical community needs a better understanding of the role of preoperative care for high-risk patients in moderate-to-high-risk surgery that is distinct from perfunctory, nontargeted preoperative testing. The purpose of this study was to compare postoperative outcomes of individuals with potentially modifiable comorbidities who had perioperative medical optimization prior to undergoing elective colectomy to those who had no preoperative optimization. We hypothesized that the optimized group would have lower 30-day complication rates and favorable total costs of care.

METHODS

Data Source and Population

Patients with employer-sponsored commercial insurance undergoing a colectomy (International Classification of Disease, 9th revision (ICD-9) procedure codes: 17.3x, 45.7x, 45.8x, 48.5) were identified in the 2010 to 2014 records of the Truven Health Analytics MarketScan database. The MarketScan database is a convenience sample of service-level claims data from over 350 unique health plans managed by United States-based employers, commercial health plans, and selected state Medicaid agencies.¹⁴

Patients were considered as having an “elective” procedure and included in this study if they could be matched to a surgical clinic visit within 90 days of an operative intervention by the same surgeon identified with a billing identifier. Patients were required to have 1 or more of 7 modifiable medical comorbidities for inclusion. We selected modifiable medical comorbidities that were both highly likely to be included in administrative billing data and routinely discussed in the perioperative optimization literature: diabetes, chronic obstructive pulmonary disease, heart failure, coronary artery disease, atrial fibrillation, chronic renal failure, and cirrhosis.^{1,15} We considered patients to have these medical comorbidities if we identified outpatient billing codes (Appendix 1, <http://links.lww.com/SLA/B436>) for any of these within the 90 days prior to the surgery.¹⁶ The Johns Hopkins University School of Medicine Institutional Review Board approved and exempted this study from review.

The time interval between the surgical visit and the colectomy was defined as the “potential preoperative optimization period.” In this time interval, patients were defined as “optimized” if they were seen by an appropriate nonsurgical clinician for at least one of their preexisting comorbidities. We defined an “appropriate” nonsurgical clinician as any provider billing as a primary care provider or as a medical specialist consistent with a specific comorbidity (eg, endocrinology visit for diabetic patient); we excluded preoperative evaluation visits to an anesthesiologist.

Covariate Identification

In addition to the primary explanatory variables described above, the MarketScan database also has relevant covariates including sex, age, geographic region, enrollment in a capitated payer program, or enrollment in managed-care plan with assignment to a primary care provider (PCP). Overall health status was captured using grouped Charlson Comorbidity Index scores.¹⁷ ICD-9 diagnoses assigned to each hospital admission as the primary diagnosis code were used to identify the operative indication and grouped into cancer (153.X, 154.0, 154.1, 154.8, 209.0–209.6, 211.1–211.4, 214.3, 230.3, 230.4, 235.2, 239.0), diverticulitis (562.10, 562.11), inflammatory bowel disease (555.X, 556.X), and ostomy complications (569.6, V55.2, V55.3). Laparoscopic versus open surgical approaches were classified also using procedural ICD-9 codes.

We identified surgeon volume and tendency to refer based on observed clinician practices across the entire population of patients with a medical comorbidity undergoing colectomy in MarketScan. Personal clinician identifiers were used to classify surgeons into colectomy 4-year volume tertiles (low <5, moderate 5–19, high ≥20; of only colectomies reported in MarketScan) and to assign a continuous variable of the tendency to use preoperative referral (ie, proportion of one’s patients sent to a nonsurgical clinician prior to surgery).

Outcomes Assessment

Postoperative complications were identified from ICD-9 diagnosis codes for the 30 days following surgery. Postoperative complications were also grouped in a manner previously reported (see Appendix 2, <http://links.lww.com/SLA/B436> for codes).^{16,18} In-hospital mortality was examined using the discharge status field within the MarketScan database. We obtained costs of care from payment data included in the MarketScan data, which

included all billed costs issues by the payer and patient in the provision of care, including copayments and deductibles. Preoperative costs were summed from all payments within 90 days preceding surgery. Postdischarge costs were the aggregation of all payments in the 30 days following surgery.

