

**Utility of a Benchmarking Report for Balancing Infection Prevention and Antimicrobial Stewardship in Children with Complicated Appendicitis**

1. Shannon L Cramm, MD, MPH (Department of Surgery, Boston Children's Hospital, Harvard Medical School, Boston, MA)
2. Dionne A Graham, PhD (Program for Patient Safety and Quality, Boston Children's Hospital, Boston, MA)
3. Martin L Blakely, MD, MS (Division of Pediatric Surgery, Vanderbilt University Medical Center, Nashville, TN)
4. Robert A Cowles, MD (Department of Pediatric Surgery, Yale New Haven Children's Hospital, Yale School of Medicine, New Haven, CT)
5. Shaun M Kunisaki, MD, MSc (Department of Surgery, Johns Hopkins Children's Center, Johns Hopkins School of Medicine, Baltimore, MD)
6. Aaron M Lipskar, MD (Division of Pediatric Surgery, Cohen Children's Medical Center, Zucker School of Medicine at Hofstra/Northwell, New Hyde Park, NY)
7. Robert T Russell, MD, MPH (Division of Pediatric Surgery, Children's of Alabama, Department of Surgery, University of Alabama at Birmingham, Birmingham, AL)
8. Matthew T Santore, MD (Department of Surgery, Children's Healthcare of Atlanta, Emory University, Atlanta, GA)
9. Jennifer R DeFazio, MD (Division of Pediatric Surgery, New York Presbyterian Morgan Stanley Children's Hospital, Columbia University Vagelos College of Physicians and Surgeons, New York, NY)
10. Cornelia L Griggs, MD (Department of Surgery, Division of Pediatric Surgery, Massachusetts General Hospital, Boston, MA)
11. Danielle I Aronowitz, MD (Division of Pediatric, General, Thoracic, and Fetal Surgery, Children's Hospital of Philadelphia, Philadelphia, PA)
12. Myron Allukian, MD (Division of Pediatric, General, Thoracic, and Fetal Surgery, Children's Hospital of Philadelphia, Philadelphia, PA)
13. Brendan T Campbell, MD, MPH (Department of Surgery, Connecticut Children's Hospital, Hartford, CT)

14. Nicole M Chandler, MD (Division of Pediatric Surgery, Johns Hopkin's All Children's Hospital, St. Petersburg, FL)
15. Devon T Collins, MPH, CPH, CES (Department of Surgery, Children's National Hospital, Washington, D.C.)
16. Sarah J Commander, MD, MHS (Department of Surgery, Duke Children's Hospital and Health Center, Durham, NC)
17. Katerina Dukleska, MD (Department of Surgery, Connecticut Children's Hospital, Hartford, CT)
18. Justice C Echols, MD (Division of Pediatric Surgery, University of North Carolina Health System, University of North Carolina School of Medicine, Chapel Hill, NC)
19. Joseph R Esparaz, MD, MPH (Division of Pediatric Surgery, Children's of Alabama, Department of Surgery, University of Alabama at Birmingham, Birmingham, AL)
20. Christina Feng, MD (Department of Surgery, Children's National Hospital, Washington, D.C.)
21. Claire Gerall, MD (Department of Surgery, UT Health San Antonio, San Antonio, TX)
22. David N Hanna, MD (Division of Pediatric Surgery, Vanderbilt University Medical Center, Nashville, TN)
23. Olivia A Keane, MD (Department of Surgery, Children's Healthcare of Atlanta, Emory University, Atlanta, GA)
24. Sean E McLean, MD (Division of Pediatric Surgery, University of North Carolina Health System, University of North Carolina School of Medicine, Chapel Hill, NC)
25. Elizabeth Pace, MD (Department of Surgery, University of Pittsburgh School of Medicine, Pittsburgh, PA)
26. Stefan Scholz, MD, PhD (Department of Surgery, University of Pittsburgh School of Medicine, Pittsburgh, PA)
27. Shelby R Sferra, MD, MPH (Department of Surgery, Johns Hopkins Children's Center, Johns Hopkins School of Medicine, Baltimore, MD)
28. Elisabeth T Tracy, MD (Department of Surgery, Duke Children's Hospital and Health Center, Duke University School of Medicine, Durham, NC)
29. Sacha Williams, MD, MPH, MS (Division of Pediatric Surgery, Johns Hopkins All Children's Hospital, St. Petersburg, FL)
30. Lucy Zhang, MD (Department of Pediatric Surgery, Yale New Haven Children's Hospital, Yale School of Medicine, New Haven, CT)
31. Katherine He, MD, MS (Department of Surgery, Boston Children's Hospital, Harvard Medical School, Boston, MA)
32. Shawn J Rangel, MD, MSCE (Department of Surgery, Boston Children's Hospital, Harvard Medical School, Boston, MA)

