

Implementing PDSA Methodology for Pediatric Appendicitis Increases Care Value for a Tertiary Children's Hospital

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Abstract

Introduction: We used the plan-do-study-act (PDSA) framework to develop and implement an evidence-based clinical practice guideline (CPG) within an urban, tertiary children's referral center. **Methods:** We developed an evidence-based CPG for appendicitis using iterative PDSA cycles. Similar CPGs from other centers were reviewed and modified for local implementation. Adjuncts included guideline-specific order sets and operative notes in the electronic medical record system. Outcomes included length of stay (LOS), 30-day readmissions, hospital costs, and patient and family experience (PFE) scores. Our team tracked outcome, process, and balancing measures using Statistical Process Charts. Outcome measures were compared over 2 fiscal quarters preimplementation and 3 fiscal quarters postimplementation, using interrupted time series, student *t* test, and chi-square tests when appropriate. **Results:** LOS for simple (uncomplicated) appendicitis decreased to 0.87 days (interquartile range [IQR] 0.87–0.94 days) from 1.1 days (IQR 0.97–1.42 days). LOS for complicated appendicitis decreased to 4.96 days (IQR 4.95–6.15) from 5.58 days (IQR 5.16–6.09). This reduction equated to an average cost-savings of \$1,122/patient. Thirty-day readmission rates have remained unchanged. PFE scores increased across all categories and have remained higher than national benchmarks. **Conclusion:** Development and Implementation of a CPG for pediatric appendicitis using the PDSA framework adds value to care provided within a large tertiary center. (*Pediatr Qual Saf* 2021;6:e442; doi: 10.1097/pq9.000000000000442; Published online July 28, 2021.)

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INTRODUCTION

Problem Description

In Fall 2018, a review of secondary administrative and claims databases identified our tertiary referral center as an outlier regarding lengths of stay (LOS) for several conditions, including pediatric appendectomy. This metric contrasted with our organizational mission to provide safe, effective, efficacious, timely, and patient-centered care for the communities that we serve. In response to this finding, our division prioritized pediatric appendectomy as a cohort for efforts to reduce LOS. We initiated a multidisciplinary quality improvement (QI) effort to investigate the causes of our increased LOS and implement interventions to improve our care processes and add value to patient care.

Available Knowledge and Rationale

Several studies have shown that variation in antibiotic selection, imaging, laboratory testing, and discharge criteria contribute to inconsistent care for children with appendicitis.^{1–8} Clinical practice guidelines (CPGs) are useful tools for implementing standardized care and reducing unnecessary variation for pediatric appendicitis.^{9–15}

Furthermore, same-day discharge (SDD) for simple appendicitis is feasible and safe in children.¹⁶⁻¹⁹

The Institute for Healthcare Improvement's Model for Improvement is the most commonly used QI approach in healthcare.¹⁰ This model relies on multiple Plan-Do-Study-Act (PDSA) cycles as initially developed by Deming.^{20,21} We present a study utilizing this approach and harnessing the PDSA method to design and implement a CPG for pediatric appendicitis.

Specific Aims

Our mission was to implement a comprehensive, evidence-based CPG for simple and complicated appendicitis to decrease unwarranted interquartile range [var]iation in care. We aimed to decrease LOS for all patients with appendicitis and standardize antibiotic selection and duration for patients presenting with complicated appendicitis. In achieving these aims, we sought to improve the efficiency of care delivered, optimize resource utilization, and reduce the overall cost of care for pediatric appendicitis.

METHODS

Context

Our multidisciplinary team is housed within a single, freestanding 364-bed urban children's hospital, a tertiary referral center for Chicago. The Division of Pediatric Surgery includes surgeons, fellows, residents, advanced practice providers, and registered nurses. At our hospital, 16 pediatric surgeons perform approximately 350 pediatric appendectomies annually. We developed our CPG incorporating decisions made throughout all phases of care, from emergency department triage through hospital discharge. We developed our understanding of the underlying system process and possible effects by eliciting multidisciplinary input, facilitated by creating a fishbone diagram (Figure 1, Supplemental Digital Content 1, which displays fishbone diagram used to identify causes and drivers for prolonged LOS after appendectomy, <http://links.lww.com/PQ9/A279>). We then constructed aim statements and key driver diagrams to ensure a clear and concise summary (Fig. 1). This work allowed us to develop target areas for improvement across all phases of care, determine the evidence supporting each decision point in our guideline, and, ultimately, develop our CPG and associated process measures.