Optimization Events

Although not a primary outcome, we also investigated which preoperative visits could be associated with a new or altered medication regimen. We identified the proportion of preoperative visits with a new insulin, antidiabetic agent, inhaler, oral steroid, cardioprotective agent, or diuretic with a filled prescription within 7 days of the nonsurgical clinician preoperative visit by text string searching the outpatient pharmacy file associated with the MarketScan database (drug names listed in Appendix 3, <http://links.lww.com/SLA/B436>). When dose and strength data were available, a change in total daily dose of more than 20% was considered a new prescription.

Analysis

We used Stata/MP 14.2 (StataCorp LP; College Station, TX). Due to the presumed differences between the optimized versus nonoptimized populations, we made the decision a priori to conduct this analysis using a matched version of the original dataset. We hypothesized that patient-, surgeon-, and hospital-level effects may confound the relationship between complications and optimization visit. Therefore, we developed a doubly-robust, propensity score frequency-weighted mixed effects logistic model to account for both the effects of patient- and surgeon-level variation on complications. We treated surgeon identity and hospital site as a random-coefficient on both patient- and surgeon-specific fixed factors akin to the following model:

$$\begin{aligned} \text{logit}\{Pr(y_{ijk} = 1 | X_{ijk}, \zeta_{jk}, \zeta_j)\} \\ = (\beta_0 + \zeta_{0j} + \zeta_{0jk}) + (\beta_1 + \zeta_{1j} + \zeta_{1jk})X_{1i} + \dots \\ + \epsilon_{ijk} \end{aligned}$$

ζ_{jk} represents the random effects of individual surgeons and ζ_j represents the random effects of surgeons within a given hospital applied to each coefficient of a traditional regression model.

Via an author-consensus-driven process consistent with our causal framework, variables historically associated with complications such as gender, age, geographic region, laparoscopic approach, indication for surgery, and grouped Charlson score were added to the regression and propensity scoring models; covariates with plausible confounding between likelihood of optimization and likelihood of complication (eg, specific comorbidity at risk, capitated payments, assigned PCP, surgeon volume, and preoperative referral tendency) were also included in the models.

We performed propensity score assignment with 1:1 nearest-neighbor matching to account for between-group covariate extremes. Because of the control group being substantially smaller than the exposure group, we matched with replacement as has been previously

described and suggested.^{19,20} We monitored for overweighting of frequency weights and weight-trimmed individuals representative of greater than 1% of the sample (1 occurrence in total). Frequency-weighted bivariate analysis was performed by covariates and outcomes above between the optimized and nonoptimized groups. Binary and categorical variables were assessed using χ^2 test and discrete variables' association was calculated using equality-of-medians test.

We identified potentially excludable covariates by stepwise backward selection with minimization of Akaike information criterion of a simplified nonclustered derived model (results not reported). We tested removal of any variable excluded by stepwise analysis to assess for changes in effect with a preference for a more parsimonious model and assessed differences by Hosmer–Lemeshow goodness-of-fit testing. We tested covariates for multicollinearity by variance inflation factor analysis using a linear regression model akin to the finalized logistic model (threshold for exclusion: variance inflation factor >10) and for effect measure modification on the key explanatory variable by stepwise inclusion of interaction terms. We assessed missingness of covariates as part of exploratory data analysis and then excluded variables from multivariable regression if missing more than 10% of the sample.

Secondary objectives included modeling the independent effect of an optimization visit on total costs of care and exploring the influence of optimization visit timing and potential effect mediation on risk of complication. We assessed optimization visit timing using multivariable regression methods similar to those described above with the primary explanatory variable stratified into time intervals of optimization visit first identified by Lowess plots. Total costs of care were assessed by a gamma distributed logistic regression model that incorporated the same covariates as the complication model described above. We used this model to assess average marginal effect differences in total costs of care with and without an optimization visit. All tests of significance used a 0.05 *P* value threshold.