On behalf of the Eastern Pediatric Surgery Network

**Corresponding Author:**

Shawn J. Rangel, MD, MSCE  
Department of Surgery  
Boston Children's Hospital  
Harvard Medical School

300 Longwood Avenue, Fegan-3  
Boston, MA 02115

Tel: 617-355-3040

Fax: 617-730-0298

Email: shawn.rangel@childrens.harvard.edu

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## **Running Head: BENCHMARKING REPORT FOR APPENDICITIS**

### **Abstract**

**Objective:** To develop a severity-adjusted, hospital-level benchmarking comparative performance report for postoperative organ space infection and antibiotic utilization in children with complicated appendicitis.

**Background:** No benchmarking data exist to aid hospitals in identifying and prioritizing opportunities for infection prevention or antimicrobial stewardship in children with complicated appendicitis.

**Methods:** This was a multicenter cohort study using NSQIP-Pediatric data from 16 hospitals participating in a regional research consortium, augmented with antibiotic utilization data obtained through supplemental chart review. Children with complicated appendicitis who underwent appendectomy from 07/01/2015 to 06/30/2020 were included. Thirty-day postoperative OSI rates and cumulative antibiotic utilization were compared between hospitals using observed-to-expected (O/E) ratios after adjusting for disease severity using mixed effects models. Hospitals were considered outliers if the 95% confidence interval for O/E ratios did not include 1.0.

**Results:** 1790 patients were included. Overall, the OSI rate was 15.6% (hospital range: 2.6-39.4%) and median cumulative antibiotic utilization was 9.0 days (range: 3.0-13.0). Across hospitals, adjusted O/E ratios ranged 5.7-fold for OSI (0.49-2.80,  $P=0.03$ ) and 2.4-fold for antibiotic utilization (0.59-1.45,  $P<0.01$ ). Three (19%) hospitals were outliers for OSI (1 high and 2 low performers), and eight (50%) were outliers for antibiotic utilization (5 high and 3 low utilizers). Ten (63%) hospitals were identified as outliers in one or both measures.

**Conclusions:** A comparative performance benchmarking report may help hospitals identify and prioritize quality improvement opportunities for infection prevention and antimicrobial stewardship, as well as identify exemplar performers for dissemination of best practices.

## Introduction

Appendicitis is the most common abdominal surgical emergency in childhood and accounts for the greatest relative burden of organ space infections (OSI) among all pediatric surgical conditions.<sup>1-4</sup> Management of appendicitis is also associated with the third highest number of cumulative antibiotic treatment days in hospitalized children, behind only cystic fibrosis and pneumonia.<sup>5,6</sup> When considering the morbidity associated with OSI and increase in antibiotic resistance over the past decade, the need to optimize OSI prevention while limiting antibiotic overuse should be considered a high priority goal in pediatric surgery.<sup>7-9</sup>

To date, no evidence-based consensus guidelines exist for the ideal length of postoperative antibiotic treatment for OSI prevention in children with complicated appendicitis. Existing evidence is limited by conflicting data, inadequate adjustment for disease severity, and use of heterogeneous definitions and administrative data sources.<sup>4, 10-15</sup> Paucity of robust comparative effectiveness data has likely led to practice variation in antibiotic use for complicated appendicitis observed across hospitals.<sup>10, 16</sup> This variation has resulted in different strategies in antibiotic utilization for both empiric treatment of complicated appendicitis and in the management of postoperative OSI, which in turn may influence both the incidence of organ space infections and cumulative antibiotic utilization among hospitals. We hypothesized that variation in risk-adjusted OSI rates and antibiotic utilization could potentially be leveraged together as balancing measures to identify hospital-level process improvement opportunities, as well as exemplar hospitals with best practices that could be disseminated through collaborative networks.

With these considerations, the goal of this proof-of-concept analysis was to examine the potential utility of a benchmarking comparative performance report for OSI and antibiotic utilization in children with complicated appendicitis, particularly the ability to identify performance outliers. More specifically, we aimed to evaluate utility of such a report by examining the distribution of risk-adjusted postoperative OSI rates and cumulative antibiotic utilization as balancing measures, and by exploring whether use of these measures could discriminate performance outliers in order to identify opportunities for potential quality improvement efforts within a cohort of 16 hospitals participating in a regional research consortium.