Description of the Intervention

In this CPG (Figure 2, Supplemental Digital Content 2, which displays CPG for pediatric appendicitis, <http://links.lww.com/PQ9/A280>), patients suspected of having appendicitis are initially resuscitated with intravenous (IV) fluids, undergo laboratory studies, and have ultrasound imaging. If the ultrasound is positive, emergency department practitioners obtain surgical consultation and initiate the appendicitis pathway order set. This order

set includes standardized antibiotic dosing (ceftriaxone/metronidazole, or ciprofloxacin/metronidazole if penicillin allergies are present), parenteral analgesia, and preoperative preparations to be initiated in the emergency department. If a patient's ultrasound is inconclusive, surgical consultation is still obtained to determine whether additional imaging (eg, magnetic resonance imaging) or observation (inpatient versus outpatient) is warranted before continuing the pathway of care.²²

Following initiation of the appendicitis pathway order set, operative and anesthesia staff prepare to take the patient to the operating room for laparoscopic appendectomy. Determination of simple versus complicated (and what degree of complication) occurs in the operating room based on the appearance of the appendix (ie, visible hole or extraluminal fecalith) and the presence or absence of associated abscesses. At our institution, the surgeon-reported grading of appendicitis into one of four possible categories determines the postoperative treatment pathway details (Figure 2, Supplemental Digital Content 2, which displays CPG for pediatric appendicitis, <http://links.lww.com/PQ9/A280>). Patients with simple appendicitis (category 1) are discharged home the same day without continued antibiotics. A simple appendicitis postoperative order set outlines pain medication, diet initiation, and conditional discharge based on specific discharge criteria.

If a patient has complicated appendicitis (categories 2A, 2B, or 2C), the patient is admitted for continued antibiotic therapy and recovery (Figure 2, Supplemental Digital Content 2, which displays CPG for pediatric appendicitis, <http://links.lww.com/PQ9/A280>). Patients with category 2A appendicitis receive a total of three days of antibiotics and can be discharged once criteria are fulfilled. Patients with category 2B or 2C appendicitis receive a 7-day course of antibiotics but may go home before the 7-day mark if they are otherwise meeting discharge criteria. The delineation of type and duration of antibiotics by the grade of severity was developed from the pediatric appendicitis literature.^{3,23} At our institution, discharge criteria include: being afebrile, tolerating diet without emesis, ambulating in the hallway, voiding (0.5-1 ml; Fax: (312) 227-9678/kg/h), and having pain controlled with oral medications. Patients with complicated appendicitis who meet discharge criteria before completing their antibiotic course go home on oral amoxicillin/clavulanic acid for the remaining days of their respective 3-day or 7-day course. All patients (simple and complicated appendicitis) are scheduled for routine follow up via telehealth or in the clinic with either the operating surgeon or a nurse practitioner.

Development of the Intervention

In September 2018, we formed a multidisciplinary team composed of representatives from the following disciplines: pediatric surgeons, advanced practice providers, anesthesiologists, emergency department physicians, nurses, an antibiotic steward, pharmacists, QI and clinical informatics consultants, data analysts, child life