RESULTS

We identified an initial 3096 preoperatively optimized patients. With propensity score matching with replacement and weighting, we further analyzed an effective sample size of 6037 (Fig. 1). A majority (68.3%) visited an appropriate nonsurgical clinician prior to surgery. Bivariate analysis of the propensity score-matched groups is reported in Table 1. After matching, differences between optimized and nonoptimized colectomy patients remained significantly different by the proportion of coronary artery disease patients in each group (respectively, 25.3% versus 27.6%, *P* = 0.041), the proportion of patients in a capitated payer arrangement (16.5% versus 14.5%), and the proportion of patients with a payer requiring a PCP assignment (27.4% versus 23.5%, *P* = 0.001).

The nonoptimized group had a higher rate of complications (35.6% versus 30.2%, OR = 1.28, *P* < 0.001), which appeared to be driven most by wound infections (19.3% versus 15.3%, OR = 1.32, *P* < 0.001), postoperative hemorrhage (3.7% versus 2.6%, OR = 1.45, *P* = 0.013), and postoperative sepsis (4.8% versus 3.6%, OR = 1.33, *P* = 0.023) (Table 2).

On univariate analysis of costs, the optimized group had increased costs of care in the preoperative period (Diff: \$684, unadjusted gamma coefficient = 0.22 (95% CI: 0.15–0.29), $P < 0.001$), but total costs of care were less in the optimized group (Diff: \$415, unadjusted gamma coefficient = 0.06 (95% CI: 0.02–0.10), $P = 0.006$). A complication increased the total costs of care by \$14,724 ($P < 0.001$). When controlling for other variables, there was no significant difference in total costs of care for those optimized versus those that were not (\$1,380 more for optimization, $P = 0.100$, Appendix 4, <http://links.lww.com/SLA/B436>).

Patients in the optimized group had 31% lower odds of a complication ($P < 0.001$) relative to the nonoptimized group (Table 3). Other contributors to the complication rate included hospital region, female sex, indication for surgery, specific comorbidity at-risk, and higher Charlson Index groups.

Figure 2 demonstrates the substantial heterogeneity in the timing of when patients attended their nonsurgical clinician visit with a median visit interval of 20 days before surgery (IQR = 11–28 d). Inflammatory bowel disease was associated with a 66% increase in the adjusted odds of an earlier visit ($P = 0.028$) with the visit timing for all other diagnoses not statistically significant. We include in Appendix 5, <http://links.lww.com/SLA/B436> an exploratory analysis that suggests that approximately 3 to 5 weeks prior to surgery may confer the most complication-protecting effect but is not powered to demonstrate significance. Table 4 reports the proportion of preoperative visits that were associated with a specific medication change. On average, pharmacologic optimization occurred with a preoperative optimization visit 19.4% of the time.

DISCUSSION

With the increased use of neoadjuvant therapies prior to cancer surgery and the broadening armamentarium for conservative medical management of inflammatory bowel disease, the time interval between first surgeon visit and an operation for many general surgery indications has grown.^{21–24} In addition, our ability to identify surgical risk factors that predict outcomes continues to mature rapidly.^{11,12,25,26} Finally, there is early evidence that suggests that intervening on modifiable risk factors preoperatively may lead to improved surgical outcomes.^{1,4,7,27} These overlapping trends necessitate a reconsideration for the surgeon's role in assessing preoperative readiness and potentially restructuring the formulaic “preoperative clearance” model into a more holistic preoperative optimization of modifiable risk factors.