## Methods

### *Study Design and Data Source*

This was a multicenter study including 16 hospitals participating in the Eastern Pediatric Surgery Network (EPSN) regional research consortium. Data from the American College of Surgeon's National Surgical Quality Improvement Program-Pediatric (NSQIP-Pediatric) were obtained and augmented with supplemental chart review at each participating center. The NSQIP-Pediatric database includes appendicitis-specific clinical data used to compare risk adjusted adverse event and resource utilization data among its 160 member hospitals.<sup>17</sup> NSQIP-Pediatric data are collected by dedicated surgical clinical reviewers using standardized definitions and chart review methods. Accuracy of these data are ensured by periodic auditing, mandatory recertification of

reviewers, and the availability of American College of Surgeons clinical support to address questions regarding data abstraction protocols.<sup>17, 18</sup>

All study sites performed supplemental chart review to collect antibiotic utilization and operative report data for patients identified in the NSQIP-Pediatric database. One of the study sites did not participate in NSQIP-Pediatric, and an alternative chart abstraction process was undertaken to replicate the NSQIP-Pediatric data collection process. A manual of operations with standardized definitions and training videos were developed and reviewed by each site prior to data collection. Data audits for each site were conducted by the data coordinating center after collection of the first 10 cases to ensure accuracy and address any data collection questions. Study data were uploaded directly to the data coordinating center using a secure transfer process. The American College of Surgeons was not involved in the management or transfer of any study data. This study was reviewed by the institutional review board of the data coordinating center, Boston Children's Hospital, and deemed exempt status (IRB-P00043683).

### *Study Cohort*

Children (ages 3-17 years) who underwent appendectomy from July 1, 2015 to June 30, 2020 at the 16 participating consortium hospitals as identified by NSQIP-Pediatric data were considered for inclusion. Patients were included if they had complicated appendicitis as defined by NSQIP-Pediatric based on the presence of at least one of four previously validated intraoperative criteria described in the operative report, including a visible hole, abscess, extraluminal fecalith, and diffuse fibrinopurulent exudate outside the right lower quadrant or pelvis (DFE).<sup>19, 20</sup>

### *Classification of Outcomes*

Outcomes included 30-day postoperative OSI rate (including both NSQIP-Pediatric defined organ space infection and/or need for postoperative drainage) and cumulative 30-day postoperative antibiotic utilization in treatment days. Cumulative 30-day postoperative antibiotic utilization was calculated as the sum of all postoperative antibiotic treatment days during the index admission, additional antibiotic days prescribed at time of discharge to be completed at home, and any additional days of antibiotic therapy prescribed following discharge for suspected or recurrent surgical site infection (including during a hospital readmission). Cumulative 30-day postoperative antibiotic utilization was used to capture each hospital's comprehensive approach to antibiotic management in children with complicated disease, including both empiric postoperative treatment as well as any extension of treatment based on subsequent OSI diagnosis.<sup>4, 10, 13, 15</sup>

### *Statistical Analyses*

Chi square and Wilcoxon rank sum tests were used for univariate comparisons. Generalized linear mixed effects models were used to estimate hospital-level observed-to-expected ratios (O/E) for each outcome, adjusting for hospitals' individual patient characteristics and appendicitis severity case-mix. Model covariates were selected a priori. Patient demographics included in the model were age at time of operation, sex, race, and insurance status (public, private, other, unknown). Appendicitis severity was adjusted for based on the presence of one

versus multiple findings of complicated disease and for the presence of individual intraoperative criteria (visible hole, extraluminal fecalith, abscess, DFE). The severity covariates have been previously validated and are independently associated with infectious complications and resource utilization.<sup>19, 20</sup> A logistic link was used for binary outcomes and a gamma link was used for continuous outcomes. Hospital-level observed to expected (O/E) ratios for each measure were estimated by exponentiating the shrinkage estimate of each hospital's random effect.<sup>21</sup> Models with hospital-level random effects were compared to models without random effects to estimate degree of hospital-level variation in outcomes. A Spearman correlation test was used to test whether a correlation existed between hospital-level O/E ratios for OSI rates and cumulative antibiotic utilization.

As a hospital's antibiotic management and outcomes may vary with appendicitis severity, a secondary analysis was performed limiting the cohort to children with high severity disease, defined as those with multiple NSQIP-Pediatric intraoperative criteria of complicated disease (visible hole, extraluminal fecalith, abscess, DFE).<sup>20</sup> The presence of multiple findings of complicated disease has been associated with higher rates of postoperative OSI, readmission, percutaneous drainage procedures, and greater resource utilization.<sup>19, 20</sup>

Analyses were performed with SAS statistical software (version 9.4; SAS Institute, Inc). Statistical significance threshold was considered with a two-sided  $P < 0.05$ .

