The Financial and Clinical Impact of an Electronic Health Record Integrated Pathway in Elective Colon Surgery

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Abstract

Background Enhanced Recovery after Surgery (ERAS) pathways have been shown to reduce length of stay, but there have been limited evaluations of novel electronic health record (EHR)-based pathways. Compliance with ERAS in real-world settings has been problematic.

Objective This article evaluates a novel ERAS electronic pathway (E-Pathway) activity integrated with the EHR for patients undergoing elective colorectal surgery.

Methods We performed a retrospective cohort study of surgical patients age ≥ 18 years hospitalized from March 1, 2013 to August 31, 2016. The primary cohort consisted of patients admitted for elective colon surgery. We also studied a control group of patients undergoing other elective procedures. The E-Pathway was implemented on March 2, 2015. The primary outcome was variable costs per case. Secondary outcomes were observed to expected length of stay and 30-day readmissions.

Results We included 823 (470 and 353 in the pre- and postintervention, respectively) colon surgery patients and 3,415 (1,819 and 1,596 in the pre- and postintervention) surgical control patients in the study. Among the colon surgery cohort, there was statistically significant ($p = 0.040$) decrease in costs of 1.28% (95% confidence interval [CI] 0.06–2.48%) per surgical encounter per month over the 18-month postintervention period, amounting to a total savings of $2,730 per patient at the 1-year postintervention period. The surgical control group had a nonsignificant ($p = 0.231$) decrease in monthly costs of 0.57% (95% CI 1.51 to – 0.37%) postintervention. For the 30-day readmission rates, there were no statistically significant changes in either cohort.

Conclusion Our study is the first to report on the reduced costs after implementation of a novel sophisticated E-Pathway for ERAS. E-Pathways can be a powerful vehicle to support ERAS adoption.

Keywords
- clinical pathways
- clinical decision support
- surgery
- cost reduction and return on investment
- evaluation

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Background and Significance

The adoption of Enhanced Recovery after Surgery (ERAS) clinical pathways has been associated with reductions in length of stay and complications.[1–5] Despite the clear benefits of ERAS pathways, staff compliance with ERAS protocols has been suboptimal.[6] Coordination and communication between members of the health care team have been similarly challenging. Protocol compliance is an independent and statistically significant factor in improvement of outcomes.[6,7] As such, technologies that can facilitate compliance would be key enablers to reduce complications during the perioperative period.

With the rise in electronic health record (EHR) use, health systems have deployed electronic order sets to help support ERAS pathways. While order sets are critical in initiating care, they do not support real-time compliance, reminder systems, and a shared clinical understanding of where and how the patient is tracking through their pathway. In this manner, electronic pathways (E-Pathways) have the potential to overcome barriers to successful implementation and compliance with ERAS protocols.[8]

To address these issues, our institution developed and initiated a comprehensive colon E-Pathway for all patients undergoing elective colorectal surgery. The comprehensive protocol spans the preoperative, intraoperative, and postoperative periods. Unique to our pathway is incorporation into the EHR predefined processes of care, such as preoperative preparation, outcomes, such as early ambulation, measured and documented in the EHR as the patients progress through their care.

While there have been theoretical discussions of how to electronically model pathway processes,[9] to our knowledge, there has been no formal evaluation of a fully integrated E-Pathway for colon surgery or any other condition, where a patient's step and associated milestones are documented and stored directly in the EHR.

Objective

Our objective was to demonstrate that implementation of a novel colon surgery E-Pathway can reduce direct variable costs and length of stay without an increase in 30-day readmissions.

Methods

Methods Study Design

The study was performed in compliance with the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects and we received ethics approval from the New York University (NYU) Langone Health Institutional Review Board. We performed a retrospective cohort study of individuals admitted to NYU Langone Tisch Hospital, an urban academic institution, from March 1, 2013 to August 31, 2016. We included all patients greater than 18 years of age who were admitted for elective colon and rectal surgery. Elective colon surgery was based on specific International Classification of Diseases, 10th Edition (ICD10) Procedure Coding System codes (see ►Supplementary Appendix Table S1 [available in the online version] for all included diagnosis) whose admission type in the scheduling system was recorded as "Elective."