Operationalizing comprehensive optimization services, however, comes into conflict with the prevailing trend among nonsurgical clinicians to minimize preoperative testing and associated physician visits due to evidence that traditional clearance visits were overused for low-risk surgery and provided little improvement to surgical outcomes.^{28–30} What remains less understood is what is the potential benefit of nonsurgical clinician expertise in the preoperative management of modifiable risk factors in *high* complication rate surgery such as colectomy. In our own practice, we find a “testing and clearance” paradigm to be woefully inadequate when assessing active and often overlapping medical comorbidities prior to major surgery. The purpose of our study was to use the natural variation in existing

practice patterns to identify if this latter population benefits from increased nonsurgical clinician healthcare utilization prior to major colon surgery. Specifically, for patients undergoing major colon surgery and with a known complication-inducing comorbidity, does visiting a nonsurgical clinician in the weeks leading up to surgery improve 30-day surgical outcomes?

We identified a large population in a private payer dataset undergoing elective colectomy with each patient having a major comorbidity such as diabetes or chronic obstructive pulmonary disease. By linking these patients' surgery to all administrative billing data for the prior 90 days, we were able to compare the subset of patients who were seen by a nonsurgical clinician qualified to care for their comorbidity (ie, the "optimized" group) to those who were not. When controlling for potential confounders at the patient-, surgeon-, and hospital-level, a patient with an optimized visit was associated with a 31% reduction in the odds of a complication with nominally increased median preoperative costs of care of \$684. Even with this observed benefit, one-third of patients with a serious comorbidity were not seen by an appropriate nonsurgical clinician prior to surgery. This latter finding raises concern that a substantial portion of patients are missing the opportunity for preoperative risk factor modification.

This study also generated hypotheses to test further in larger populations in the future or with more granular clinical data using evolving analytical approaches. For example, we examined administrative data for changes in management associated with nonsurgical clinician visits. We attributed changes in medications that occurred during the potential optimization period between surgeon clinic visit and surgery to the nonsurgical clinician and thereby identified a trend where 19.4% of patients had a changed or new prescribed therapy potentially responsible for a component of the improved outcomes. While we would not expect every nonsurgical clinician visit to result in a therapeutic change identifiable in the billing data, we believe that these new medical therapies being instituted are an indirect signal of the perioperative optimization occurring (Table 4). That many of nonsurgical clinician visits and corresponding therapeutic changes occurred weeks rather than days before surgery is also reassuring (Fig. 2). An important consideration for current and future preoperative optimization given the association between time prior to surgery and nonsurgical clinician visit is that—where possible—elective surgery may need to be delayed by a week or 2 to optimize comorbidities and improve outcomes. With alternative approaches to studying this issue using clinical data, clinicians' optimizing actions and the explicit rationale for referrals may be detectable. We advocate for the infrastructure and resources to conduct studies that incorporate natural language processing of the electronic health record and large-scale abstracting of clinical datasets to answer these difficult questions.

Our interpretation of these findings ultimately relies on a few critical assumptions that on average should be true to maintain fidelity with the conceptual framework of medical optimization prior to surgery. First, nonsurgical clinician visits during the potential optimization period are intentional and not solely routine occurrences that by coincidence occur in the period under study. Second, nonsurgical clinician visits occur with knowledge of an upcoming surgery and involve a combination of pharmacologic but also potentially

unmeasured psychosocial and behavioral interventions. Finally, the nonsurgical clinician visits we observe are more than perfunctory “preoperative clearance” where risk factors are noted but not intervened upon. The long lead times in Figure 1 support the assumption that many of the visits were long enough before surgery to reasonably allow for care measures to take effect. Importantly, the secondary analysis reported in Appendix 5, <http://links.lww.com/SLA/B436> suggests that the nonsurgical clinician visits occurring approximately 1 month before surgery confer the best advantage in contrast to those only 1 to 2 weeks before surgery. In addition, Table 4 demonstrates that at least an important minority of these visits coincided with initiation of a new medication relevant to the patient’s underlying comorbidity suggestive of an explanatory mechanism between nonsurgical clinician visit and observed reduction in complications. An important reassuring element is that all of these assumptions should have a conservative bias on our findings, and thus our statistically significant associations may have even larger effect sizes than reported here.