#### *Defining Hospital-Level Performance Outliers*

Hospitals were considered statistical outliers if the 95% confidence interval of their adjusted O/E ratio did not include 1.0 for a given measure. Hospitals were considered exemplary if they had lower-than-expected O/E ratios ( $< 1.0$ ) for both measures or a lower-than-expected O/E ratio for one measure with an as-expected O/E ratio for the other. This definition was used as hospitals identified as exemplars may have developed best practices for minimizing OSI risk, optimizing antibiotic stewardship with reduced cumulative utilization, or both. Hospitals identified as potentially in need of improvement were defined as those with a higher-than-expected O/E ratio ( $> 1.0$ ) for OSI or antibiotic utilization, as these represent hospitals where there could exist opportunities to improve their clinical outcomes or antibiotic stewardship.

## **Results**

#### *Patient Population and Appendicitis Severity*

1790 patients with complicated appendicitis (hospital median: 109 [IQR 74-148]) from 16 hospitals were included in the analysis. The median age was 10 years (IQR 7-14) and 38.5% of patients were female. 906 (50.6%) had one intraoperative finding of complicated disease (hospital range: 28.2% to 73.1%) and 884 (49.4%) had high severity disease (hospital range: 26.9% to 71.8%).

#### *Variation in 30-day Postoperative Organ Space Infection Rates*

The overall OSI rate was 15.6%, which ranged from 2.6% to 39.4% across hospitals. After adjustment, the O/E ratios for OSI rate ranged 5.7-fold from 0.49 to 2.80 ( $P=0.03$ ; Figure 1). Three (19%) hospitals were statistical outliers for OSI, with one hospital having lower and two having higher than expected OSI rates (Figure 1).

In the subgroup of patients with high severity disease, the OSI rate was 19.2%, which ranged from 3.6% to 37.2% across hospitals. After adjustment, the O/E ratios for OSI rate ranged 3.7-fold from 0.52 to 1.91 ( $P=0.07$ , Figure 1). One (6%) hospital was a statistical outlier based on OSI rates (Figure 1).

#### *Variation in 30-day Postoperative Cumulative Antibiotic Utilization*

The median 30-day postoperative cumulative antibiotic utilization for the cohort was 9.0 days (IQR 6.0-13.0), which ranged from 3.0 to 13.0 days across hospitals. O/E ratios for antibiotic utilization ranged 2.4-fold, from 0.59 to 1.45 across hospitals ( $P<0.01$  Figure 2). Eight (50%) hospitals were statistical outliers for antibiotic utilization, with three (19%) hospitals having lower and five (31%) hospitals having higher than expected cumulative antibiotic utilization (Figure 2).

In the subgroup of patients with high severity disease, the median 30-day postoperative cumulative antibiotic treatment utilization was 10.0 days (IQR 6.0-13.0), ranging from 3.5 to 12.0 across hospitals. O/E ratios ranged 2.1-fold, from 0.63 to 1.34 across hospitals ( $P=0.01$ ; Figure 2). Six (38%) hospitals were statistical outliers for antibiotic utilization, with four (25%) having lower and two (13%) having higher than expected antibiotic utilization (Figure 2).

#### *Assessment of Performance Outliers*

In the analysis of all patients with complicated appendicitis, four (25%) hospitals were identified with exemplary performance, one (6%) with a lower-than-expected OSI rate and three (19%) with lower-than-expected cumulative antibiotic utilization (Figure 3). Six (38%) hospitals were identified as potentially needing improvement. These included one (6%) with higher-than-expected OSI rates and antibiotic utilization, one (6%) with higher-than-expected OSI rates, and four (25%) with higher-than-expected antibiotic utilization (Figure 3). There was a moderate positive correlation between hospitals' O/E ratios for OSI rates and antibiotic utilization (Spearman's  $\rho$ : +0.63,  $P=0.01$ ).

In the subgroup analysis of patients with high severity disease, five (31%) hospitals were identified with exemplary performance, one (6%) with a lower-than-expected OSI rate and four (25%) with lower-than-expected cumulative antibiotic utilization (Figure 4). Two (12%) hospitals were identified as needing improvement with higher-than-expected antibiotic utilization (Figure 4). No significant correlation was found between hospitals' O/E ratios for OSI rates and antibiotic utilization in the subgroup of high severity disease (Spearman's  $\rho$ : +0.41,  $P=0.11$ ).

## **Discussion**

In this multicenter analysis of 1790 children from 16 hospitals with complicated appendicitis, marked variation was observed in risk-adjusted rates of postoperative organ space infection and cumulative antibiotic utilization. Observed-to-expected ratios of OSI rates ranged more than 5-fold across hospitals, while observed-to-expected ratios of antibiotic utilization varied more than 2-fold, with performance and utilization outliers identified for both measures following adjustment for differences in appendicitis severity and patient demographics among hospital populations. These data suggest that a risk-adjusted comparative report can meaningfully discriminate hospital performance and antibiotic utilization in children with complicated appendicitis, with more than half of all hospitals identified as outliers in at least one measure.

