Challenge of balancing duration of stay and readmissions in children's operation

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Background. *Surgeons balance competing interests of minimizing duration of stay with readmissions. Complications that occur early after discharge often result in readmissions. This study examines the relationship between duration of stay, timing of complications, and readmission risk.*
Methods. *Cases from the 2012–2014 National Surgical Quality Improvement Project—Pediatric were organized into 30 procedural groups. Procedures where duration of stay approximated the median day of complication were identified. A theoretical model was applied to minimize readmissions by extending duration of stay.*
Results. *From 30 procedure groups, 3 were identified where duration of stay approximated median day of compilations: complicated appendectomy, antireflux operation, and abdominal operation without bowel resection. The complicated appendectomy readmission rate drops from 12.2% to 8.2%, increasing duration of stay from 3 to 8 days at the cost of 16,428 additional hospital days among 4,740 patients (3.5 days/patient). Readmission optimization tapers after duration of stay of 8 days. Similar findings were observed for antireflux operation and abdominal operation without bowel resection with readmission optimization at duration of stay of 5 days (2.6 days/patient) and 7 days (5.3 days/patient), respectively.*
Conclusion. *Our theoretical model aimed at balancing readmissions by extending duration of stay to capture early complications results in a substantial increase in hospital days illustrating the conflict between competing quality metrics and limited resources. (Surgery 2017;162:950-7.)*

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Under the hospital readmissions reduction program (HRRP), designated as Section 3025 of the Patient Protection and Affordable Care Act, the Centers for Medicare and Medicaid Services began penalizing hospitals for readmissions.[1] This policy aims to reduce 30-day readmissions as a part of a larger strategy to control rising healthcare costs. Effective in October 2012, the HRRP initially required a 1% reduction in Medicare payments to hospitals with high readmissions for 3 common adult diagnoses. In 2015, these penalties increased to 3% and additional conditions, including patients undergoing operative procedures, were added to the HRRP.[2] Although there are no national policies pertaining to readmission after pediatric hospitalization, several state-level Medicaid programs are beginning to implement policies similar to those described in the HRRP.[3-8]

The use of readmission rates as a quality metric and determinant of reimbursement has received widespread criticism with many arguing that readmissions do not reflect hospital- or provider-level performance uniformly. Several factors that extend beyond the control of hospitals and providers have been shown to influence readmissions including race, ethnicity, education, income, and payer.[9] Furthermore, readmissions are less common among pediatric populations compared with adults.[10] While reasons for readmission are multifactorial, complications that occur early after

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discharge often result in readmissions.[11,12] In theory, these complication-associated readmissions could be avoided if duration of stay is extended. Uniformly extending duration of stay must be balanced with opportunity costs such as resource utilization and expense. The purpose of this study is to examine the relationship between duration of stay, timing of complications, and readmission risk.

METHODS

Data source. The National Surgical Quality Improvement Project-Pediatric (NSQIP-P) was developed in 2005 as a collaboration between the American College of Surgeons and the American Pediatric Surgical Association. NSQIP-P provides nationally validated, risk-adjusted outcomes data to be used for improving the quality of operative care in pediatric patients. NSQIP-P is a multispecialty program that includes orthopedic surgery, urology, neurosurgery, otolaryngology, plastic surgery, gynecology, and general/thoracic surgery from >80 pediatric hospitals. Registry data are collected prospectively at each institution by an American College of Surgeons trained abstractor. The data provide 30-day readmission, postoperative morbidity, and mortality outcomes.[13,14] This study was submitted to the Children's Healthcare of Atlanta institutional review board and was deemed exempt from review.

Procedure selection. The present study includes all cases in the 2012, 2013, and 2014 NSQIP-P participant use file. Individual current procedural terminology codes were reviewed and procedures were categorized based on procedure type, operative subspecialty, and similar operative time.[15] This process resulted in 30 distinct procedural groups used in this study. The appendix operative procedure group was further subcategorized into simple appendectomy and complex appendectomy (CA). CA was defined as any case with a duration of stay >2 days.[16,17] Cases with missing 30-day readmission status, postoperative day of readmission, or postoperative hospital duration of stay were excluded, in addition to cases involving preoperative complications.

For the 30 procedural groups, the temporal relationship between duration of stay and median day of complications was examined. For some procedures, the median day of complication occurred prior to discharge and these procedures were excluded. For other procedures, the median day of complications occurred >2 days after discharge and these procedures also were excluded. The procedures where the median day of complications approximated duration of stay within 2 days of discharge were identified for further analysis.