We also studied a surgical control group of patients undergoing elective procedures with similar length of stay as colon surgery (3–5 days). We included patients age ≥ 18 years undergoing surgeries that, on average, had a mean length of stay of 3 to 5 days during this period, though we excluded surgeries that were part of other hospital initiatives during this period, which included hip and knee arthroplasty, heart valve procedures, and bariatric procedures. Included procedures are listed in ►Supplementary Appendix Table S1 (available in the online version).

The primary data sources for the study were the Epic EHR (Epic Systems, Verona, Wisconsin, United States) and EPSi, the institution's cost accounting system (Allscripts, Chicago, Illinois, United States).

Methods Intervention

The intervention was based on an innovative computerized pathway template developed by the EHR vendor with content developed by a local multidisciplinary team. The local team consisting of physicians, nurses, care managers, residents, nurse practitioners, physician informaticists, nurse informaticists, information technology analysts, financial analysts, and a project manager collaborated in incorporating best practice guidelines for patients undergoing elective colon and rectal surgery, including ERAS protocols, into discrete electronic pathway components. Prior to this initiative, our institution did not have formalized ERAS protocols in place for colon surgery.

The pathway activity was organized into discrete steps, each of which comprised clinical orders, care plans, and outcomes (►Fig. 1). Clinicians could view a patient's status on the pathway in the pathway activity as well as on a clinician's patient list (►Fig. 2). Upon patient arrival, a provider (physician/nurse practitioner, physician assistant) on the patient's clinical care team initiated the pathway and was responsible for initiating subsequent steps. Each step had outcomes designated for completion by a specific care team role (e.g., provider/nurse/care manager/social worker). That member would document a patient's progress or variation on the associated outcomes and care plans. The ERAS processes and outcomes were based on prior literature.[2,3,5] Preoperative goals included that the patient used chlorhexidine shower or wipes, prepped for surgery with an osmotic laxative, and took two antibiotics. Postoperative goals include early ambulation, early discontinuation of urinary catheter, and avoidance of nasogastric tubes. The patient either completed the pathway or the physician discontinued the pathway because of complications (►Fig. 1).

Along with the E-Pathway, the team developed an interactive dashboard (Tableau Software, Seattle, Wisconsin, United States) to display descriptive elements about pathway use including volume of pathways implemented, discontinue reasons, outcomes, and documentation compliance. Pathway leaders used this dashboard to provide feedback to the clinical care teams charged with pathway adoption.