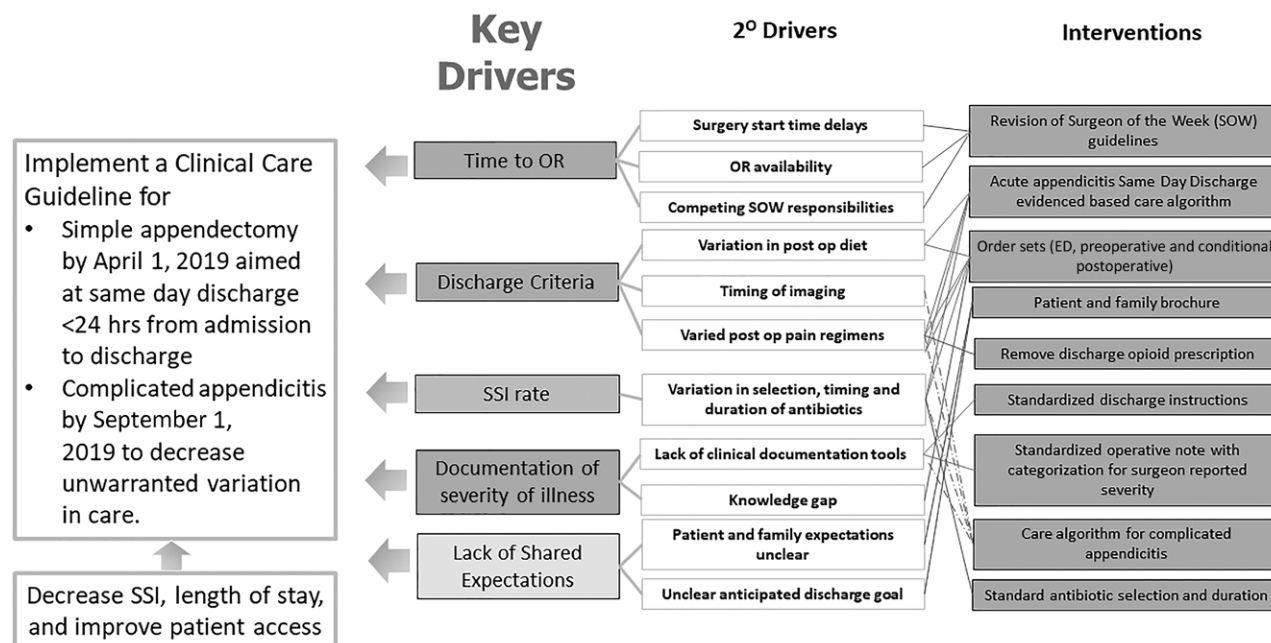


Fig. 1. Key driver diagram used to identify causes and drivers for the LOS after appendectomy. ED, emergency department; OR, operating room; SOW, surgeon of the week; SSI, superficial site infection.

specialists, patient and family educators, and social workers. This multidisciplinary team met monthly for the first 4 months. Also, project leads met with the Division of Pediatric Surgery monthly to update the CPG development and obtain feedback. We completed a comprehensive review of the literature to provide an evidence base for crucial decision points. For decision points with a lack of evidence, consensus among the stakeholder teams defined local recommendations. For our institution, division meeting discussions with our group of pediatric surgeons led to excluding nonoperative management (for either simple or delayed presentation) as part of the standard CPG. Iterative development of the CPG occurred from January 2019 to March 2019.

In March 2019, we implemented the CPG for simple appendicitis supported by specific clinical interface features in the electronic medical record system: a patient and family brochure distributed by nursing at diagnosis, standard preoperative and postoperative order sets, and an appendectomy operative note. In July 2019, we implemented the CPG for complicated appendicitis, releasing an order set including postoperative pain control and antibiotic selection. Testing and monitoring of the interventions occurred from March 2019 to March 2020 for simple appendicitis and from July 2019 to March 2020 for complicated appendicitis. Our team modified the adjuncts to the CPG iteratively based on clinician and family feedback over the intervention period. We monitored outcome and process measures monthly and readmissions weekly.

Study of Intervention and Measures

The primary outcome of interest was LOS measured as hours of admission until discharge, excluding time in the

emergency department. In our evaluation, we report LOS in hours for simple appendicitis and days for complicated appendicitis. Process measures included the rate of order set use and rate of operative note use. Our business analyst evaluated estimated hospitalization costs (estimated average direct costs [EADC]) for appendicitis care (including medications, cost of bed type, and nurse staffing), stratified by patient admission status (ie, extended recovery, observation, or inpatient), over 2 and 3 fiscal quarters for the immediate preimplementation and postimplementation of the March CPG, respectively. We evaluated balancing measures of 30-day readmission and postoperative infection rates using institutional NSQIP-P measures over the study period. We then compared overall differences in process and outcome measures between preimplementation and postimplementation of the CPGs for summative evaluation.

Patient and family experience (PFE) was measured using standardized feedback. All patients and families at our institution receive invitations to complete an online survey after their hospital discharge unless they have completed a similar survey within the previous 90 days. The survey asks parents to rank their experiences with the physician and nursing teams, communication with their healthcare team, understandability of dialog provided by healthcare staff, and clarity of discharge instructions. An outside vendor (NRC Health, National Research Corporation, Lincoln, Neb.) administers these surveys electronically, calculates mean scores by admission type, and provides a report of mean scores per domain compared against national benchmarks for inpatient and outpatient visits. The reports can be administered by division, unit, and overall institution. We compared mean

PFE scores received by our division across 6 months pre-CPG and 6 months of post-CPG implementation.

