# Final Progress Report for Research Projects Funded by Health Research Grants

Instructions: Please complete all of the items as instructed. Do not delete instructions. Do not leave any items blank; responses must be provided for all items. If your response to an item is "None", please specify "None" as your response. "Not applicable" is not an acceptable response for any of the items. There is no limit to the length of your response to any question. Responses should be single-spaced, no smaller than 12-point type. The report **must be completed using MS Word**. Submitted reports must be Word documents; they should not be converted to pdf format. Questions? Contact Health Research Program staff at 717-783-2548.

1. **Grantee Institution: The Children's Hospital of Philadelphia**

2. **Reporting Period (start and end date of grant award period): January 1, 2010 to December 31, 2013**

3. **Grant Contact Person (First Name, M.I., Last Name, Degrees): Prema Sundaram, Ph.D.**

4. **Grant Contact Person's Telephone Number: 267-426-9251**

5. **Grant SAP Number: 4100050891**

6. **Project Number and Title of Research Project: Project 1, "Pediatric Hospital Quality, Safety and Cost Project"**

7. **Start and End Date of Research Project: January 1, 2010 to December 31, 2013**

8. **Name of Principal Investigator for the Research Project: Ron Keren MD MPH**

9. **Research Project Expenses**.

   9(A) Please provide the total amount of health research grant funds spent on this project for the entire duration of the grant, including indirect costs and any interest earned that was spent:

   $ 1,674,057.06

   9(B) Provide the last names (include first initial if multiple individuals with the same last name are listed) of **all** persons who worked on this research project and were supported with health research funds. Include position titles (Principal Investigator, Graduate Assistant, Post-doctoral Fellow, etc.), percent of effort on project and total health research funds expended for the position. For multiple year projects, if percent of effort varied from year to year, report in the % of Effort column the effort by year 1, 2, 3, etc. of the project (x% Yr 1; z% Yr 2-3).

| Last Name, First Name | Position Title | % of Effort on Project | Cost |
|---|---|---|---|
| Keren, Ron | Principal Investigator | 20% yr1and 5; 18.86% yr 2; 17.5% yr 3; 22.38% year 4 | $174,259 |
| Bonafide, Christopher | Co-Investigator | 40% yrs 2,4,5; 39.9% yr 3 | $206,867 |
| McLeod, Lisa | Co-Investigator | 40% yr 3 & yr 4 | $82,771 |
| Kenyon, Chen | Co-Investigator | 100% yr 5 | $57,480 |
| Localio, Russell | Biostatistician | 10% yrs 1-3, 11.5% yr 4 | $50,584 |
| Hillman, Debra | Project Manager | 10% yrs 1-5 | $41,750 |
| Roberts, Kathryn | Nurse Co-Investigator | 5% yr 2 | $4,520 |
| Czaplicki, Donna | Nurse Research Coordinator | 56.44% yr 3 | $8,921 |
| Graham, Christian | Research Assistant | 100% yr 4 | $7,068 |
| Zander, Miriam | Research Assistant | 44.28% yr 5 | $9,363 |
| Huang, Emily | Research Coordinator | 92.38% yr 2 | $2,283 |

9(C) Provide the names of **all** persons who worked on this research project, but who *were not* supported with health research funds. Include position titles (Research Assistant, Administrative Assistant, etc.) and percent of effort on project. For multiple year projects, if percent of effort varied from year to year, report in the % of Effort column the effort by year 1, 2, 3, etc. of the project (x% Yr 1; z% Yr 2-3).

| Last Name, First Name | Position Title | % of Effort on Project |
|---|---|---|
| Luan, Xianqun | Programmer/Data Analyst | 7% yr 1; 43% yr 2; 93% yr 3; 51% yr 4; 17% yr 5 |
| Song, Lihai | Programmer/Data Analyst | 47% yr 3; 38% yr 4; 8.5% yr 5 |
| Mohamad, Zeinab | Programmer/Data Analyst | 10% yr 3; 15% yr 4; 25% yr 5 |
| Dai, Dingwei | Programmer/Data Analyst | 100% yr1; 36% yr 2 |
| Tieder, Joel | Co-Investigator | 5% yrs 1, 2, 4, 5; 10% yr 3 |
| Mahant, Sanjay | Co-Investigator | 5% yrs 1,2,4,5; 10% yr 3 |
| Wilson, Karen | Co-Investigator | 5% yrs 1,2,3,5; 10% yr 4 |
| Rangel, Shawn | Co-Investigator | 10% yr 4, 5% yr 5 |
| Srivastava, Raj | Co-Investigator | 20% yr 1-5 |
| Shah, Samir | Co-Investigator | 5% yr 1,2,3,5; 10% yr 4 |
| Hall, Matt | Co-Investigator | 5% yr 1-5 |
| McLaughlin, Kathleen | Qualitative Data Analyst | 75% yr 1 |

| | | |
|---|---|---|
| Bateman, Xenia | Nurse Co-Investigator | 5% yr 1 |
| Holmes, John | Consultant, qualitative research | 5% yr 1 |
| Keddem, Shimrit | Program Manager, Mixed Methods Research Lab (MMRL) | 10% yr 4 |
| Barg, Frances | Program Director, MMRL | 4% yr 4 |
| Paciotti, Breah | Research Assistant, MMRL | 2% yr 4 |