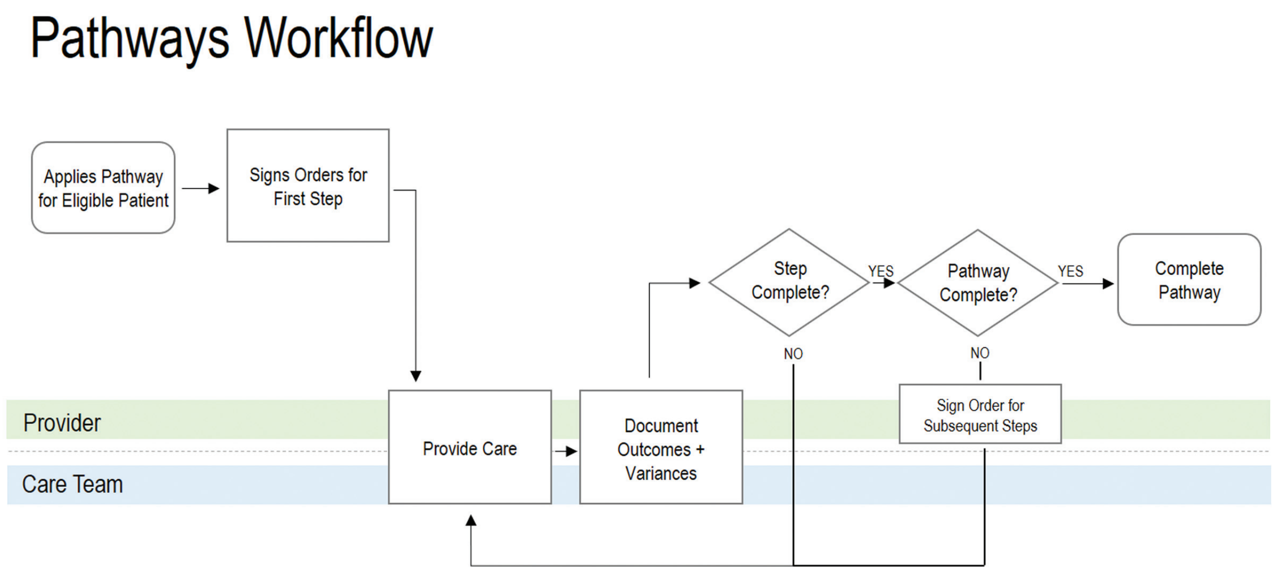

Fig. 1 Pathway workflow for the provider and care team.

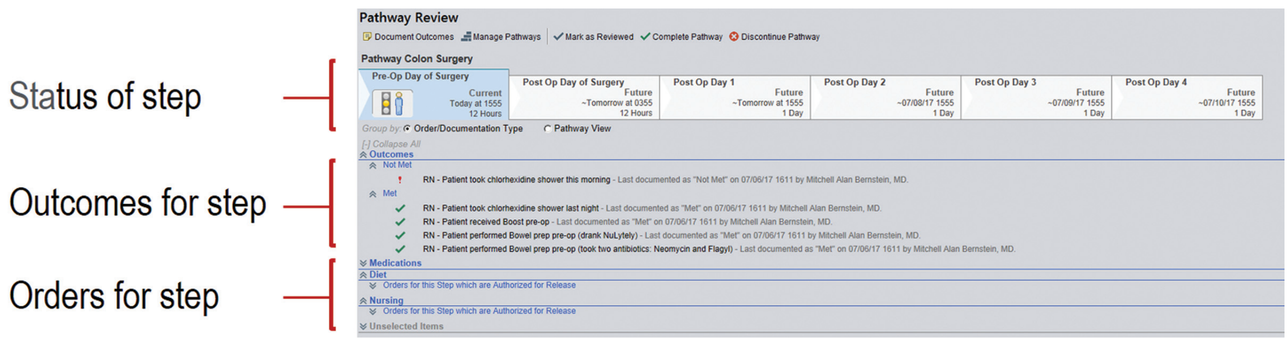

Fig. 2 Screenshot from the electronic health record (EHR) of the Pathway Review Activity. In one screen, care team members can synthesize the current step of the pathway, the status of outcomes for the step, and associated orders for that step. Screenshots published with permission from Epic Systems 2019.

Clinicians were trained on the pathway through a multimodal approach of Web-based learning, tip sheets, and presentations at service meetings and care huddles. Adoption was reinforced by presentations at surgical department meetings, in which evidence for ERAS pathways was presented. Providers were informed that use of the pathway was mandatory for all elective colon resections. Once the pathway was implemented, the surgeon champion monitored use and providers were contacted if their patients were not compliant with the pathway. If a reasonable rationale was not present, the provider was warned that the next eligible case that did not comply with the pathway would be canceled. Due to high pathway compliance, there were no cases that were canceled.

The E-Pathway was piloted on two hospital units starting on March 2, 2015. On May 1, 2015, the pathway expanded to all hospital units supporting elective colon surgery patients. For our analysis, we considered March 2, 2015 to be the start date of the intervention.

Methods Outcomes and Covariates

The primary outcome was total variable costs per case. Total variable costs were itemized costs that were captured in the hospital's cost-accounting system, which interfaces with the EHR; notably, these costs do not represent hospital charges and they did not include fixed hospital costs. We focused on cost as our primary outcome as it is commonly used in evaluation of clinical pathways[10,11] and was a focus of a large value-based management program at our hospital. Secondary outcomes were length of stay, observed to expected (O:E) length of stay, and 30-day readmissions to our hospital. We also performed a post hoc analysis of cost subcategories, which included operating room (OR), room and board, laboratory and imaging, pharmacy, and other costs. All costs were rebased to a mean value of $17,774 for all hospitalizations in the preintervention cohort. This was done to aid generalizability to other hospitals as the value chosen is the mean cost of similar colorectal surgical procedures according to Vizient, a performance improvement company that aggregates data from hundreds of member health systems.[12] Notably, the rebasing would have no effect on the analyses. Observed to expected length of stay was also obtained from Vizient, which creates risk-adjustment models using data from these health systems.[11]