The role of “healthy user bias” in a study such as this one should also be addressed. Many observational studies are confounded by associated health prevention activities that are correlated with more optimal health-seeking behavior,³¹ and one may argue that those who seek preoperative nonsurgical clinician care are the healthy users of this study. By selecting a comorbid study population, all observed patients are “sick,” and a large evidence base supports that patients in poor health are typically higher utilizers of healthcare.³² We assume these preoperative visits as healthcare use for-cause and not purely preventive motivations given current referral practices in perioperative care. Further study of our framework assumptions and potential biases provides opportunities for hypothesis testing for how we may be able to prospectively take advantage of the observed risk reduction observed here.

Limitations

This study is not without its limitations. The MarketScan database is derived from private payer administrative billing data and has the associated limitations of a study performed in secondary datasets. Linking of initial surgeon visits to operating surgeon was dependent upon pass-through physician identifiers provided by the original private payers. Nonsurgical clinician visit identification was dependent upon a medical specialty classification scheme used by a subset of the payers. While the limitations of such administrative data limited our ability to use the full size of the MarketScan population, we would not expect these limitations to affect the optimized and nonoptimized populations in a differential manner.

A related limitation of the MarketScan population is the limited generalizability to socioeconomically vulnerable populations such as the elderly. Controlling for population-wide variation in socioeconomic status and other psychosocial risk factors is limited by the quality of such data collection in administrative data sets as well as the limited number of structured data fields included. Extrapolating these findings requires confirmation in future prospective studies or alternative data sources. Given the disparities in outcomes found in these populations,³³ there may be an even greater benefit to improving access to focused preoperative assessment for economically vulnerable groups.

A final limitation of the use of the MarketScan database is the potential for residual confounding. One temporal trend that overlaps with the time period of our study is the rapid proliferation of enhanced recovery protocols in the United States that have been shown to decrease postoperative complications and readmissions.³⁴ However, we believe these programs to be unlikely to be confounders since our primary exposure variable—preoperative visit with a nonsurgical clinician—is not included in published enhanced recovery guidelines and protocols of the same time period.³⁵ Enhanced recovery programs may improve surgical outcomes but should not drive the observed preoperative referrals at the other end of our analytical framework.

An inherent limitation of our framework approach must be acknowledged. The associations we report here have limited inferential scope in their present form. We demonstrate a clear association between outcomes for those who receive care from a nonsurgical clinician versus those who do not in the period between their initial surgeon visit and surgery. Causality, however, is largely suggested through the framework we have constructed rather than direct evidence of intentional optimization in the data itself.

Finally, propensity matching did not demonstrate complete balance with statistically significant difference in exposure groups by coronary artery disease, capitated payer status, and PCP assignment by payer. The clinical magnitude of the differences between groups was small. Two of these 3 variables ultimately did not meet inclusion criteria for the final doubly robust multivariable regression. We find it unlikely that these differences would affect our overall conclusions, and we observed similar effects by optimization visit status with or without inclusion of coronary artery disease as a potentially modifiable comorbidity.

Despite these limitations, we believe this work to be a clear contribution to the literature as it sheds light on an important area for future prospective work focusing on implementation, evaluation, and assessment of optimization in high-risk patients who confer a disproportionate cost burden on the health system.

Next Steps

This study has identified an important association between improved surgical outcomes and greater utilization of nonsurgical clinician care in the preoperative period for surgery-bound patients with modifiable high-risk surgical risk factors. These findings provide initial empirical evidence that for a subset of high-risk patients increased healthcare utilization in the preoperative period may be justified. Importantly, this study is an important foundational contribution to current efforts to justify enhanced preoperative optimization efforts, which have so far been used empirically with little evidence of their comprehensive benefit.¹ Specifically, it supports the use of these resource-intensive programs with targeting by patients' comorbidities rather than more intensive risk assessments previously used.³ The importance of continuity for chronic disease care is well established, and our findings here emphasize that more attention to comorbidities in the preoperative period may be warranted. Future studies should examine the best methods of implementation, formative evaluation of these programs, and assess potential benefits prospectively with an emphasis on demonstrating that targeted optimization efforts directly contribute to decreased postoperative complications and improved recovery from surgery.