Defining duration of stay, complications, and readmissions. For the purposes of this study, duration of stay included only postoperative inpatient days. Median duration of stay was determined for each procedure group. The number of patients discharged on each postoperative day ≤30 days was determined for the procedure groups of interest.

Complications were defined as any wound infection (superficial, deep, or organ space infection), deep wound disruption, superficial wound disruption/dehiscence, pneumonia, reintubation, pulmonary embolism, progressive renal insufficiency, acute renal failure, urinary tract infection, coma, stroke with neurologic deficit, seizure, nerve injury, intraventricular hemorrhage, cardiac arrest, bleeding/transfusions, septic shock, sepsis, central line associated bloodstream infection, and any unplanned readmission or reoperation.

The median day of complication was calculated based on the median postoperative day any complication occurred. The median and interquartile range were reported. Readmission was defined as any inpatient admission to the hospital within the 30 days after an operation. Readmission rates were stratified by the presence and timing of complication into 3 cohorts: 1) no complication, 2) complications only before discharge, and 3) complications only after discharge. Patients who experienced complications before and after discharge were excluded from the model. Readmission rates for each of these groups were determined for the procedure groups of interest. Within each procedure group of interest, the proportion of patients who experienced 1) no complication, 2) complications only before discharge, and 3) complications only after discharge were determined from NSQIP-P. For each of these groups, empiric cumulative distribution functions depicting the relationship between duration of stay and readmission were plotted.

Theoretical model. We developed a theoretical model to test the effect of adding additional days to duration of stay on readmission rates. This model was applied to the procedure groups where median day of complications approximated duration of stay within 2 days of discharge. Using the number of patients discharged on each postoperative day from NSQIP, patients had 1 additional day added to their duration of stay in a forward stepwise fashion. Readmission rates for the 3 complication categories (1) no complication, 2) complications only before discharge, and 3) complications only after discharge) were applied to these patient groups based on their discharge status (in hospital versus at home). The

readmission rate based on this theoretical extended duration of stay was calculated.

Our approach to determining a theoretical readmission rate is described below. Within a category of operative procedures, patients can be divided into 2 groups, depending on if they had a complication. These groups are NC are patients with no complications and WC are patients with complication. The proportions of patients in each group out of the total patients in the surgical procedure category total can be expressed in a vector P = {proportion of NC, proportion of WC}. Relatedly, the readmission rates within each group can be expressed in a vector R = {readmission rate for NC, readmission rate for WC}. Using the 2 vectors P and R, from patients discharged on postoperative day duration of stay, denoted by D_{DOS}, we can predict the number of patients who will later be readmitted to be $(P \cdot R) \times D_{DOS}$, where $\cdot$ indicates dot product and $\times$ is regular multiplication. Extending this idea further, among patients discharged on or before day t, the predicted the number of patients who will later be readmitted would be $(P \cdot R) \times \sum_{DOS=1}^{t} D_{DOS}$.

The predicted number of patients who will be readmitted is calculated similarly for patient discharged after day t. The number of patients discharged after day t can be expressed by $TOTAL - \sum_{DOS=1}^{t} D_{DOS}$. Because complication rate can vary for these patients, depending on the timing of complication relative to discharge, we further divide patients discharged after day t into 3 groups: NC = patients with no complications, BD = patients with complications only before discharge, and AD = patients with complications only after discharge. The proportions of patients in each of these groups out of the total patients in the operative procedure category total is expressed through the vector P^* = {proportion of NC, proportion of BD, proportion of AD}. Correspondingly, we can create a vector R^* = {readmission rate for NC, readmission rate for BD, readmission rate for AD}. Using P^* and R^*, the number of patients discharged after day t is $(P^* \cdot R^*) \times (TOTAL - \sum_{DOS=1}^{t} D_{DOS})$.

After predicting the number of readmissions among patients discharged before, during, and after a day of discharge t, the theoretical readmission rate $TR(t)$ can be determined as follows:

$$TR(t) = \frac{(P \cdot R) \times \sum_{DOS=1}^{n} D_{DOS}}{TOTAL} + \frac{(P^* \cdot R^*) \times \left(TOTAL - \sum_{DOS=1}^{t} D_{DoS}\right)}{TOTAL}$$

In the rate $TR(t)$, the left term represents the theoretical readmission rate for patients discharged on or before day t and the right term represents the theoretical readmission rate for patients discharged after day t. All modeling, statistical analyses, and data cleaning were performed using Microsoft Excel, R version 3.2.3 "Wooden Christmas-Tree,"[18] and SAS 9.4 (Cary, NC).