We assessed the following covariates: age, gender, American Society of Anesthesiology (ASA) class, Charlson comorbidity index, and body mass index (BMI). These covariates were chosen because they are factors known to influence mortality and morbidity in colon surgery and used in adjustment for national quality measurement.[13]

All procedures were identified based on ICD-10 codes. For procedures that occurred before our institution's transition to coding in ICD-10 on October 1, 2015, we leveraged a commercial product, the 3M Code Translation Tool (3M, St. Paul, Minnesota, United States) to suggest the corresponding ICD-10 code for each ICD-9 coded procedure in our cohort. The suggested ICD-10 codes were validated with our colon surgery expert (M.B.).

We also assessed measures of pathway implementation. These metrics included the number of appropriate patients, defined as those in our postintervention study cohort who were started on the pathway. We also measured percent of patients who started on the pathway that completed the pathway. Of those who started the pathway, we also measured those who completed and documented the following EHR-based process measures: preoperative bowel prep, preoperative chlorhexidine shower or wipes, not inserting a nasogastric tube, and discontinuation of Foley catheter by postoperative day 1. Process measures could be documented as "met," "not met," or not documented. For the chlorhexidine measure, we only included hospitalizations after February 20, 2016, the time at which the documentation of this measure was included in the pathway.

Methods Statistical Analysis

We performed an interrupted time series study with segmented regression analysis[14–16] with month being the unit of time separately on patients in the treatment and control arms (R version 3.4.1). If the intervention, defined as the EHR-based implementation of the ERAS E-Pathway, is effective, a change would be observed in the model built for the treatment arm patients but not on the control arm patients. For outcome variables with a high degree of skewness, including total variable costs, length of stay, and cost subcategories, we used a gamma regression with a log link function-interrupted time series analysis model. The output from this type of gamma regression can be interpreted as the percentage change in costs for each one-unit increase in the independent variable.[17] Logistic models were used for 30-day readmissions. In each model, we included three variables to measure the relationship of time and the outcome of interest: (1) a continuous time variable to represent the underlying temporal trends; (2) a dummy variable for the postintervention period to determine the change in outcome related to the intervention; and (3) a continuous time variable which began at the start of the intervention, to represent the change in slope.[15–17] The coefficients of the latter two variables were of primary interest and indicated whether the pathway had an immediate or ongoing effect on the outcome of interest, respectively. As outcomes at two consecutive time points may be similar,[17] we tested for first-order autocorrelation using Durbin–Watson statistic and by examination of the autocorrelation and partial autocorrelation functions.[18] As we did not find significant autocorrelation, we did not adjust for it in our models.

We performed a secondary analysis using a difference-in-difference approach. In this approach, we calculated the change in outcomes with the introduction of all patients greater than age 18 arriving in hospital on the day of surgery for a "concurrent control surgery." However, this approach was dropped as the data did not meet the "parallel paths" assumption, which requires that an outcome has similar trends in intervention and control groups in the preintervention period.[19]

Results

We included 823 colon surgery patients, of whom 470 were from the preintervention period and 353 were from the postintervention period. As compared with postintervention colon surgery patients, those in the preintervention period were younger (mean age 60.0 vs. 61.2; $p = 0.007$) but were similar in other characteristics including sex, ASA score, comorbidity burden, and BMI (►Table 1). Of 3,415 patients included in the surgical control group, 1,819 and 1,596 were in the pre- and postintervention periods, respectively. Postintervention control patients had a higher mean Charlson comorbidity score (1.6 vs. 1.3; $p = 0.001$) and a slightly higher mean ASA scores (2.6 vs. 2.5; $p = 0.027$) as compared with preintervention control patients (►Table 1).

For the colon surgery group, the median cost per case using a rebased scale was $18,456 in the preintervention period and $17,337 in the postintervention period for a decrease of $1,118 or 6.1% ($p < 0.001$; ►Table 2) in unadjusted analysis. In adjusted interrupted time series model, there was nonsignificant decrease in variable cost at the time of introduction of the intervention (1.18%; 95% confidence interval [CI] −12.08 to 16.51%) followed by a significant averaged decrease of 1.28% (95% CI 0.06–2.48%) per month compared with baseline (►Table 3; ►Fig. 3). This trajectory of cost savings amounts to a total savings of $2,730 per patient (15.4% decrease) at the 1-year postintervention period. Conversely, median cost for surgical control patients were $17,093 in the preintervention period and $17,232 in the postintervention period ($p = 0.80$ for difference). For the control group, we found no change in cost either at time of introduction of the intervention or in the period following the intervention (►Table 3).