9(D) Provide a list of **all** scientific equipment purchased as part of this research grant, a short description of the value (benefit) derived by the institution from this equipment, and the cost of the equipment.

| Type of Scientific Equipment | Value Derived | Cost |
|---|---|---|
| Projector, cables & accessories | Enhance ability to review video from 'Video for physiologic monitor alarms' study as part of aim 3c | $1100 |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**10. Co-funding of Research Project during Health Research Grant Award Period.** Did this research project receive funding from any other source during the project period when it was supported by the health research grant?

Yes_____x____ No_____

If yes, please indicate the source and amount of other funds:

Sponsor – Child Health Corp of America (now known as Children's Hospital Association), subcontract to University of Utah. Amount of Funds: $258,207

**11. Leveraging of Additional Funds**

11(A) As a result of the health research funds provided for this research project, were you able to apply for and/or obtain funding from other sources to continue or expand the research?

Yes__x_____ No_____

If yes, please list the applications submitted (column A), the funding agency (National Institutes of Health—NIH, or other source in column B), the month and year when the application was submitted (column C), and the amount of funds requested (column D). If

you have received a notice that the grant will be funded, please indicate the amount of funds to be awarded (column E). If the grant was not funded, insert "not funded" in column E.

Do not include funding from your own institution or from CURE (tobacco settlement funds). Do not include grants submitted prior to the start date of the grant as shown in Question 2. If you list grants submitted within 1-6 months of the start date of this grant, add a statement below the table indicating how the data/results from this project were used to secure that grant.

| A. Title of research project on grant application | B. Funding agency (check those that apply) | C. Month and Year Submitted | D. Amount of funds requested: | E. Amount of funds to be awarded: |
|---|---|---|---|---|
| Treatment Options for African Americans and Hispanics/Latinos with Uncontrolled Asthma (Dr. Kenyon) | ☐NIH<br>✓ Other federal (specify:PCORI_____)<br>☐ Nonfederal source (specify: _____) | 9/2013 | $498,000 | Not funded |
| Organizational Interventions for SSI Prevention in Pediatric Spinal Surgery (Dr. McLeod) | ☐NIH<br>✓ Other federal (specify:__AHRQ _____)<br>☐ Nonfederal source (specify: _____) | 3/2013 | $298,321 | $298,321 |
| Impacts of False Alarms in Critically Ill Patients with Heart and Lung Failure (Dr. Bonafide) | ✓NIH<br>☐ Other federal (specify:_____ _____)<br>☐ Nonfederal source (specify: _____) | 11/2013 | $766,530 | pending |

Data generated in sub-aim 2 of the DOH project was used to show the existence of variation in processes of care and outcomes for children undergoing spinal fusions in this AHRQ grant application that proposed to explore organizational factors that may influence the care received at lower vs higher performing hospitals.

11(B) Are you planning to apply for additional funding in the future to continue or expand the research?

Yes__x_____ No_____

If yes, please describe your plans:

Dr. Kenyon, who led the severe asthma pathway project (aim 1b), will apply for a career development award to continue work related to effective treatment of asthma.

Dr. Mahant, who led the tonsillectomy drilldown (aim 1b) is considering applying for funding with relevant stakeholders to study implementation and dissemination of high quality tonsillectomy care.

Dr. McLeod, who led aim 2, will use results from the K99 project that resulted from aim 2 to submit an R00 proposal for a multicenter study aimed at evaluating the implementation of interventions to overcome hospital-specific barriers to effective care that were found to be unique to low performing hospitals in phase 1.

Dr. Bonafide also plans to apply for additional funding in the future to continue his work on rapid response systems.