RESULTS

We identified 172,813 cases within the 2012–2014 NSQIP-P. All cases organized by procedure group are included in Table I. We identified 3 procedure groups where median day of complication approximated duration of stay within 2 days of discharge: 1) CA, 2) antireflux operation (ARS), and 3) abdominal operation without bowel resection (AS). All other procedure groups were excluded from further analysis.

Within the CA procedure group, 22 patients were identified as having complications before and after discharge and were excluded. Of the remaining 5,865 patients, 87.82% (n = 5,151) had no complications, 7.30% (n = 428) had complications only before discharge, and 4.87% (n = 286) had complications only after discharge. Fig 1 represents readmission rates for each of these groups with patients with no complications having the lowest readmission rate and patients with complications only after discharge having the highest readmission rate. The reported results were entered into our theoretical model. The CA readmission rate dropped from 12.20% to 8.18% when duration of stay increased from 3 to 8 days at which point readmission optimization tapers (Fig 2, Table II). By increasing duration of stay to 8 days, the number of inpatient days increased by 3.5 days per patient (16,428 days/4,740 patients).

Within the ARS procedure group, 6 patients were identified as having complications before and after discharge and were excluded. Of the remaining 2,224 patients, 89.20% (n = 1,984) had no complications, 8.23% (n = 183) had complications only before discharge, and 2.56% (n = 57) had complications only after discharge. Readmission rates for each of these groups were 3.50%, 5.46%, and 33.33%, respectively. Results of the theoretical model for ARS are reported in Table II. The ARS readmission rate dropped from 6.69% to 5.49% when duration of stay increased from 0 to 5 days at which point readmission optimization tapers. By increasing duration of stay to 5 days, the number of inpatient days increased by 2.6 days per patient (3,126 days/1,206 patients).

Table I. Readmission rates, median postoperative duration of stay and day of postoperative complication for 30 NSQIP-P procedure groups

Procedure group	*No. of procedures* n *(%)*	*Readmissions* n *(%)*	*Median postoperative duration of stay (d) [IQR]*	*Median day of postoperative complication [IQR]*
All procedures	172,813 (100)	4,326 (2.5)	1 [0,3]	1 [0,9]
Appendix operation	23,001 (13.3)	751 (3.3)	1 [1,3]	8 [6,13]
Simple appendectomy	17,114 (9.9)	318 (1.9)	1 [1,1]	9.5 [7,15]
Complex appendectomy	**5,887 (3.4)**	**433 (7.4)**	**5 [4,7]**	**7 [6,11]**
Spine operation	11,548 (6.7)	389 (3.4)	4 [3,5]	0 [0,0]
Gastrostomy	4,339 (2.5)	155 (3.6)	3 [2,8]	8 [2,19]
Antireflux operation	**2,230 (1.3)**	**99 (4.4)**	**4 [2,9]**	**5 [1,11]**
Neurosurgery (nonspine, nonshunt)	5,092 (2.9)	242 (4.8)	3 [3,5]	0 [0,0]
Neurosurgery (shunt or EVD)	6,437 (3.7)	694 (10.8)	2 [1,4]	9 [2,18]
Chest wall	1,126 (0.6)	36 (3.2)	4 [4,5]	15 [4,20]
Congenital abdominal wall defects*	935 (0.5)	11 (1.2)	24 [15,39]	4 [1,15]
Abdominal operation (without bowel resection)	**5,591 (3.2)**	**202 (3.6)**	**2 [0,6]**	**2 [0,9]**
Abdominal operation (with bowel resection or operation)	4,947 (2.9)	253 (5.1)	6 [4,16]	3 [0,9]
Foregut	3,080 (2.2)	60 (1.9)	1 [0,1]	6 [2,12]
Colorectal	3,186 (1.8)	224 (7.0)	5 [3,11]	4 [0,10]
Anorectal	1,122 (0.6)	47 (4.2)	3 [2,5]	8 [4,12]
Pyloric	4,279 (2.5)	58 (1.4)	1 [1,2]	4 [1,10]
Cholecystectomy	3,951 (2.3)	68 (1.7)	1 [1,1]	9.5 [2,14]
Liver/Biliary/Pancreas	609 (0.4)	25 (4.1)	6 [4,10]	0 [0,5]
Splenectomy	491 (0.3)	9 (1.8)	2 [1,3]	0 [0,5]
Diaphragm	529 (0.3)	7 (1.3)	16 [6,31]	2 [0,7]
Tracheoesophageal fistula*	443 (0.2)	10 (2.3)	21 [13,41]	3 [0,9]
Thoracic	2,566 (1.5)	67 (2.6)	4 [2,7]	1 [0,4]
Urology (other than nephrectomy)	17,431 (10.0)	330 (1.9)	0 [0,1]	9 [4,17]
Nephrectomy	1,284 (0.7)	33 (2.6)	3 [1,5]	0 [0,3]
Cleft lip or palate	8,340 (4.8)	70 (0.8)	1 [1,1]	11 [6,18]
Retropharyngeal abscess	558 (0.3)	15 (2.7)	2 [1,3]	3 [0,9]
Tracheostomy*	401 (0.2)	7 (1.7)	25 [14,50]	5 [2,11]
Other ENT	14,229 (8.2)	133 (0.9)	0 [0,1]	11 [5,20]
Orthopedic operation	26,830 (15.5)	227 (0.8)	1 [0,1]	2 [0,15]
Gynecology	1,437 (0.8)	26 (1.8)	1 [1,2]	7 [1,12]
Facial plastics	771 (0.4)	13 (1.7)	1 [1,3]	0 [0,4]
Skin/Soft tissue	16,030 (9.2)	65 (0.4)	0 [0,0]	12 [7,19]