In unadjusted analysis of secondary outcomes, the median O:E length of stay for the colon surgery group decreased from 0.61 in the preintervention period to 0.49 in the postintervention period and from 0.73 to 0.66 in the surgical control group. Although these unadjusted results were not significant (►Table 2), introduction of the intervention was associated with a 1.49% (95% CI 0.07–2.90%) decrease in O:E length of stay per month for the intervention group in the adjusted time series analysis (►Table 3). We found no change in length of stay in the surgical control group.

The readmission rate remained constant at 6.2% for the colon surgery group both before and after the intervention. While readmission rates decreased from 7.7 to 6.5% in the control group, this difference did not reach statistical significance ($p = 0.18$; ►Table 2). The intervention had no effect on readmission rates in time series models (►Table 3).

Table 1 Demographic characteristics

	Intervention group	Before intervention	After intervention	*p*-Value
		$n = 470$	$n = 353$	
	Control group	$n = 1,819$	$n = 1,596$	
Age mean (SD)	Intervention group Control group	60.0 (14.0) 53.6 (16.5) $p < 0.001$	61.2 (14.7) 55.3 (15.9) $p < 0.001$	0.007 0.259
% Male	Intervention group Control group	49% 54% $p = 0.057$	55% 56% $p = 0.722$	0.097 0.199
ASA score mean (SD)	Intervention group Control group	2.3 (0.6) 2.4 (0.6) $p < 0.001$	2.4 (0.6) 2.5 (0.6) $p < 0.001$	0.778 0.027
Charlson comorbidity score	Intervention group Control group	2.2 (2.7) 1.3 (2.1) $p < 0.001$	2.3 (2.8) 1.6 (2.2) $p < 0.001$	0.243 0.001
BMI mean (SD)	Intervention group Control group	26.5 (5.4) 28.6 (9.7) $p < 0.001$	26.7 (5.8) 28.6 (7.4) $p < 0.001$	0.318 0.072

Abbreviations: ASA score, American Society of Anesthesiologists score; BMI, body mass index; SD, standard deviation.

Table 2 Unadjusted outcomes by time period

Indicator		Before intervention	After intervention	*p*-Value
Rebased cost[a], median ($) (IQR)	Colon surgery group	18,456 (15,153–23,175)	17,337 (13,527–20,955)	< 0.001
	Surgical control group	17,093 (14,156–23,227)	17232 (13,055–23,821)	0.798
Length of stay (d), median (IQR)	Colon surgery group	4 (3–6)	3 (2–4)	< 0.001
	Surgical control group	3 (2–4)	3 (2–4)	0.001
Observed / Expected LOS median (IQR)	Colon surgery group	0.61 (0.47–0.81)	0.49 (0.34–0.67)	< 0.001
	Surgical control group	0.73 (0.46–1.11)	0.66 (0.41–1.02)	< 0.001
Readmission rate (95% CI)	Colon surgery group	6.2 (4–8.5)	6.2 (4–8.8)	0.967
	Surgical control group	7.7 (5.3–10.2)	6.5 (4–9.1)	0.179

Abbreviations: CI, confidence interval; IQR, interquartile range; LOS, length of stay.
[a]Cost rebased to the median cost in the time period prior to the intervention.

In our interruptive time series analysis examining subcategories of costs, we found that the intervention led to a decrease in cost for many, though not all, of cost categories (►Table 4). Specifically, we found that OR and pharmacy-related costs were stable with introduction of the intervention but then decreased by 2.02% (95% CI 1.08–2.95) and 4.32% (95% CI 2.33–6.27) per patient per month, respectively; notably, similar reductions in OR costs were also observed among control patients. Room and board costs nonsignificantly decreased with introduction of the intervention (change of –19.66, 95% CI –36.43 to 1.68) and monthly thereafter (change of –1.84% per month; 95% CI –3.83 to 0.19). Postintervention monthly costs also decreased for laboratories and imaging costs (change of –2.40% per month; 95% CI –4.91 to 0.18), though the change did not reach statistical significance. The intervention was not associated with any difference in all other costs.

