Effect of a Clinical Practice Guideline for Pediatric Complicated Appendicitis

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IMPORTANCE Complicated appendicitis is a common condition in children that causes substantial morbidity. Significant variation in practice exists within and between centers. We observed highly variable practices within our hospital and hypothesized that a clinical practice guideline (CPG) would standardize care and be associated with improved patient outcomes.

OBJECTIVE To determine whether a CPG for complicated appendicitis could be associated with improved clinical outcomes.

DESIGN, SETTING, AND PARTICIPANTS A comprehensive CPG was developed for all children with complicated appendicitis at Monroe Carell Jr Children's Hospital at Vanderbilt, a freestanding children's hospital in Nashville, Tennessee, and was implemented in July 2013. All patients with complicated appendicitis who were treated with early appendectomy during the study period were included in the study. Patients were divided into 2 cohorts, based on whether they were treated before or after CPG implementation. Clinical characteristics and outcomes were recorded for 30 months prior to and 16 months following CPG implementation.

EXPOSURE Clinical practice guideline developed for all children with complicated appendicitis at Monroe Carell Jr Children's Hospital at Vanderbilt.

MAIN OUTCOMES AND MEASURES The primary outcome measure was the occurrence of any adverse event such as readmission or surgical site infection. In addition, resource use, practice variation, and CPG adherence were assessed.

RESULTS Of the 313 patients included in the study, 183 were boys (58.5%) and 234 were white (74.8%). Complete CPG adherence occurred in 78.7% of cases (n = 96). The pre-CPG group included 191 patients with a mean (SD) age of 8.8 (4.0) years, and the post-CPG group included 122 patients with a mean (SD) age of 8.7 (4.1) years. Compared with the pre-CPG group, patients in the post-CPG group were less likely to receive a peripherally inserted central catheter (2.5%, n = 3 vs 30.4%, n = 58; P < .001) or require a postoperative computed tomographic scan (13.1%, n = 16 vs 29.3%, n = 56; P = .001), and length of hospital stay was significantly reduced (4.6 days post-CPG vs 5.1 days pre-CPG, P < .05). Patients in the post-CPG group were less likely to have a surgical site infection (relative risk [RR], 0.41; 95% CI, 0.27-0.74) or require a second operation (RR, 0.35; 95% CI, 0.12-1.00). In the pre-CPG group, 30.9% of patients (n = 59) experienced any adverse event, while 22.1% of post-CPG patients (n = 27) experienced any adverse event (RR, 0.72; 95% CI, 0.48-1.06).

CONCLUSIONS AND RELEVANCE Significant practice variation exists among surgeons in the management of pediatric complicated appendicitis. In our institution, a CPG that standardized practice patterns was associated with reduced resource use and improved patient outcomes. Most surgeons had very high compliance with the CPG.
Appendicitis is a common surgical condition, with a cumulative lifetime incidence of 9%.1 Children experience the greatest risk of disease, and incidence among children is 4 times greater than the overall population. Appendicitis is often categorized as uncomplicated or complicated, with the latter referring to a gangrenous or perforated appendix and characterized by greater morbidity.2 Children, particularly those younger than 15 years, are at very high risk of perforated appendicitis compared with young adults.1 The Healthcare Cost and Utilization Project3 estimates that appendicitis with peritonitis accounted for 25,410 pediatric hospital admissions in 2012, with a mean length of stay of 5.2 days and mean costs of $13,076. Appendicitis is a common and costly condition,4 but the care of children with appendicitis is highly variable.5 Complicated appendicitis is associated with substantial postoperative morbidity. Nationwide, the readmission rate following appendectomy for complicated appendicitis is estimated at 12.8%.6 Clinical trials have consistently found a postoperative intra-abdominal abscess rate of approximately 20% in cases of perforated appendicitis.2,8 Other adverse events, such as superficial surgical site infections (SSIs) and small-bowel obstruction, occur less frequently. These adverse events result in substantially increased costs,6,9 additional exposure to ionizing radiation, additional operative interventions, prolonged antibiotic exposure, and delay in return to premorbid function.