*Indicates procedure groups where the median day of complication occurred prior to discharge.
Procedure groups in bolded text indicate that the median day of complication approximated duration of stay within 2 days of discharge.

Within the AS procedure group, 51 patients were identified as having complications before and after discharge and were excluded. Of the remaining 5,540 patients, 89.96% ($n = 4,984$) had no complications, 8.05% ($n = 446$) had complications only before discharge, and 1.98% ($n = 110$) had complications only after discharge. Readmission rates for each of these groups were 2.68%, 4.26%, and 37.27%, respectively. Results of the theoretical model for ARS are reported in Table II. The reported results were entered into our theoretical model. The AS readmission rate dropped from 6.16% to 4.13% when duration of stay increased from 0 to 7 days at which point readmission optimization tapers. By increasing duration of stay to 7 days, the number of inpatient days increased by 5.3 days per patient (22,279 days/4,209 patients).

DISCUSSION

Postoperative complications, especially those occurring after discharge, are strongly associated with readmissions.[11,12] In theory, readmissions can be prevented by extending duration of stay past the typical time when complications occur for specific procedures. By doing this, complications could be addressed while the patient is in-house

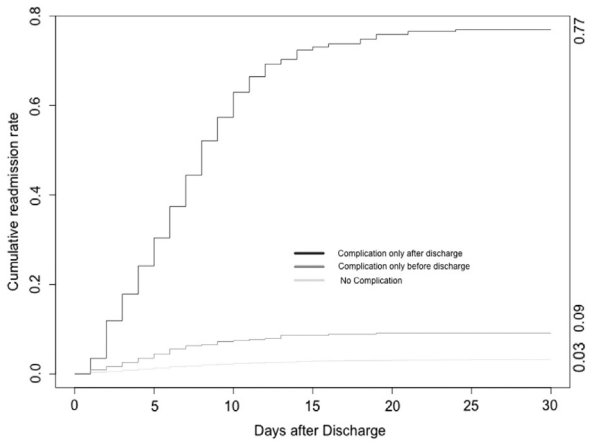

Fig 1. Cumulative readmission rates for complicated appendectomy for patients with no complication, complications only before discharge, and complications after discharge.