**12. Future of Research Project.** What are the future plans for this research project?

The prioritization project team will continue to use the data derived from the analysis to focus on sources of variation for those conditions that were common, costly to the healthcare system, and that demonstrated high levels of variation, and to implement best practices to standardize care for those conditions.
-Dr. Tieder is working with Children's Hospital Association (CHA) to create hospital specific report cards related to Diabetic Ketoacidosis (DKA) care to be used by local hospital quality leaders and endocrinologists.
-The appendectomy drill-down team will use the standardized costing methodology as the "gold standard" resource utilization measure for a National Surgical Quality Improvement Program (NSQIP)/CHA pediatric surgery prioritization project. This project represents a collaborative effort between the American College of Surgeons & CHA to merge the NSQIP (surgical complications) and Pediatric Health Information System (PHIS) (resource utilization & cost) databases as a demonstration project to identify procedures and surgical conditions that have particularly high public health relevance on the basis of cost variation and complication burden. The project is currently designed to use the non-standardized cost data from PHIS but we are hoping to use the standardized cost approach for the final analysis. Second, the team hopes to use the standardized cost methodology within the framework of the appendicitis report card for both uncomplicated and complicated disease. This report card is currently being used as a foundation for a knowledge-sharing collaborative to identify and disseminate "best practices" from exemplar hospitals on the basis of value-based care (hospitals that have low median-case-related cost as well as low readmission rates). We are currently using the non-standardized cost-to-charge ratio-based financial data from PHIS for this purpose but would like to use the standardized cost to improve the validity of the value-based benchmarks.
-The tonsillectomy drilldown team plans to complete their examination of variation in resource utilization.
-The pneumonia drilldown team plans to finish their analysis and publish the results.
-The severe asthma pathway team plans to develop a risk stratification approach to identify individuals at risk of future repeat asthma-related emergency department and hospital use while they are hospitalized for tailored interventions designed to prevent these outcomes.

- Dr McLeod's team will perform a series of multi-center studies aimed at more deeply exploring the organizational factors that may influence quality of care for children undergoing spinal fusion operations. (See Q.11a above for information about funding received for this project) The researchers have recruited seven hospitals that have higher than or lower than expected rates of readmissions and other poor outcomes and will be exploring the organizational factors that may predominate at the lower versus higher performing hospitals. Researchers are currently in the process of performing site visits, observing the care processes, and interviewing staff and families. Qualitative data about the contexts of care at each participating hospital will then be paired with outcomes data pulled from the PHIS database, allowing researchers to compare and contrast organizational factors present at hospitals with better than average versus poorer than average outcomes.
-Dr. Bonafide's team plans to establish a video research laboratory in order to study interdisciplinary patient safety issues using video and analytics tools.

**13. New Investigator Training and Development**. Did students participate in project supported internships or graduate or post-graduate training for at least one semester or one summer?

Yes_____x____ No_____

If yes, how many students? Please specify in the tables below:

| | Undergraduate | Masters | Pre-doc | Post-doc |
|---|---|---|---|---|
| Male | | | | 2 |
| Female | 1 | | | 1 |
| Unknown | | | | |
| **Total** | **1** | | | **3** |

| | Undergraduate | Masters | Pre-doc | Post-doc |
|---|---|---|---|---|
| Hispanic | | | | |
| Non-Hispanic | 1 | | | 2 |
| Unknown | | | | 1 |
| **Total** | **1** | | | **3** |

| | Undergraduate | Masters | Pre-doc | Post-doc |
|---|---|---|---|---|
| White | | | | 2 |
| Black | | | | |
| Asian | 1 | | | |
| Other | | | | |
| Unknown | | | | 1 |
| **Total** | **1** | | | **3** |

**14. Recruitment of Out-of–State Researchers**. Did you bring researchers into Pennsylvania to carry out this research project?

Yes_____ No____x_____

If yes, please list the name and degree of each researcher and his/her previous affiliation:

**15. Impact on Research Capacity and Quality**. Did the health research project enhance the quality and/or capacity of research at your institution?

Yes____x_____ No_____

If yes, describe how improvements in infrastructure, the addition of new investigators, and other resources have led to more and better research.

Funded expansion of the healthcare analytics unit.
Funded creation of Dr. Bonafide's video monitoring laboratory.
Cost master index created by the prioritization project team is being used by other researchers.

**16. Collaboration, business and community involvement.**

16(A) Did the health research funds lead to collaboration with research partners outside of your institution (e.g., entire university, entire hospital system)?

Yes____x_____ No_____

If yes, please describe the collaborations:

CHOP researchers collaborated with Children's Hospital Association and the PRIS (Pediatric Research in the Inpatient Setting) Network to perform the prioritization project and drilldowns. This included researchers from Primary Children's Hospital, Utah, Seattle Children's Hospital, The Hospital for Sick Kids, Toronto, Children's Hospital Colorado, Cincinnati Children's Hospital and Children's Hospital Boston. Results from the analysis of variation in resource utilization across hospitals was used by the team to develop hospital-specific reports for all 43 participating CHA hospitals. The report card information was shared with hospital CFOs and quality leaders in a series of webcasts led by the project team. The project team will continue to work with CHA to use the knowledge gained from the project to impact care across hospitals.

16(B) Did the research project result in commercial development of any research products?

Yes_____ No__x_____

If yes, please describe commercial development activities that resulted from the research project:

16(C) Did the research lead to new involvement with the community?