The appropriate management of children with complicated appendicitis has been the subject of substantial research, focusing on aspects including diagnosis, timing of surgery, surgical approach, preoperative and postoperative antibiotic management, and discharge criteria. Still, many questions remain about optimal management in all phases.10-12 A 2004 survey of pediatric surgeons revealed considerable variation in the management of appendicitis.12

Medical conditions that are common, costly, and characterized by substantial variation in care are ideal targets for quality improvement via standardization of care.4 Pediatric appendicitis has been the subject of effective quality-improvement initiatives that have reduced the use of computed tomographic (CT) scans for diagnosis13 and standardized the overall care of complicated appendicitis.14 In the Monroe Carell Jr Children’s Hospital at Vanderbilt, we identified significant variability in the management of complicated appendicitis along with high rates of intra-abdominal abscess formation and readmission. Therefore, we designed a clinical practice guideline (CPG) with the goal of standardizing the operative and postoperative management of complicated appendicitis (Figure). The CPG was developed with multidisciplinary input from all services involved in these patients’ care as recommended by the Institute of Medicine.15 We hypothesized that CPG implementation would result in reduced health care use and fewer overall adverse events.

Methods

CPG Development

Monroe Carell Jr Children’s Hospital at Vanderbilt is a 271-bed, freestanding, tertiary referral center in Nashville, Tennessee. Prior to guideline development, an internal review of the management and outcomes of complicated appendicitis revealed substantial practice variation and high rates of postoperative intra-abdominal abscess and readmission. Therefore, a CPG was proposed with the goals of standardizing practice and improving outcomes. The CPG was developed with input from pediatric surgeons and pediatric surgery nurse practitioners, residents, and clinic nurses. The development team also consulted with specialists from radiology; infectious diseases; emergency medicine; and gastroenterology, hepatology, and nutrition. The final CPG was implemented on July 1, 2013.

The CPG applies to all patients with complicated appendicitis, defined as the operative finding of a gangrenous or perforated appendix. The CPG encourages early rather than interval appendectomy (Figure).16,17 For patients in whom an abscess is discovered at operation, placement of a closed-suction drain is encouraged. All patients are administered piperacillin-tazobactam before and after the operation,18 with transition to a 7-day course of oral ciprofloxacin and metronidazole when tolerating a diet. A white blood cell (WBC) count is not checked to determine the duration of antibiotic therapy or hospitalization. A follow-up clinic visit is scheduled within 2 weeks. For patients with ongoing fever, diarrhea, or intolerance of oral intake, along with physical examination findings suspicious for intra-abdominal abscess, a CT scan is obtained on the seventh postoperative day. If an abscess is discovered, the patient may undergo operative or percutaneous drainage or ongoing medical management as clinically indicated at the discretion of the treating surgeon.

To allow individual surgeons to assess their performance, all pediatric surgeons received monthly reports detailing overall and individual CPG adherence. Small incentives in the form of gift cards were awarded to the monthly top performer.

Patients and Data Collection

From July 1, 2013, the date of CPG implementation, until November 1, 2014, all patients treated for complicated appendicitis in Monroe Carell Jr Children’s Hospital at Vanderbilt were prospectively added to a study-specific REDCap database.19 To
determine baseline patient outcomes, resource use, and practice variation, a cohort of patients treated for complicated appendicitis in the 30 months prior to CPG implementation (January 1, 2011, to June 30, 2013) was created. All records in that time frame were reviewed, and demographic and clinical data were extracted into the database. Only patients who were treated by early appendectomy (occurring during the index admission for appendicitis) were included in this analysis. Because of the subjective nature of the diagnosis of gangrenous appendicitis, these patients were also excluded from the primary analysis (n = 34), leaving only patients with a grossly perforated appendix or gross peritoneal contamination. Because the CPG did apply to patients with gangrenous appendicitis, a secondary analysis was conducted that included these patients. The study was approved by the institutional review board of the Vanderbilt University School of Medicine. The institutional review board determined it to be a quality improvement project with no consent required.

Outcome Measures

The primary outcome measure was the occurrence of any adverse event within 30 days of appendectomy. Adverse events assessed included SSIs, classified as superficial incisional, deep incisional, or organ/space infection;5 emergency department visits; hospital readmissions; additional operative procedure; any interventional radiology procedure; and adverse effects of antibiotics requiring discontinuation and/or medical treatment. Health care use measures included length of stay, proportion of patients undergoing interval appendectomy, proportion undergoing open appendectomy, proportion receiving a postoperative CT scan, proportion receiving a peripherally inserted central catheter (PICC), proportion having a WBC count checked to determine duration of antibiotic administration, and proportion receiving parenteral nutrition. The CPG strongly discouraged use of PICC unless indicated for parenteral nutrition. Initial diagnostic evaluation was not addressed by the CPG, but the proportion of patients receiving a preoperative CT scan was gathered to assess baseline trends in CT use.