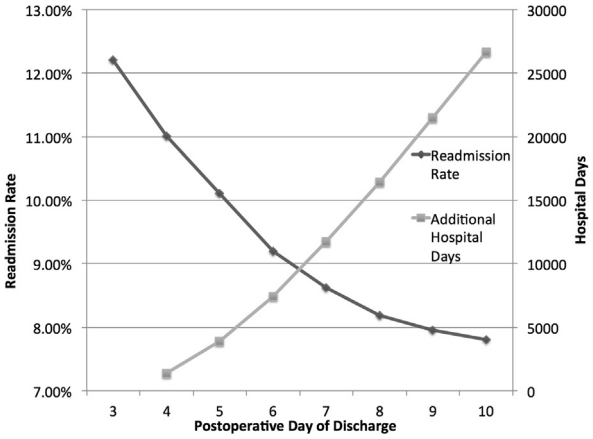

Fig 2. For complicated appendectomy, readmission rates decrease as additional hospital days increase when duration of stay is prophylactically increased to capture early complications prior to discharge.

avoiding a return to the hospital and obligatory readmission. Using NSQIP-P, we identified 3 procedure groups where duration of stay approximated the median day of complication and applied our theoretical model in which duration of stay was arbitrarily increased to minimize readmissions. While readmission rates decreased with longer duration of stay, this approach resulted in a substantial increase in hospital days illustrating the conflict between competing quality metrics and limited resources. Other procedure groups were excluded from our analysis, because the median day of complication occurred >2 days after the median discharge day. For example, the neurosurgery (shunt or external ventricular drain) procedure group has a median duration of stay of 2 days; however, the median day of complication is day 9 (Table I). If providers were to extend duration of stay past day 9 to capture these complications while patients are inpatient, the number of overall hospital days would increase dramatically at huge costs to patients and hospitals.

Our data demonstrated an increased rate of readmission among patients who are subject to postdischarge complications after an operative procedure. Similarly, adult patients with major, postdischarge complications have been shown to be >8 times more likely to be readmitted than patients with no complications.[11] This finding could prompt surgeons to prophylactically increase duration of stay so that patients are still in-house when a complication occurs. We attempted to demonstrate the effects of such an intervention through our theoretical model. Although we did see readmission rates decrease when duration of stay was extended, this action resulted in thousands of additional hospital days. To put this in perspective, consider CA where the median day of postoperative complications is postoperative day (POD) 7, while the median duration of stay is only 5 days. This means that with traditional postoperative management half of the CA patients are home by POD 5. As demonstrated by our model, if surgeons were to prophylactically increase duration of stay past the median day of complication, POD 8 in this case, 235 readmissions would be prevented. However, this would come at the cost of 16,428 additional hospital days for patients who would have been discharged earlier based on their clinical status. Although hospitals could reduce the costs associated with readmissions using this strategy, the cost of longer duration of stay would far exceed these savings.

Hospital readmissions negatively impact patient quality of life and result in huge costs within the health care system. Because of this, reducing readmission rates has become a quality improvement focus with current policy penalizing hospitals for excess readmissions. At present, these policies largely affect adult hospitals, but unplanned pediatric readmissions are beginning to be targeted as well.[19] While there is a large body of literature examining modifiable factors associated with adult operative readmissions, the pediatric literature is less robust. Additionally, there are striking differences between pediatric and adult readmissions.[20] Perhaps most importantly, reported 30-day readmission rates among children are considerably lower than among adults ranging from 4.4% to 6.5%.[10,20,21] Because pediatric readmission rates

Table II. Results of the theoretical model in which duration of stay was extended in a stepwise fashion demonstrating decreasing readmission rates with longer duration of stay for 3 procedure groups of interest