Of patients in the postintervention cohort, 94.9% were started on the colon E-Pathway. Of patients who started on the pathway, 82.7% completed the pathway. Documentation of completion of individual process measures related to the E-Pathway ranged from 61.5 to 89.7% (►Table 5).

Discussion

We found that a novel colon E-Pathway integrated into an EHR was associated with a 15.4% decrease in direct variable cost per patient at the end of the 1 year. These cost savings amounted to $2,730 per patient. If we extrapolate these findings to the 247,000 colon procedures performed annually in the United States,[20] our results would suggest that universal implementation of such EHR-based ERAS pathways could lead to $600 million in savings per year, although further evidence would be needed to confirm such a benefit.

We found that the pathway was associated with decreasing costs even when accounting for temporal trends and important predictors of surgical outcomes, but we did not observe such savings among a similar surgical comparator

Table 3 Interruptive time series model for outcomes

Model	Colon surgery group				Surgical control group			
	Estimated % change	Lower 95% CI	Upper 95% CI	*p*-Value	Estimated % change	Lower 95% CI	Upper 95% CI	*p*-Value
Total variable cost								
Overall time trend	−0.14	−0.82	0.54	0.67	6.32	−4.81	18.80	0.28
Change in level after intervention	1.18	−12.08	16.51	0.87	0.19	−0.34	0.72	0.49
Change in slope	−1.28	−2.48	−0.06	0.04	−0.57	−1.51	0.37	0.23
Length of stay								
Overall time trend	−0.24	−1.23	0.77	0.63	−0.52	−1.19	0.16	0.14
Change in level after intervention	−8.95	26.06	12.27	0.38	11.17	−3.53	28.19	0.14
Change in slope	−1.30	−3.09	0.51	0.15	−0.34	−1.65	0.87	0.58
Observed over expected length of stay								
Overall time trend	−0.10	−0.89	0.68	0.79	−12.18	−30.94	12.77	0.30
Change in level after intervention	−6.99	21.08	9.72	0.39	−0.27	−0.83	0.3	0.36
Change in slope	−1.49	−2.90	−0.07	0.04	1.87	−9.57	14.81	0.76
Model	**Odds ratio**	**Lower 95% CI**	**Upper 95% CI**	***p***	**Odds ratio**	**Lower 95% CI**	**Upper 95% CI**	***p***
Readmission Rate								
Overall time trend	0.99	0.93	1.04	0.63	0.99	0.96	1.01	0.24
Change in level after intervention	1.64	0.50	5.31	0.41	1.19	0.69	2.05	0.53
Change in slope	0.97	0.87	1.08	0.57	0.99	0.95	1.04	0.78

Abbreviations: ASA score, American Society of Anesthesiologists score; CI, confidence interval.
Note: All models also included age, sex, ASA score, and Charlson comorbidity score.

group. Some of this decrease in cost may be attributed to the findings of a concurrent decrease in O:E length of stay, a major driver of hospital variable cost. We found that expenses were decreased across most cost categories that would be affected by decreased length of stay, although the decreases in these cost categories—which included pharmacy, room and board, and imaging costs—were not always significant due to category size. Other outcomes that have