To assess CPG adherence, we calculated the adherence rate for each individual surgeon and tabulated the most common reasons for nonadherence. To be considered CPG-adherent, an individual patient had to meet the following criteria: (1) received only appropriate inpatient antibiotics (piperacillin-
tazobactam or ciprofloxacin plus metronidazole if allergic to penicillin); (2) did not have a WBC count checked to determine duration of antibiotics or readiness for discharge; (3) prescribed ciprofloxacin plus metronidazole for 7 days at discharge; and (4) attended a follow-up surgery clinic appointment within 30 days of discharge. Responsibility for nonadherence was assigned to the medical team or family. For example, if no follow-up appointment was scheduled, then responsibility for nonadherence was assigned to the surgical team. If a patient failed to attend a scheduled follow-up appointment, responsibility was assigned to the family. To determine the effect of the CPG on practice variation, between-surgeon use of PICCs, parenteral nutrition, and WBC count to determine discharge eligibility was tabulated.

Data Analysis
Dichotomous measures were assessed with χ² test and Fisher exact test as appropriate. For dichotomous outcome measures, relative risk (RR) with 95% CI was calculated with the pre-CPG group as the referent. For continuous measures and outcomes, a t test was used when data were normally distributed. When data were not normally distributed, the Wilcoxon rank sum test was used. All tests were 2-tailed, with a P value less than .05 considered statistically significant. Analyses were conducted using Stata/IC 13.1 (StataCorp).

Results
Demographic and Clinical Presenting Characteristics
Of 219 patients assessed for inclusion in the pre-CPG cohort, 19 were excluded because of interval appendectomy and 9 were excluded for nonperforated appendicitis, for a final pre-CPG cohort of 191 patients. One hundred fifty-two patients were assessed for inclusion in the post-CPG cohort, after excluding 5 because of interval appendectomy and 25 because of nonperforated appendicitis, for a final post-CPG group of 122 patients.

Data regarding patients’ demographic and clinical characteristics are presented in Table 1. There were no significant differences in the age (P = .79), sex (P = .88), race (P = .43), or Hispanic ethnicity (P = .99) between patients in the pre-CPG and post-CPG groups. There were no significant differences in preoperative duration of symptoms (P = .16) or WBC count (P = .41) on admission. There was no difference in the proportion of patients diagnosed as having appendicitis more than 48 hours after admission (n = 4).

Preoperative Imaging and Operative Management
Preoperative and operative management are summarized in Table 1. There was no difference in operative approach be-

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pre-CPG (n = 191)</th>
<th>Post-CPG (n = 122)</th>
<th>P Value</th>
</tr>
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<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>8.8 (4.0)</td>
<td>8.7 (4.1)</td>
<td>.79</td>
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<tr>
<td>Male, No. (%)</td>
<td>111 (58.1)</td>
<td>72 (59.0)</td>
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<td>Race, No. (%)</td>
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<td>American Indian or Alaska Native</td>
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<td>3 (1.6)</td>
<td>4 (3.3)</td>
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<td>Black or African American</td>
<td>23 (12.0)</td>
<td>8 (6.6)</td>
<td>.43</td>
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<td>White</td>
<td>141 (73.8)</td>
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<td>23 (12.0)</td>
<td>16 (13.1)</td>
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<td>Ethnicity, No. (%)</td>
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<td>Hispanic</td>
<td>44 (23.0)</td>
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<td>Presenting characteristics, mean (SD)</td>
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<td>Duration of symptoms, h</td>
<td>76.6 (65.1)</td>
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<tr>
<td>White blood cell count, /μL</td>
<td>17.2 (6.4)</td>
<td>17.8 (6.0)</td>
<td>.41</td>
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<tr>
<td>No. of patients</td>
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<td>Preoperative imaging, No. (%)</td>
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<td>CT</td>
<td>128 (67.0)</td>
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<td>Ultrasonography</td>
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<td>Operative management, mean (SD), h</td>
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<td></td>
<td></td>
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<tr>
<td>Time from presentation to OR</td>
<td>10.2 (10.1)</td>
<td>11.3 (7.2)</td>
<td>.26</td>
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<tr>
<td>No. of patients</td>
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<td>Laparoscopic, No. (%)</td>
<td>167 (87.4)</td>
<td>105 (86.1)</td>
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<td>Open</td>
<td>11 (5.8)</td>
<td>8 (6.6)</td>
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<td>Laparoscopic converted to open, No. (%)</td>
<td>13 (6.8)</td>
<td>9 (7.4)</td>
<td>.92</td>
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<td>Abscess identified at operation</td>
<td>79 (41.4)</td>
<td>53 (43.4)</td>
<td>.72</td>
</tr>
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Abbreviations: CPG, clinical practice guideline; CT, computed tomography; OR, operating room.
SI conversion factor: to convert white blood cell count to × 10⁹ per liter, multiply by .001.
*Excluding patients diagnosed as having appendicitis more than 48 hours after admission (n = 4).
Substantial variation in practice was observed before CPG implementation. Prior to CPG implementation, individual surgeons’ use of PICCs ranged from 7% to 48%; after CPG implementation, no operating surgeon ordered placement of more than 1 PICCs (range, 0%-5%). Parenteral nutrition use ranged from 6% to 22% before implementation and from 0% to 5% after implementation. Before the CPG, individual surgeons’ use of the WBC count to determine eligibility for discharge ranged from 7% to 100%; following implementation, the range was 0% to 11%. The intersurgeon distribution of surgical approach was similar between the cohorts: the use of an open approach ranged from 0% to 17% for both cohorts.