In our own practice, we have already begun to incorporate this paradigm shift into how we care for patients prior to major, elective gastrointestinal surgery. We believe that despite the intrinsic limitations of this retrospective analysis, the low-risk associated with increased healthcare utilization and the substantial benefit observed in this diverse population of patients justifies incorporation of preoperative optimization measures into our routine practice. Historically, we have tended to send patients for comorbidity optimization based on extrinsic triggers (eg, preoperative anesthesia assessment concerns, proactive primary care partners). We are now actively assessing the use of proactive risk identification tools (eg, NSQIP Surgical Risk Calculator, active screening of the electronic medical record problem list) which then facilitates early identification of comorbid patients and direct referrals to relevant specialists (eg, diabetes management, COPD medication regimen optimization). While such practices may seem obvious or even routine, our institution's internal referral practices mirror the heterogeneity that we observed in the MarketScan data. Formalizing these comorbidity identification and referral patterns prioritizes the importance of preoperative optimization, and we anticipate future quality improvement data will highlight a greater rate of preoperative optimization and subsequent decrease in postoperative complications.

CONCLUSIONS

The role of preoperative optimization for improving surgical outcomes may be intuitive but remains underexplored. We demonstrated an association between increased nonsurgical clinician visits in comorbid patients prior to surgery and significantly lower rate of complications when controlling for other variables. Moreover, one-third of patients with concurrent, serious medical illness may not be receiving comprehensive care of their comorbidity prior to surgery. These findings justify further prospective investigation into the role of formalized preoperative optimization programs to improve surgical outcomes in patients with modifiable surgical risk factors.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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FIGURE 1.

Flow diagram for selection of medically comorbid patients within the MarketScan database (2010–2014) undergoing elective colectomy.

FIGURE 2.

Optimized patients undergoing elective colectomy by week of nonsurgical clinician visit and date of surgery (MarketScan, propensity matched and weighted sample 2010–2014 n = 3096).

Propensity-matched and Weighted Patient Demographics and Baseline Characteristics Undergoing Elective Colectomy (MarketScan, 2010–2014)

TABLE 1.

Characteristic, No. (%)	Total N = 6037	Optimized N = 3096	Nonoptimized N = 2941	P
Age (yrs) (median, IQR)	57 (51–61)	57 (51–61)	57 (52–61)	0.094
Sex				0.300
Male	3126 (51.8)	1583 (51.1)	1543 (52.5)	
Female	2911 (48.2)	1513 (48.9)	1398 (47.5)	
Indication for surgery				0.073
Cancer	3434 (56.9)	1733 (56.0)	1701 (57.8)	
Diverticulitis	1692 (28.0)	899 (29.0)	793 (27.0)	
Inflammatory bowel disease	283 (4.7)	150 (4.8)	133 (4.5)	
Ostomy complications	134 (2.2)	78 (2.5)	56 (1.9)	
Other	494 (8.2)	236 (7.6)	258 (8.8)	
Modifiable comorbidities				
Diabetes	3150 (52.2)	1624 (52.5)	1526 (51.9)	0.659
Chronic lung disease	2043 (33.8)	1075 (34.7)	968 (32.9)	0.138
Heart failure	410 (6.8)	209 (6.8)	201 (6.8)	0.897
Coronary artery disease	1595 (26.4)	783 (25.3)	812 (27.6)	0.041
Atrial fibrillation	491 (8.1)	249 (8.0)	242 (8.2)	0.792
Chronic renal failure*	227 (3.8)	128 (4.1)	99 (3.4)	0.117
Cirrhosis	144 (2.4)	66 (2.1)	78 (2.7)	0.185
Charlson Index Group				0.849
0	1306 (21.6)	674 (21.8)	632 (21.5)	
1	1574 (26.1)	814 (26.3)	760 (25.8)	
2	3157 (52.3)	1608 (51.9)	1549 (52.7)	
Hospital region				<0.001
Northeast	1119 (18.6)	641 (20.8)	478 (16.3)	
North Central	1074 (17.8)	506 (16.4)	568 (19.3)	
South	2986 (49.5)	1491 (48.3)	1495 (50.8)	
West	850 (14.1)	450 (14.6)	400 (13.6)	
Capitated Payment Payer	913 (15.5)	486 (16.5)	427 (14.5)	0.038