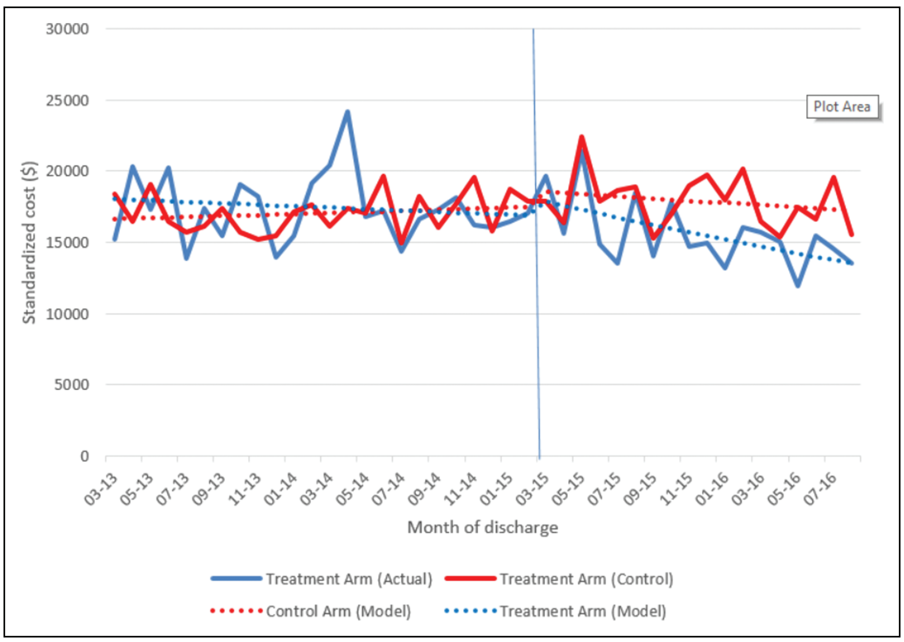

Fig. 3 Median standardized costs in the colon pathway (treatment) and surgical control groups over time. The costs are standardized to the overall median cost in the preintervention period. Solid lines represent actual median standardized cost per month, dotted lines represent adjusted cost based on the interrupted time series model.

Table 4 Interruptive time series model for subcosts groups

Model	Colon surgery group				Surgical control group			
	Estimated % change	Lower 95% CI	Upper 95% CI	*p*-Value	Estimated % change	Lower 95% CI	Upper 95% CI	*p*-Value
OR cost								
Overall time trend	1.73	1.19	2.27	< 0.001	1.45	1.09	1.81	< 0.001
Change in level after intervention	−2.48	−12.59	8.85	0.65	−4.33	−11.18	3.06	0.24
Change in slope	−2.02	−2.95	−1.08	< 0.001	−1.13	−1.76	−0.50	< 0.001
Room and board								
Overall time trend	0.48	−0.67	1.65	0.39	−0.20	−1.02	0.63	0.65
Change in level after intervention	−19.66	−36.43	1.68	0.07	14.05	−4.19	35.91	0.14
Change in slope	−1.84	−3.83	0.19	0.07	−0.58	−2.06	0.91	0.44
Labs and imaging								
Overall time trend	−0.44	−1.86	1.00	0.53	−0.16	−1.01	0.70	0.72
Change in level after intervention	−1.63	−26.80	32.52	0.91	10.70	−7.47	32.59	0.26
Change in slope	−2.40	−4.91	0.18	0.06	−0.62	−2.15	0.92	0.42
Pharmacy								
Overall time trend	1.57	0.39	2.76	0.01	−0.38	−1.65	0.89	0.54
Change in level after intervention	20.88	−4.52	53.25	0.12	3.12	−20.62	34.25	0.82
Change in slope	−4.32	−6.27	−2.33	< 0.001	0.37	−1.85	2.65	0.74
Other costs								
Overall time trend	−2.24	−2.87	−1.61	< 0.001	−0.23	−0.89	0.42	0.49
Change in level after intervention	7.53	−6.16	23.28	0.30	6.51	−7.39	22.59	0.38
Change in slope	0.49	−0.69	1.68	0.42	−0.19	−1.39	1.01	0.75

Abbreviation: CI, confidence interval.

Table 5 Percent of patients meeting process measures related to colon surgery E-Pathway

	Met	Not met	Not documented
Started pathway	94.9		
Completed pathway[a]	82.7		
Preoperative bowel prep completed[a]	80.6	4.2	15.2
Preoperative chlorhexidine shower/wipes[a,b]	89.7	1.7	8.6
No nasogastric tube inserted[a]	70.5	0.9	28.7
Foley discontinued by postop day 1[a]	61.5	5.1	33.4

Note: Values are in percentages.
[a]Among those who started pathway.
[b]Includes pathway patients after February 20, 20116, the time at which documentation for this measure began.

been associated with ERAS pathways, including reduced complications and less time spent in intensive care, may also have contributed to findings of reduced costs.[10,21] Concurrently, we found no association between introduction of the E-Pathway and 30-day readmission, suggesting the intervention was not associated with unintended adverse events.