Duration of stay	*Patients with extended duration of stay (%)*	*Patients with unchanged duration of stay (%)*	*Additional hospital days*	*Readmission rate*	*No. of readmissions avoided*
Complex appendectomy*					
3	0 (0)	5,865 (100)	—	12.20%	—
4	1,388 (23.7)	4,477 (76.3)	1,388	11.01%	70
5	**2,484 (42.4)**	**3,381 (57.6)**	**3,872**	**10.11%**	**123**
6	3,587 (61.2)	2,287 (39.0)	7,459	9.20%	176
7	4,429 (72.1)	1,636 (27.9)	11,688	8.62%	211
8†	4,740 (80.9)	1,125 (19.1)	16,428	8.18%	235
9	5,009 (85.4)	856 (14.6)	21,437	7.95%	252
10	5,187 (88.4)	678 (11.6)	26,624	7.82%	257
Antireflux operation					
0	0 (0)	2,224 (100)	—	6.69%	—
1	22 (1)	2,202 (99)	22	6.74%	1
2	232 (10.4)	1,992 (89.6)	254	6.47%	5
3	672 (30.2)	1,552 (69.8)	926	6.03%	15
4	**994 (44.7)**	**1,230 (55.3)**	**1,920**	**5.71%**	**22**
5†	1,206 (54.2)	1,018 (48.8)	3,126	5.49%	27
6	1,347 (60.6)	877 (39.4)	4,473	5.35%	30
7	1,476 (66.4)	748 (33.6)	5,949	5.21%	33
8	1,567 (70.5)	657 (29.5)	7,516	5.17%	34
9	1,636 (73.6)	588 (26.4)	9,152	4.99%	38
10	1,684 (75.8)	540 (24.2)	10,836	5.03%	37
Abdominal operation (without bowel resection)					
0	0 (0)	5,540 (100)	—	6.16%	—
1	1,755 (31.7)	3,785 (68.3)	1,755	5.32%	46
2	**2,528 (45.6)**	**3,012 (54.4)**	**4,283**	**4.95%**	**67**
3	2,941 (53.1)	2,599 (46.9)	7,224	4.77%	77
4	3,304 (59.6)	2,236 (40.4)	10,528	4.57%	88
5	3,615 (65.3)	1,925 (34.7)	14,143	4.44%	95
6	3,927 (70.9)	1,613 (29.1)	18,070	4.28%	104
7†	4,209 (76.0)	1,331 (24.0)	22,279	4.13%	112
8	4,377 (79.0)	1,163 (21.0)	26,656	4.06%	116
9	4,517 (81.5)	1,023 (18.5)	31,173	4.00%	119
10	4,625 (83.5)	915 (16.5)	35,798	3.95%	122

*Complex appendectomy was defined as any appendectomy case with a duration of stay >2 days. No calculations were made based on a duration of stay ≤2 days.
†Postoperative day at which readmission optimization tapered.
Median duration of stay for each procedure group is in bolded text.

are so low, it may not be as financially advantageous to target readmissions as a quality or value metric in this population. It is also important to note that prolonging duration of stay for certain procedure groups would likely not result in a decrease in readmissions. These groups are those where median day of complication occurs several days prior to the median duration of stay, such as the congenital abdominal wall defects, tracheoesophageal fistula, and tracheostomy procedure groups. In these groups, complications are likely being captured and addressed while patients are inpatient, which effectively reduces the risk of readmission.

Then the question becomes how do pediatric surgeons balance the competing interests of preventing readmissions while maintaining a reasonable duration of stay for patients. Policymakers should be aware that by introducing a penalty for readmissions, they may be motivating physicians to keep their patients in-house longer. Our model demonstrates that this is clearly not the answer to solve the readmission problem. Rather efforts should continue to focus on prevention of complications through evidence-based protocols targeting reduction of postoperative complications such as surgical site infections,[22] catheter-related bloodstream infections,[23] urinary tract infections,[24] and

pneumonia.[25] With outpatient complications as the driving factor for many readmissions, discharge plans and outpatient resources need to be assessed to assure that patient's postdischarge needs are being met. It is possible that with additional outpatient resources many minor complications could be addressed without a readmission.

This study is limited by several factors. First and foremost, our methods are purely theoretical. We used actual data from NSQIP-P to develop a mathematic equation to predict the effect of extending duration of stay on readmission rates. We are not suggesting the practice of extending duration of stay for all patients, instead we attempted to demonstrate the negative impact of such an intervention. Our model also assumes that complications are the primary driver for readmissions, but, in reality, both duration of stay and readmissions are guided by more than just complications (ie, social issues). Additionally, we did not investigate the readmission rates associated with specific complications. It is possible that specific complications have higher complication rates than others and may warrant further concentrated investigation. In addition, our procedure categorization schema generated 30 groups, but granularity down to the specific procedure level may be necessary to better understand the relationships between complications and readmissions. Finally, NSQIP-P data are limited to the hospitals that elect to participate in the program and may not be generalizable to all hospital types.

With present policy penalizing hospitals for excess readmissions, quality improvement efforts need to focus on interventions to prevent these readmissions. With postdischarge complications driving readmissions in many cases, it seems intuitive to extend duration of stay past the typical time when complications occur to avoid a readmission. However, our theoretical model demonstrates a substantial increase in hospital days when duration of stay is extended to capture early complications illustrating the conflict between competing quality metrics and limited resources.

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