Characteristic, No. (%)	Total N = 6037	Optimized N = 3096	Nonoptimized N = 2941	P
Payers Assigns PCP	1500 (25.5)	808 (27.4)	692 (23.5)	0.001
Volume of operating surgeon				0.309
Low (<5)	3542 (58.7)	1838 (59.4)	1704 (57.9)	
Moderate (5–19)	1906 (31.6)	950 (30.7)	956 (32.5)	
High (>19)	589 (9.8)	308 (10.0)	281 (9.6)	
Referral frequency of surgeon (mean, SD)	0.65 (0.33)	0.82 (0.20)	0.37 (0.29)	<0.001

Missing data: hospital region, n = 8; capitated payer, n = 147; PCP assigned, n = 147.

* Patients on dialysis were excluded from this study and not reported here.

IQR interquartile range; SD, standard deviation.

TABLE 2.

Postoperative Outcomes, Compared by Optimized Versus Nonoptimized Patients (Propensity Matched and Weighted Sample, MarketScan, 2010–2014)

Outcome, No. (%)	Total N = 6037 36 (0.6)	Optimized N = 3096 21 (0.7)	Nonoptimized N = 2941 15 (0.5)	Unadj. OR (95% CI) 1.33 (0.69–2.59)	P 0.398
Mortality					
At least 1 complication	1981 (32.8)	935 (30.2)	1046 (35.6)	0.78 (0.70–0.87)	<0.001
Specific complication					
Cardiovascular	73 (1.2)	40 (1.3)	33 (1.1)	1.15 (0.73–1.83)	0.546
Respiratory	824 (13.7)	409 (13.2)	415 (14.1)	0.93 (0.80–1.07)	0.309
Liver	10 (0.2)	6 (0.2)	4 (0.1)	1.43 (0.40–5.06)	0.583
Renal	240 (4.0)	103 (3.3)	137 (4.7)	0.70 (0.54–0.91)	0.008
Gastrointestinal	182 (3.0)	74 (2.4)	108 (3.7)	0.64 (0.48–0.87)	0.004
Wound Complication	1,041 (17.2)	475 (15.3)	566 (19.3)	0.76 (0.67–0.87)	<0.001
Sepsis	253 (4.2)	112 (3.6)	141 (4.8)	0.75 (0.58–0.96)	0.023
Postoperative hemorrhage	191 (3.2)	81 (2.6)	110 (3.7)	0.69 (0.52–0.93)	0.013
VTE/PE	57 (0.9)	29 (0.9)	28 (1.0)	0.98 (0.58–1.66)	0.951
Unadj. Coeff. * (95% CI)					
Total costs, (median, IQR) ‡	\$35,997 (\$25,824–\$50,164)	\$35,757 (\$25,740–\$50,155)	\$36,172 (\$26,185–\$50,164)	0.06 (0.17–0.10)	0.006
90 d prior to surgery	\$5,180 (\$2,859–\$9,197)	\$5,484 (\$3,139–\$9,314)	\$4,800 (\$2,575–\$9,118)	0.22 (0.15–0.29)	<0.001
Index inpatient stay	\$26,110 (\$18,519–\$36,548)	\$25,845 (\$18,440–\$36,166)	\$26,313 (\$18,671–\$36,961)	0.04 (0.00–0.08)	0.044
30 d following surgery	\$302 (\$16–\$306)	\$273 (\$8–\$1,468)	\$306 (\$24–\$2013)	0.43 (0.28–0.58)	<0.001
LOS (median, IQR)	4 (3–7)	5 (3–7)	4 (3–7)		0.040

* Logistic regression model with gamma distribution.