Analyses

Our team created monthly statistical process control charts to track progress on LOS, postoperative infection rates, and return to the healthcare system. Comparisons of outcomes for preimplementation and postimplementation periods were aggregated over fiscal quarters and calculated using Shewhart Charts computed in SAS.²⁴ Time series analysis was performed for LOS following CPG intervention implementation for cases of simple appendicitis. We evaluated the balancing measures of 30-day readmission and postoperative infection rates using institutional NSQIP-P measures over the corresponding pre- and post-implementation periods. We evaluated all pre-post comparisons of outcome and process measures using student *t* test and chi-square tests where appropriate. Our perioperative business office calculated EADC for all patients treated with appendicitis, stratified by admission type, within 2 fiscal quarters pre-CPG implementation and 3 fiscal quarters postimplementation. These measures included costs related to LOS, bed type, and total direct costs of care. Finally, our QI leads worked with the outside vendor to compile mean scores for each category of PFE measures over 6 months preimplementation and 6 months postimplementation. The outside vendor conducted the analysis and interpretation of the PFE scores preimplementation and postimplementation using 2-tailed Z tests with 90% confidence intervals.

Ethical Considerations

Throughout the development of this CPG, our team incorporated parents' and patients' feedback on the process of receiving care for pediatric appendicitis using the PFE surveys. Families received preoperative education on the diagnosis of appendicitis and the safety of SDD for simple appendicitis during the surgical consent process. This study was considered exempt from review by the Lurie Children's Institutional Review Board (IRB #2021-4113).

RESULTS

From March 2019 to March 2020, LOS for simple appendicitis decreased 21% from an average of 1.1 days (interquartile range [IQR] 0.98–1.22) in the 12 months before implementation to an average of 0.87 days (IQR 0.75–0.94) (Fig. 2). In particular, the utilization of our simple appendicitis postoperative order set increased from 29.4% to 82.3% after May 2019 (Figure 3A, Supplemental Digital Content 3, which displays statistical process control charts for simple appendectomy depicting (A) Order set use and (B) 30-day readmissions, <http://links.lww.com/PQ9/A281>). This compliance was associated with a significant drop in LOS between fiscal quarters April 2019 and January 2020, as confirmed with interrupted time series analysis (LOS slope: -0.031

over April 2016 to February 2018 versus -0.045 over January 2019 to February 2020, Fig. 3). Readmission rates for simple appendicitis have remained low and have not changed significantly since our CPG implementation (2% pre to 2% post, $P = 0.93$, Figure 3B, Supplemental Digital Content 4, which displays statistical process control charts for simple appendectomy depicting (A) Order set use and (B) 30-day readmissions, <http://links.lww.com/PQ9/A282>). Postoperative infections (wound and organ space infections) have decreased for patients with simple appendicitis, though this was not a statistically significant change (6% preimplementation to 1.4% postimplementation, $P = 0.16$, Table 1). Finally, utilization of a standard operative note, which included a standardized grading scheme of appendicitis severity, increased from 40% to 95% over 12 months (Figure 5, Supplemental Digital Content 7, which displays statistical process control chart for operative note use (simple and complicated appendectomy), <http://links.lww.com/PQ9/A285>).

We implemented the complicated appendicitis guideline in July 2019. LOS decreased by 11% from an average of 5.58 days (IQR 5.18–6.09) preimplementation to 4.96 days postimplementation (IQR 4.95–6.15) (Fig. 4). Our complicated appendicitis postoperative order set is undergoing active revisions, and utilization is currently 32.6% per quarter (Figure 4A, Supplemental Digital Content 5, which displays statistical process control charts for complicated appendectomy depicting (A) order set use (B) 30-day readmissions, <http://links.lww.com/PQ9/A283>). Readmission for complicated appendicitis has not significantly changed (12.66% postimplementation vs. 9.8% preimplementation, $P = 0.53$, Figure 4B, Supplemental Digital Content 6, which displays statistical process control charts for complicated appendectomy depicting (A) order set use (B) 30-day readmissions, <http://links.lww.com/PQ9/A284>) in the two quarters since the implementation of the CPG. Last, postoperative infection rates have not increased for complicated appendicitis over the past 6 months of evaluation (16.9% preimplementation to 16.7% postimplementation, $P = 0.61$, Table 1).