Prior work has suggested that several factors may contribute to success of clinical pathways.[22,23] Some of these potential factors are related to health information technology (HIT), including using HIT to support quality, execution, and adherence to protocols. Our results support our hypothesis that use of the EHR to implement evidence-based ERAS guidelines can decrease costs without a resultant increase in 30-day readmissions. Although we cannot determine if the use of HIT independently enhanced the benefit of the ERAS pathway, our study demonstrates that such protocols can be successfully implemented in the EHR. Indeed, we found that the pathway was used in the vast majority of appropriate patients, and there was high compliance with process measures and completion of the pathway.

Clinical pathways with well-defined interval tasks have been shown in the literature to have clinical benefit. ERAS pathways are well known and widely used in patients undergoing elective colon and rectal surgery and many surgical subspecialties endorse their use. While basic order sets are one component standardizing care, they are not sufficient. Consequently, as institutions continue to place increased emphasis on standardization of best practice, E-

Pathways can be powerful, cost-effective vehicles to support those changes in the new EHR-centric care model.

The success of our colon E-Pathway may provide insight to features that help with successful implementation of similar pathway. The pathway provides a clear evidence-based plan of care that encompasses every phase of patient care. The pathway contains predefined outcomes and variances measures, which are documented in the EHR as the patient progresses through their care. Finally, all documentation can be aggregated and analyzed to provide compliance metrics back to the pathway care teams.

Importantly, because computerized pathway templates are included with the standard Epic Inpatient application, other institutions using the Epic EHR can employ the same functionality without added purchase cost or customized coding. Consequently, E-Pathways for ERAS can be rapidly reproduced in other institutions.

This study has several limitations. First, this was a single-site study, so findings might not be applicable to other institutions. Second, the study was observational in nature, so the association between E-Pathway and outcomes may be related to other factors. However, we implemented a rigorous methodology to control for both temporal trends and important confounder, a significant improvement over other studies that have attempted to evaluate pathways.[23] Furthermore, we used a similar surgical control group as a historical control. Third, given the low base rate of surgical complications in this population, we were not powered to detect differences in this important clinical outcome in the 18-month postimplementation phase. Fourth, our intervention was implemented at a similar time that billing coding switched from ICD-9 to ICD-10. We used a commercial vendor to translate between these two codes schema. Although the translator has been used in prior studies[24] and had face validity based on clinical expertise at our own institution, we are unaware of any external validation for the translator. As a result, some of our findings may be attributable to these coding changes. Fifth, some of our findings could also be related to the Hawthorne effect, in which provider behavior was changed due to being observed.

Conclusion

Two driving forces in health care, standardized best practice care and computerization of paper processes, will increase the demand for electronic pathway-like interventions. Our research supports the assertion that electronic pathways coupled with operational leadership and analytics can reduce cost of care without leading to increased readmissions. Future evaluations can help determine whether the advantages of such pathways can be sustained over the long term.

Clinical Relevance Statement

Clinical and operational leaders can implement electronic pathways not only for colon surgeries but any care condition requiring sequential care. Electronic pathways overcome barriers of existing EHR tools like order sets that can successfully guide initiation of care but lack follow-up decision support and monitoring capabilities.

Multiple Choice Questions

1. E-Pathways are comprised of the following components EXCEPT
   a. Orders.
   b. Outcomes.
   c. Steps.
   d. Notes.

   Correct Answer: The correct answer is option d, notes.

2. Which clinical role was responsible for initiating and advancing the patient on the pathway?
   a. Provider (physician, physician assistant, nurse practitioner).
   b. Nurse.
   c. Care Manager.
   d. Social Worker.

   Correct Answer: The correct answer is option a, provider.

3. Electronic Pathways were shown to reduce cost of care in the following area:
   a. reduced readmissions.
   b. reduced observed: expected length of stay.
   c. reduced indication for colon surgeries.
   d. reduced complications.

   Correct Answer: The correct answer is option b, reduced observed: expected length of stay.

Protection of Human and Animal Subjects

The study was performed in compliance with the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects and we received ethics approval from the NYU Langone Health Institutional Review Board.

Conflict of Interest

None declared.

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