To our knowledge, this is the first multicenter comparative performance analysis of OSI rates and antibiotic utilization as balancing measures in children or adults with complicated appendicitis. These data add to a growing body of evidence that substantial variation exists in postoperative organ space infections rates and antibiotic utilization in children with complicated appendicitis.<sup>10, 16</sup> Based on the principles of positive deviance, this risk-adjusted analysis aimed to leverage the natural variation in practice and outcomes to identify opportunities for both process improvement and collaborative knowledge sharing among hospitals.<sup>22</sup>

The validity of this multicenter comparative analysis was facilitated through adjustment for patient demographic characteristics and disease severity using previously validated intraoperative criteria.<sup>19, 20</sup> The wide variation in risk-adjusted outcomes observed across hospitals was therefore likely driven by differences in management rather than differences in patient populations being treated. Inter-hospital variation in adjusted OSI rates may be due to differences in perioperative management, including antibiotic type and duration, technical considerations such as method of appendectomy and management of peritoneal contamination, and approach to postoperative OSI surveillance and diagnosis through use of laboratory and imaging tests.<sup>23-27</sup> With respect to surveillance, hospitals with lower thresholds to obtain imaging (e.g., as driven by postoperative clinical pathways using mandatory laboratory or imaging protocols) may disproportionately lead to the diagnosis and treatment of relatively mild or subclinical OSI's that would otherwise not at other hospitals. This could result in relatively higher adjusted OSI rate and antibiotic utilization compared with hospitals with higher thresholds for postoperative diagnostic imaging and may underlie the positive correlation between adjusted OSI O/E ratios and antibiotic utilization characterized in this analysis. Despite this correlation, it is noteworthy that most hospitals identified as outliers for antibiotic utilization (either higher or lower than expected use) had as-expected adjusted rates of OSI's. Drivers of variation in antibiotic utilization may include differences in empiric postoperative management (including use and duration of antibiotics following discharge) and differences in the approach to extending antibiotic treatment for managing postoperative OSI's.<sup>10, 13, 15, 16</sup> These data would suggest opportunities may exist for many hospitals to reduce antibiotic utilization for improved stewardship without risk for increased OSI rates. Optimizing antibiotic utilization by identifying the shortest effective duration of therapy is important to reduce unnecessary antibiotic-related adverse events for patients and minimize the development of resistant organisms.<sup>28-32</sup> Furthermore, the magnitude of variation observed in the risk-adjusted outcomes suggests the opportunities for both OSI reduction and antimicrobial stewardship improvement are substantial if best practices from exemplar hospitals were identified, disseminated, and broadly implemented.



In this analysis, 31% of hospitals were identified as exemplary and 38% as potentially in need of quality improvement based on OSI rates and cumulative antibiotic utilization. Identification of high-performing outliers can provide a collaborative approach to facilitate quality improvement through knowledge sharing and dissemination of best practices.<sup>22</sup> Such an approach could be particularly impactful if focusing on hospitals with both lower than expected OSI rates and antibiotic utilization. Given the number and relatively wide geographic distribution of participating hospitals, the variation observed in the present analysis is likely representative of the variation that exists on a national scale. Identification of best practices developed at exemplary hospitals could likely be widely generalizable and impactful. An example of this approach was recently reported by the Pediatric Surgical Quality Collaborative (PSQC), which successfully leveraged practice variation among its NSQIP-Pediatric member hospitals to characterize and disseminate best practices for reducing CT utilization in children with suspected appendicitis.<sup>33</sup> Data from the present analysis has provided preliminary data for a PSQC collaborative currently in development with the goal of creating a balancing measures report card for its 90-member consortium.<sup>34</sup>

This analysis must be interpreted within the context of its limitations. Although rigorous methods for data abstraction were employed by NSQIP-Pediatric and during supplemental chart review, data collection was retrospective, and therefore potentially subject to errors in misclassification. While this analysis demonstrated performance discrimination across its balancing measures, it was unable to identify the specific practices associated with exemplary outcomes due to lack of granularity in data regarding clinical practices including hospitals' empiric antibiotic choice, use of postoperative imaging, or other aspects in the care of children with complicated appendicitis. Further efforts will need to explore these practices in more detail, such as use of qualitative survey methodology to focus on hospitals with both lower than expected OSI rates and antibiotic utilization. The analysis may have been underpowered to detect all performance outliers, particularly at hospitals with smaller sample sizes. However, the analysis was able to identify outliers on both sides of the performance and antibiotic utilization spectrum, supporting the proof-of-concept that a benchmarking report can provide meaningful discrimination within hospital networks. The risk-adjustment for patient demographic characteristics in this analysis was limited to data available NSQIP-Pediatric (race/ethnicity, sex, age at operation, insurance status). Other baseline characteristics of children presenting with appendicitis may influence outcomes, though prior studies demonstrate that validated adjustment for disease severity, as done in this analysis, is the most important driver of OSI risk.<sup>19,20</sup> While this analysis included geographically diverse hospitals, the participating institutions are largely academic, freestanding children's hospitals, and therefore these results may not be generalizable to other clinical settings.