Hospitalization costs for all patients with appendicitis (simple and complicated) were compared over 7 months preimplementation and 10 months postimplementation (Table 2). In the preimplementation phase, 198 patients were hospitalized for 580 days, averaging approximately 2.9 days per patient. The total EADC during this time was \$8,099 per patient. Following CPG implementation, our inpatient bed utilization decreased from 38% to 32%, with a corresponding increase in observation or extended recovery bed usage from 62% to 69%. We cared for 346 patients for a total of 280 hospitalization days, equating to 1.24 days per patient. The total EADC decreased to \$6,977 per patient, saving an average of \$1,122 per patient treated for appendicitis (Table 2). This overall estimated cost-savings has been higher than that attributable to modifying bed type and LOS alone (Table 2).

Xbar S chart of Length of stay (hour method), December 2015–February 2020 by Fiscal quarter

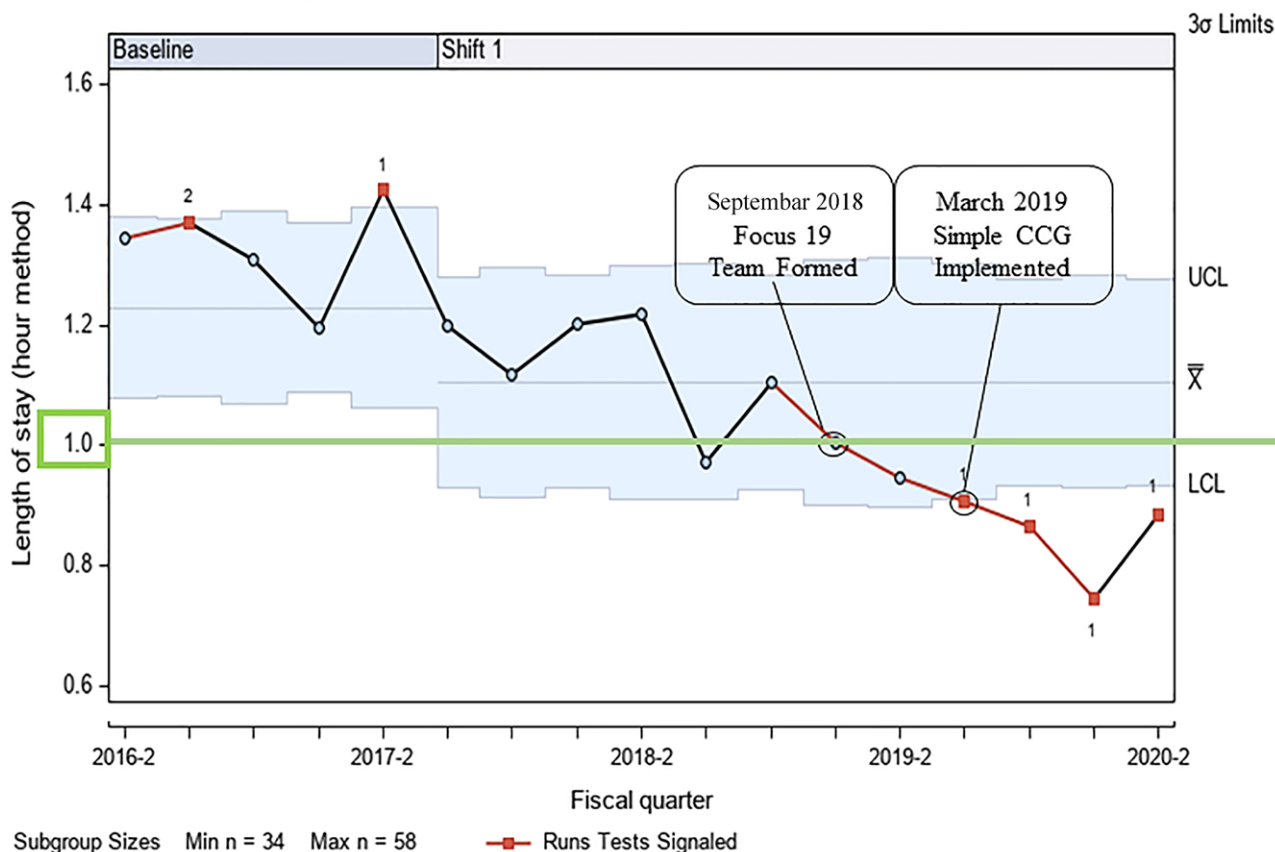


Fig. 2. LOS for simple appendicitis, by fiscal quarter.