‡ Propensity-matched, cost analysis performed on subset of data due to incomplete payment information for 2692 patients. Patients who died were excluded.

IQR, interquartile range; LOS, length of stay; PE, pulmonary embolism; VTE, venous thromboembolism.

TABLE 3.

Multivariable Logistic Regression With Multilevel Clustering by Hospital and Surgeon Identity of Having At Least 1 Complication Following Elective Colectomy by Preoperative Risk Factors (Propensity Matched and Weighted Sample; n = 4704)

Variable	Unadj. OR (95% CI)	P	Adj. OR (95% CI)	P
Optimization visit	0.78 (0.70–0.87)	<0.001	0.69 (0.57–0.84)	<0.001
Age	1.01 (1.00–1.01)	0.056	1.00 (0.98–1.01)	0.447
Female sex	1.16 (1.04–1.30)	0.006	1.29 (1.07–1.57)	0.009
Region				
Northeast	Reference		Reference	
North Central	0.77 (0.64–0.91)	0.003	0.63 (0.41–0.99)	0.043
South	0.67 (0.58–0.77)	<0.001	0.57 (0.40–0.83)	0.003
West	0.59 (0.49–0.71)	<0.001	0.53 (0.33–0.85)	0.009
Laparoscopic approach	0.50 (0.45–0.56)	<0.001	0.33 (0.26–0.40)	<0.001
Indication for surgery				
Cancer	Reference		Reference	
Diverticulitis	1.82 (1.61–2.06)	<0.001	3.71 (2.85–4.83)	<0.001
IBD	1.28 (0.98–1.66)	0.066	1.91 (1.20–3.05)	0.007
Ostomy complications	1.63 (1.14–2.33)	0.007	1.64 (0.90–2.98)	0.108
Other	2.74 (2.26–3.32)	<0.001	3.94 (2.79–5.56)	<0.001
Modifiable comorbidity				
Diabetes	0.90 (0.81–1.00)	0.050	1.36 (1.08–1.72)	0.009
COPD/asthma	1.11 (0.99–1.24)	0.067	1.69 (1.34–2.14)	<0.001
CHF	1.74 (1.42–2.12)	<0.001	2.16 (1.47–3.16)	<0.001
Coronary artery disease	1.44 (1.28–1.63)	<0.001	1.93 (1.52–2.45)	<0.001
Atrial fibrillation	1.94 (1.61–2.34)	<0.001	1.71 (1.18–2.46)	0.004
Chronic renal failure	1.26 (0.96–1.66)	0.098	1.39 (0.85–2.26)	0.188
Cirrhosis	2.55 (1.83–3.56)	<0.001	2.54 (1.38–4.65)	0.003
Charlson Index Group				
0	Reference		Reference	
1	1.13 (0.97–1.32)	0.116	1.36 (1.04–1.79)	0.027
2	1.02 (0.89–1.17)	0.767	1.56 (1.17–2.08)	0.002

Average variance inflation factor: 1.36.

CHF indicates congestive heart failure; COPD, chronic obstructive pulmonary disease; IBD, inflammatory bowel disease.

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TABLE 4.
Proportion of Preoperative Visits to a Nonsurgical Clinician With a Documented Medical Optimization Intervention

Comorbidity	Intervention	% of Total With Comorbidity With New Agent
Diabetes	New insulin therapy or dose change	8.9
	New antihyperglycemic or dose change	18.2
COPD/asthma	New inhaler or oral steroid therapy or dose change	15.3
CHF/CAD/AFib	New cardioprotective medication or dose change	5.6
	New diuretic therapy or dose change	14.6
Cirrhosis	New diuretic therapy or dose change	10.2

AFib indicates atrial fibrillation; CAD, coronary artery disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.