Postoperative Resource Use

Inpatient use of hospital services and procedures was lower in the post-CPG group (Table 3). Specifically, in the pre-CPG group, 84 patients (44%) had a WBC count drawn prior to discharge compared with 5 (4.1%, P < .001) in the post-CPG group. Fifty-eight patients (30.4%) in the pre-CPG group and 3 patients (2.5%) in the post-CPG group (< .001) underwent PIcc placement. Twenty-three patients (12.0%) in the pre-CPG group underwent an interventional radiology procedure compared with 3 (2.5%) in the post-CPG group (P = .003). Parenteral nutrition was administered to 22 patients (11.5%) in the pre-CPG group and to 2 patients (1.6%) in the post-CPG group (P = .001). In the pre-CPG group, 56 patients (29.3%) underwent a postoperative CT scan, compared with 16 (13.1%) in the post-CPG group (P = .001).

Patient Outcomes

The proportions of patients experiencing adverse events between the 2 groups are presented in Table 4. In the pre-CPG group, 59 patients (30.9%) experienced any adverse event, while 27 post-CPG patients (22.1%) experienced any adverse event (RR, 0.72; 95% CI, 0.48–1.06). In the pre-CPG group, 27 patients (14.1%) returned to the emergency department within 30 days of appendectomy, while 14 post-CPG patients (11.5%) returned to the emergency department (RR, 0.81; 95% CI, 0.44–1.49). The 30-day readmission rate was 16.2% in the pre-CPG group and 11.5% in the post-CPG group (RR, 0.71; 95% CI, 0.39–1.27). Prior to CPG implementation, 9.4% of patients returned to the operating room, while 3.3% of post-CPG patients required a second surgical procedure (RR, 0.35; 95% CI, 0.12–1.00). There was a significant decrease in the proportion of patients who had an organ-space SSI, from 24.1% in the pre-
CPG group to 9.8% in the post-CPG group (RR, 0.41; 95% CI, 0.23-0.74). Superficial incisional and deep incisional SSIs were uncommon and no different between the groups. Postoperative length of stay was significantly shorter in the post-CPG cohort (median of 5.1 days vs 4.6 days, *P* < .05). For patients with an intra-abdominal abscess at the time of appendectomy, the median postoperative length of stay was 5.8 days in the pre-CPG cohort vs 4.9 days in the post-CPG cohort (*P* < .05).

Results of a secondary analysis of patient outcomes, in which patients with gangrenous appendicitis were included, are displayed in the eTable in the Supplement. There were 9 such patients in the pre-CPG group and 25 such patients in the post-CPG group (4.5% vs 17.0%, *P* < .001). Adverse events occurred in 2 of these patients, both in the post-CPG group.