PFE scores collected and measured over the study period increased globally postimplementation of the CPG. Our response rate in the last 2 quarters of the preimplementation period (September 2018–March 2019) was 28.4%, and in the postimplementation period (April 2019–January 2020) was 22.6%. Before implementation, interstaff communication and understandability of dialog were ranked higher than the national average for children’s hospitals at 85% and 86%, respectively ($P < 0.05$). This ranking remained significant in the postimplementation period. We saw improvement in perceived staff timeliness in assisting patients with their discomfort (from 82% preimplementation to 92% in the postimplementation phase) and in discharge instruction (from 86.4% to 91.8%, $P < 0.05$), bringing our institution’s PFE scores statistically significantly higher than the national average.

DISCUSSION

The development and implementation of a CPG for pediatric appendicitis resulted in a decreased LOS and increased value in care (quality/cost) provided by our institution. We could reduce our LOS to 0.87 days for simple appendicitis and 4.96 days for complicated appendicitis. The delivery of high-quality care was maintained,

as measured by no increases in healthcare utilization, no significant changes in postoperative infection rates, and increased PFE scores. Finally, we improved our institution’s resource utilization by improving antibiotic stewardship and utilization of inpatient beds. This improvement resulted in an average cost reduction of approximately \$1,122 per patient. Utilization of specified order sets and standardized operative note templates in the electronic medical record helped streamline decision-making and increased consistency and timeliness of care provided.

CPGs for pediatric appendicitis are not novel, and the positive effects of these CPGs on antibiotic stewardship and LOS have been well-documented.^{11–14,16,18,25–30} Nonetheless, many large, nationally recognized hospitals, such as ours, still do not have these guidelines in place. Although other guidelines have published associated improvements in national quality metrics (such as infection rates or LOS) with CPGs, we show that implementing CPGs also adds economic value to hospital productivity. Dissemination of this work is essential to strengthen the evidence that standardizing care pathways for common surgical illnesses can also contribute significant economic value, as it aligns delivery in patterns for best practices.^{1,2} The successes found by our institution

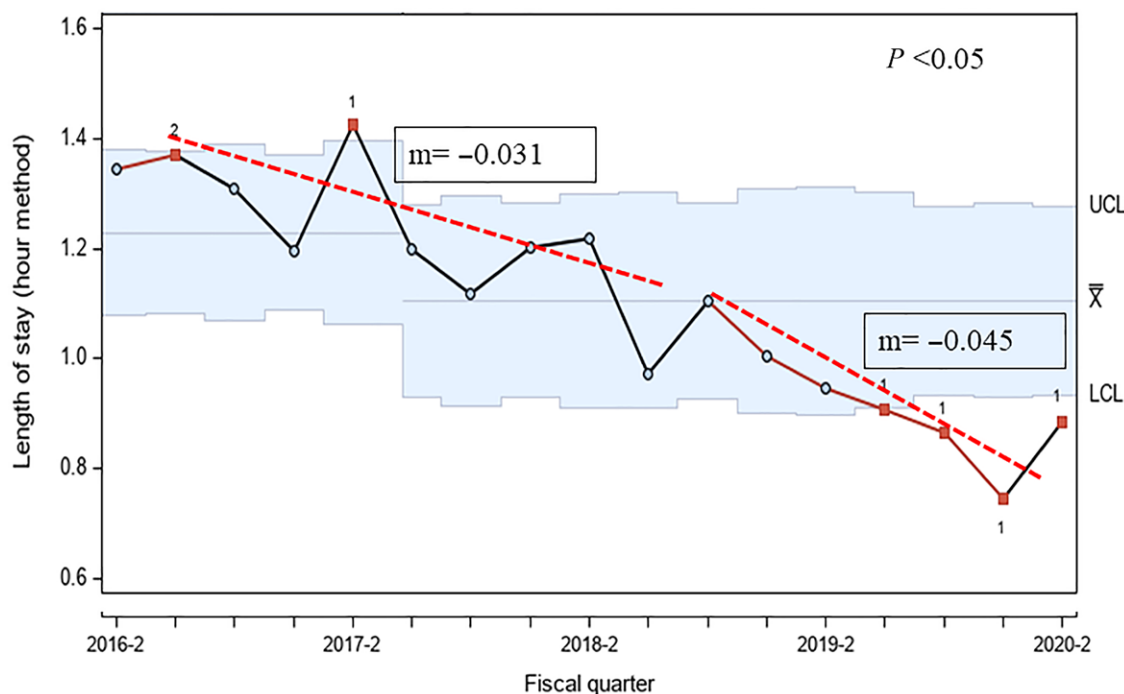


Fig. 3. Interrupted time series analysis for LOS for simple appendicitis, pre- and post-CPG implementation.

may further encourage other institutions to develop and implement CPGs.