In conclusion, the results of this analysis suggest report cards based on postoperative organ space infection and cumulative antibiotic utilization have utility in improving care of children with complicated appendicitis through comparative benchmarking and identification of hospitals with exemplary performance. Multi-institutional collaboratives like the EPSN and the PSQC are well poised to act on these data through future qualitative investigation to identify and disseminate best practices in the care of children with complicated appendicitis. The conceptual framework

used in this analysis could also be applied to other surgical conditions where optimizing outcomes and antimicrobial stewardship are important management considerations.

#### Author Contribution Form:

Please see below for a description of each author's individual contributions to this manuscript.

1. Shannon L Cramm, MD, MPH
  - a. Substantial contributions to conception and design, acquisition of data, analysis and interpretation of data
  - b. Participated in drafting the manuscript
  - c. Gave final approval for this version to be published
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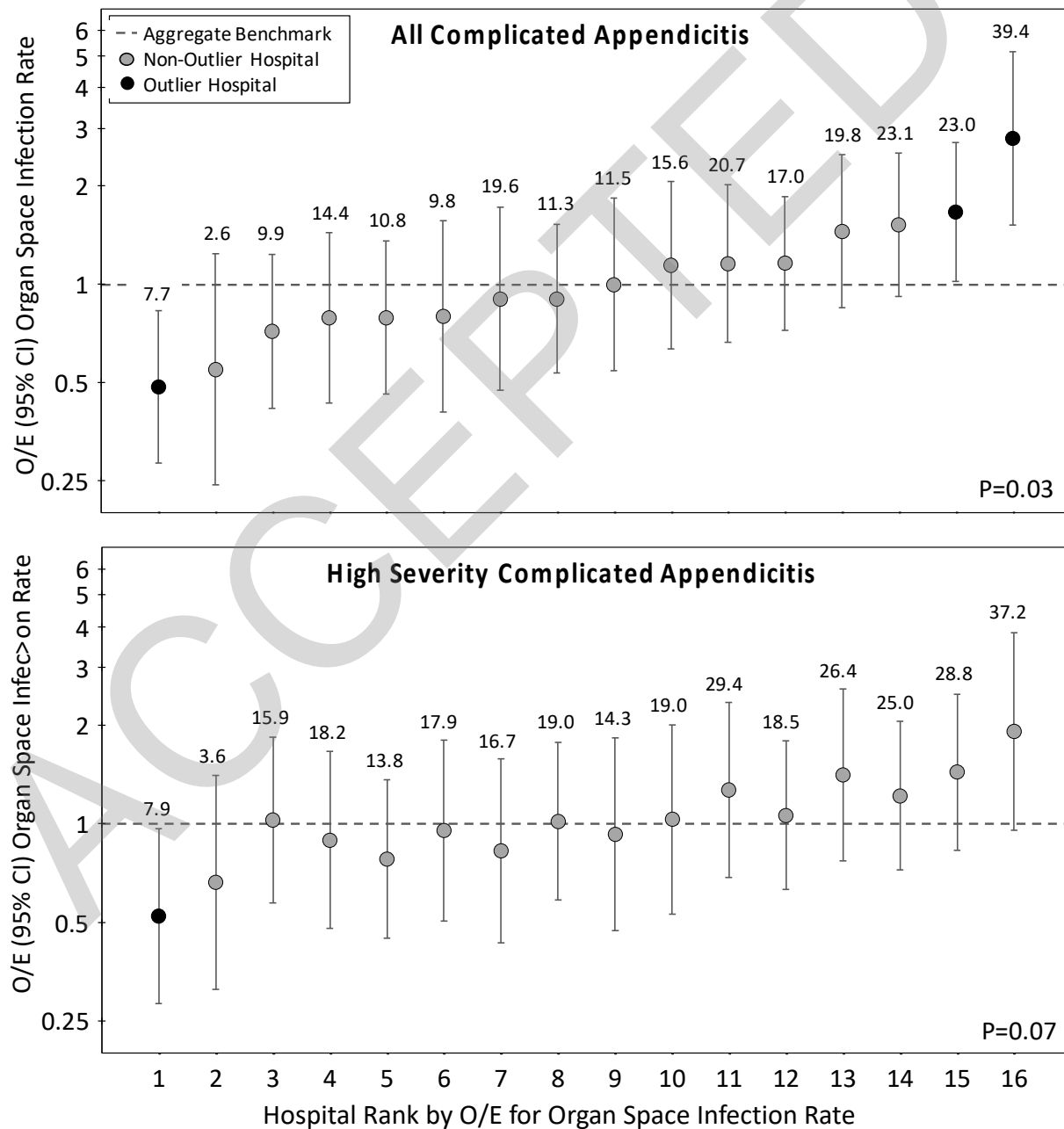
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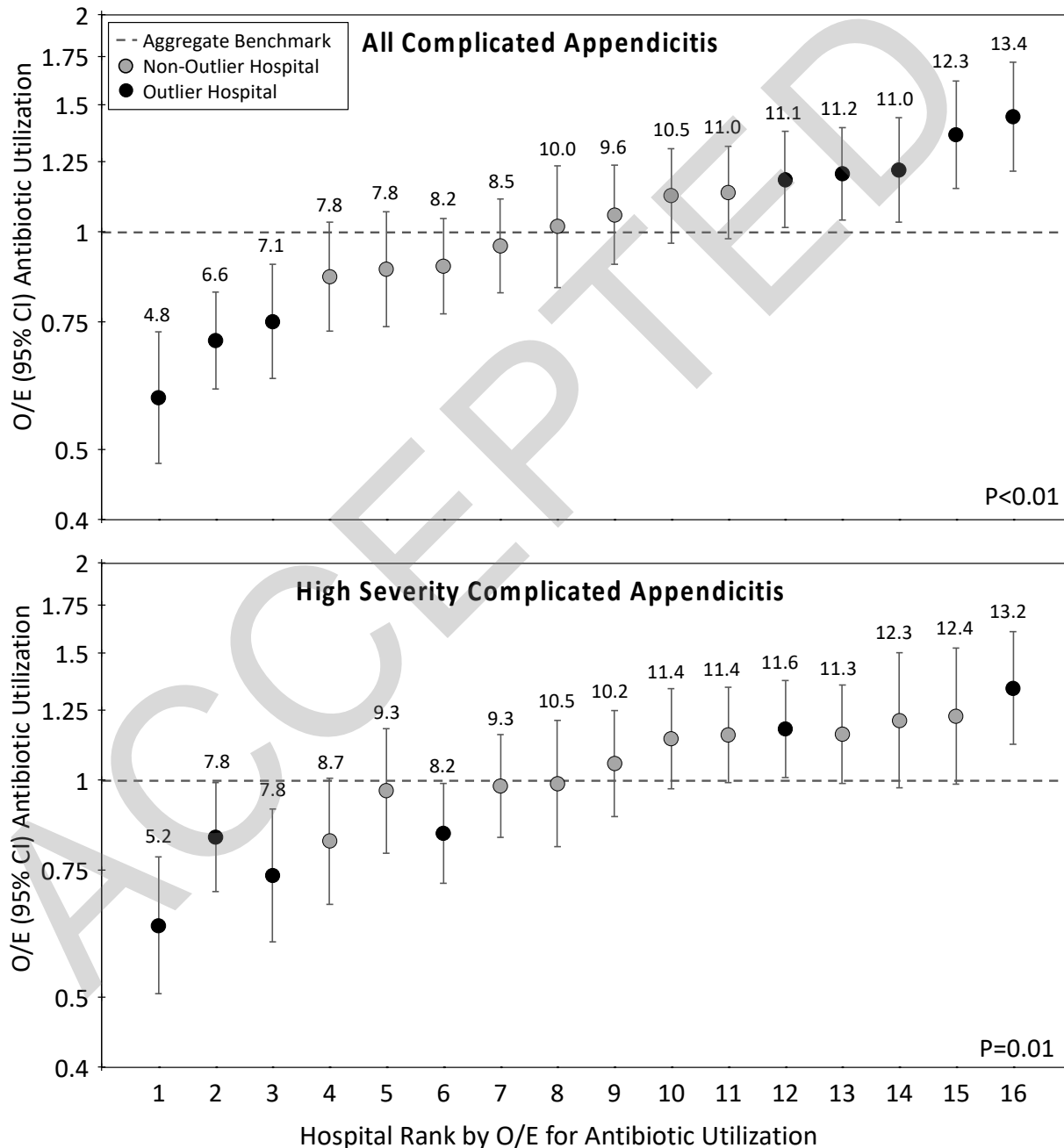
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**Figure 1. Variation in observed-to-expected ratios for 30-day postoperative organ space infection rates in children with complicated appendicitis.** Hospitals are ranked by observed-to-expected (O/E) ratios for their organ space infection rate in all children with complicated disease. Unadjusted rates (%) of OSI are presented above the confidence interval of the O/E ratio for each hospital.