### Discussion

Implementation of a CPG for complicated appendicitis in our institution was associated with greater standardization of care; decreased postoperative use of CT scans, interventional radiology procedures, and PICCs; shorter inpatient length of stay; and lower rates of postoperative infectious complications. The high adherence rate suggests that the CPG was acceptable to pediatric surgeons, pediatric surgery nurse practitioners, residents, and clinic nurses, likely owing to the collaborative process by which the guideline was developed. Among the 122 patients treated after CPG implementation, there were only 13 deviations attributed to the pediatric surgery service (10.7%). We observed a 14.3% reduction in the absolute risk of an organ-space SSI, translating to a number needed to treat of 7 patients to avoid one such complication. This improvement is reflected in the observed reductions in the length of stay and the risks of requiring an interventional radiology procedure or a second operative procedure.

Since 2010, several research groups have reported successful efforts to reduce CT scan use in the diagnosis of pediatric appendicitis.11,21,22 In our study, the use of preoperative CT scans was significantly lower in the post-CPG group because diagnosis relied increasingly on ultrasonography. Because diagnostic approach was not a target of the CPG, this change is likely associated with a secular trend. More strikingly, patients treated after CPG implementation were 55% less likely to undergo a postoperative CT scan than their predecessors, a reduction of 22 CT scans per 100 patients treated. Postoperative CT scans were not replaced by ultrasonographies as in preoperative patients because the use of postoperative ultrasonographies did not rise. Because the CPG specified triggers for a postoperative CT scan, the decline in CT use is believed to be caused by improvements in patient outcomes. Furthermore, the decrease in CT use was not accompanied by an increase in length of stay or readmissions, suggesting that this approach did not result in missed diagnoses of postoperative SSIs.

Similar benefit was seen with the reduction in PICC placements. Rice-Townsend et al23 found that PICC use by hospital ranged from 1.7% to 81.8% for patients with complicated appendicitis, with a weighted average of 18.9%. Use of PICCs fell from 30.4% to 2.5% in our cohort, a 92% reduction. While there were no major complications related to PICCs in either group, a 2012 study24 found that 31% of children who have a PICC placed experience a medically attended complication. The CPG recommends against PICC use except in unusually complicated cases such as when parenteral nutrition was required. In the pre-CPG cohort, PICCs were placed frequently and with highly variable frequency among attending surgeons. Following CPG implementation, PICCs were rarely placed. Similarly, there was a broad range of practice prior to CPG implementation with regard to obtaining a WBC count to determine duration of antibiotic therapy and/or eligibility for discharge. In the post-CPG cohort, the WBC count was rarely checked by any of the attending surgeons.

Our study had several limitations. There was a significantly greater proportion of patients with gangrenous appendicitis in the post-CPG era than the pre-CPG era. The reason for this is unclear. Gangrenous appendicitis is a subjective diagnosis, and surgeons’ propensity to assign this diagnosis may have been affected by the presence of the CPG. The diagnosis of perforated appendicitis required gross perforation and/or gross contamination of the peritoneal cavity with bowel contents; this diagnosis is far less subjective. To eliminate this difference in patient groups before and after the CPG implementation, gangrenous appendicitis cases were excluded from the primary analysis. Consequently, the patient cohorts prior to and after CPG implementation were very similar (ie, all had perforated appendicitis and were similar in other regards). There was little difference between our primary results and the results of a secondary analysis in which patients with gangrenous appendicitis were included. Any assessment of a guide-
line implementation is biased by time: we do not know how management and outcomes might have changed over time without intervention. Establishing a contemporaneous control group with such a study design was not feasible because all clinicians were necessarily aware of the CPG. Additionally, the failure to find a statistically significant difference on several important outcome measures was likely a consequence of inadequate power. Finally, because several interventions were incorporated simultaneously, it is difficult to determine which changes had the greatest benefit.

Despite these limitations, our results suggest that a concerted effort to standardize the care of children with complicated appendicitis may substantially improve patient outcomes. Our guideline was designed not to replace the surgeon’s judgment with respect to any individual case. For a heterogeneous condition with many open questions about optimal management, flexibility within a guideline is likely to increase its acceptability.

Conclusions

Complicated appendicitis is an important target for quality improvement. In the absence of national management guidelines, individual institutions may develop their own guidelines based on the best available evidence, taking into account their particular surgeons’ experience, case mix, trainee involvement, and imaging capability. A careful assessment for local practice variation and undesirable outcomes will identify points of emphasis for institutional guidelines.

REFERENCES