Incorporating rigorous QI initiatives in complex healthcare teams can be challenging. One of the main obstacles for this project was the volume of diverse providers (pediatric surgeons, emergency department and anesthesia providers, nursing, and ancillary staff involved with the care of a given patient with appendicitis). The early engagement of these stakeholders to develop the CPG was critical for our buy-in and success. For example, the utilization of our postoperative order set for simple appendicitis was initially low for several months (29.4%) after implementation. Our original simple postoperative order set included a final discharge order, giving nursing staff the ability to independently discharge a patient if a patient met specified discharge criteria. Discussions with pediatric surgery physicians and advanced practice practitioners revealed that low rates of use were due to practitioners’ concerns about the possibility of erroneous hospital discharge. We then revised the discharge order to be conditional, requiring approval from the pediatric surgical fellow or APN before discharge. Subsequently, the utility of the order

set increased significantly to 82.3%, and our mean LOS decreased significantly.

Similarly, designing an operative note that would be usable for 16 independent surgeons while achieving standardization of appendicitis grading and reporting required significant time and multiple cycles of revisions. Incorporating order sets into the electronic medical record can be time-intensive and lead to perceived delays in implementing change after decisions have been made regarding decision points along the standardized care path. Such was the case for our complicated CPG order set. Ultimately, the fundamental mechanisms facilitating our implementation and revisions of the CPG and its components included harnessing division meetings to disperse and collect information and having influential stakeholders to champion the intervention across disciplines.

This study does have several limitations. Our single-center QI intervention was tailored for local context and may not be generalizable to other settings. Nonetheless, the major drivers and decision points mirror those found in numerous other published appendicitis CPGs.^{11–13,15,18,25–27,29} Second, the initial successes in decreasing LOS and compliance with order set or operative note use will need

Table 1. Infection Rates Preimplementation and Postimplementation (March 2019–March 2020), NSQIP-P Sampled Data

		Pre-CPG Rate (%)	Post-CPG Rate (%)	P
Simple* ±	SSI/DSI	2	1.4	0.16
	Organ space infection	4	0	
Complicated†	SSI/DSI	4.9	0	0.51
	Organ space infection	12	16.7	

*Postevaluation for simple CPG occurred over March 2019–March 2020.

†Post- Evaluation for Complicated CPG occurred over July 2019–March 2020.