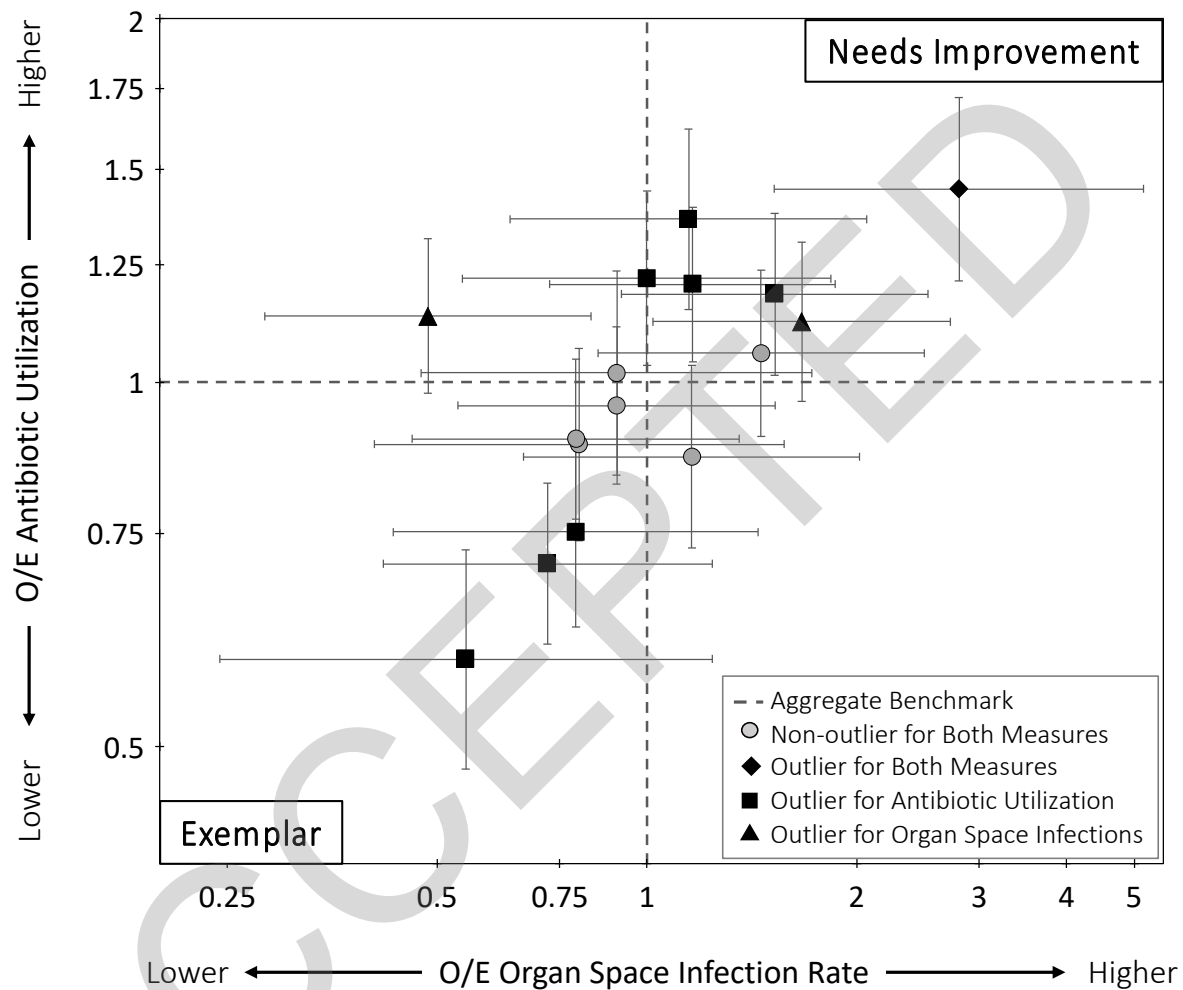




**Figure 2. Variation in observed-to-expected ratios for 30-day postoperative cumulative antibiotic utilization in children with complicated appendicitis.** Hospitals are ranked by observed-to-expected (O/E) ratios for their antibiotic utilization in all children with complicated disease. Unadjusted means for antibiotic utilization in days are presented above the confidence interval of the O/E ratio for each hospital.



**Figure 3. Relationship between 30-day postoperative organ space infection rates and cumulative antibiotic utilization in children with complicated appendicitis at 16 hospitals.** Hospital-level data are presented as observed-to-expected (O/E) ratios with 95% confidence intervals, adjusted for patient characteristics and appendicitis severity.



**Figure 4. Relationship between 30-day postoperative organ space infection rates and cumulative antibiotic utilization in children with high severity complicated appendicitis at 16 hospitals.** Hospital-level data are presented as observed-to-expected (O/E) ratios with 95% confidence intervals, adjusted for patient characteristics and appendicitis severity.