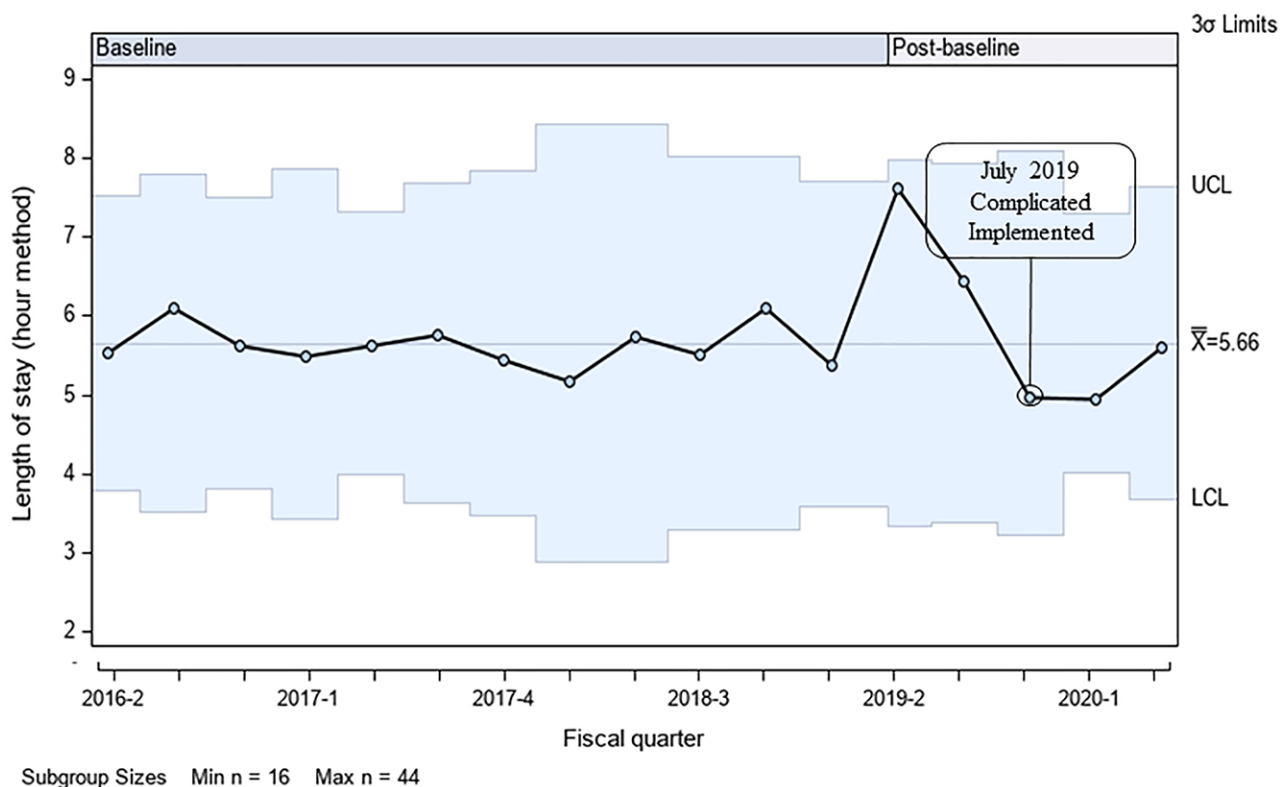


Fig. 4. LOS for complicated appendicitis, by fiscal quarter.

Table 2. EADC for Appendicitis (Simple and Complicated), Preimplementation and Postimplementation of Clinical Practice Guideline for Pediatric Appendicitis

	Bed Type*	Case Volume	Days Treated	Average Costs per Patient, LOS, and Bed Type	Total Average Direct Cost per Patient†
Preimplementation	Inpatient	75 (38%)	459	\$2,117	\$11,251
	Observation	77 (39%)	54.8	\$389	\$5,969
	Extended recovery	46 (23%)	24	\$1,590	\$6,524
	Total	198	580	—	\$8,099
Postimplementation	Inpatient	110 (32%)	524	\$1,630	\$9,649
	Observation	168 (49%)	103.7	\$343	\$5,761
	Extended recovery	68 (20%)	23.8	\$1,063	\$5,658
	Total	346	280	—	\$6,977

++ Preimplementation: September 2018–March 2019; postimplementation: April 2019–January 2020.

*Inpatient: LOS across 2 or more midnights on surgical floor; observation: LOS < 2 midnights on surgical floor; extended stay: LOS ≤ 4 hours after surgery in post anesthesia care unit extension.

†Average direct costs per patient are calculated by type of hospitalization (inpatient, observation, and extended recovery) and reflect the average costs for total care of all patients included for the hospitalization type over the total days treated.

further assessment to ensure sustainability. Our team is continuously implementing PDSA cycles to monitor progress and refine the CPGs (eg., in our most recent PDSA cycle, category 2A patients are now being considered for SDD). Third, assessing changes in value attributable to QI projects can be challenging. Our study demonstrated how LOS and resource utilization for appendicitis (ie, bed type, standardization of antibiotics, and standardization of analgesia postoperatively) affected the costs of care provided for pediatric appendicitis. However, we know that estimations of costs of care are complex, potentially reflecting the interplay of more factors that may be mentioned in this study. Other institutions have

suggested employing time-based accounting methods to detail the attributability of specific QI changes to associated changes in costs.³¹ Though this was not the approach of our study, the overall trends of cost-savings provided in this article still suggest that improved resource utilization, as performed in this study, can have positive effects on overall cost-savings for an institution.

CONCLUSIONS

In conclusion, implementing a CPG for a commonly treated pediatric surgical condition adds value to patient care. Furthermore, the use of QI methods, including PDSA

cycles, created a system of improvement that will facilitate future adaptations to this and future CPGs developed by our institution.

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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