Yes__x_____ No_____ _____

If yes, please describe involvement with community groups that resulted from the research project:

In addition to the involvement with CHA hospitals as described in response to Question #16, the PA-DOH research led to other community involvement as follows.
-Dr. Mahant's team engaged in a series of knowledge translation activities with the community and relevant stakeholders regarding the findings of the tonsillectomy drilldown.
-Research activities on the Severe Asthma pathway project led to greater exposure to the Community Asthma Prevention Program – an organization that utilizes community health workers to reduce reliance on emergency care for high risk asthmatics in Philadelphia. They were a partner on the PCORI grant noted in response to Question 11. We have also partnered with them and Keystone First, a regional Medicaid managed care plan on a related upcoming pilot RCT investigating the efficacy of electronic adherence monitoring and adherence alerts using community health worker outreach on asthma medication fills.
-The activities on the volume-quality-outcomes project served as a bridge to the surgical outcomes and complex care communities. Development of the AHRQ grant involved disseminating results of the DOH-supported research to national surgical quality groups including the Pediatric Orthopedic Society of North America (POSNA) Quality Safety and Value Initiative (QSVI), local and national patient safety working groups, and family advisory council advocates for the care of children with complex chronic conditions. In addition, dissemination of this work has stimulated collaborations between hospitalists across the country whose interests are in medical/surgical outcomes research and pediatric surgical co-management. A review article detailing the current status of hospitalist co-management programs and variation in surgical outcomes across the country is currently in progress.

**17. Progress in Achieving Research Goals, Objectives and Aims.**

List the project goals, objectives and specific aims (as contained in the grant agreement). Summarize the progress made in achieving these goals, objectives and aims for the period that the project was funded (i.e., from project start date through end date). Indicate whether or not each goal/objective/aim was achieved; if something was not achieved, note the reasons why. Describe the methods used. If changes were made to the research goals/objectives/aims, methods, design or timeline since the original grant application was submitted, please describe the changes. Provide detailed results of the project. Include evidence of the data that was generated and analyzed, and provide tables, graphs, and figures of the data. List published abstracts, poster presentations and scientific meeting presentations at the end of the summary of progress; peer-reviewed publications should be listed under item 20.

This response should be a DETAILED report of the methods and findings. It is not sufficient to state that the work was completed. Insufficient information may result in an unfavorable performance review, which may jeopardize future funding. If research findings are pending publication you must still include enough detail for the expert peer reviewers to evaluate the progress during the course of the project.

Health research grants funded under the Tobacco Settlement Act will be evaluated via a performance review by an expert panel of researchers and clinicians who will assess project work using this Final Progress Report, all project Annual Reports and the project's strategic plan. After the final performance review of each project is complete, approximately 12-16 months after the end of the grant, this Final Progress Report, as well as the Final Performance Review Report containing the comments of the expert review panel, and the grantee's written response to the Final Performance Review Report, will be posted on the CURE Web site.

**There is no limit to the length of your response. Responses must be single-spaced below, no smaller than 12-point type. If you cut and paste text from a publication, be sure symbols print properly, e.g., the Greek symbol for alpha (α) and beta (ß) should not print as boxes (□) and include the appropriate citation(s). DO NOT DELETE THESE INSTRUCTIONS.**

The broad objective of the Pediatric Hospital Quality, Safety, and Cost Project was to perform research aimed at improving the quality and efficiency of care provided to children in the inpatient setting. The project had 3 separate but related specific aims, each with their own sub-aims, which together inform the research agenda for pediatric hospital medicine and provide answers to key questions about how we can best organize and deliver hospital care to children in order to improve outcomes and reduce costs. Below we list each aim and summarize the progress made in achieving it during the project period, along with details regarding methods and findings.

**Specific Aim 1: Prioritization Project**

The goal of the prioritization project was to use existing detailed administrative data to identify pediatric hospital conditions that are prevalent, cumulatively expensive to the healthcare system and that exhibit high degrees of variation in resource utilization. Extreme variation across hospitals in resource utilization for the same condition often signals an opportunity for standardization of care, improved outcomes and reduced costs. The sub-aim of the prioritization project (aim 1b) was, for prevalent and expensive conditions that exhibited a high degree of inter-hospital variation in cost, to conduct 'drilldowns' to explore explanations for the variation, both in terms of resource categories (e.g. radiology, laboratory, or length of stay costs) driving variation, as well as organizational factors associated with more cost-effective care (e.g. use of and adherence to clinical practice guidelines).

The prioritization project team was led by Ron Keren MD MPH, and included researchers from the Pediatric Hospital in the Inpatient Setting (PRIS) Network. They included Raj Srivastava MD MPH, Primary Children's Medical Center, Salt Lake City Utah, Joel Tieder MD MPH, Seattle Children's Hospital, Sanjay Mahant MD MSc, The Hospital for Sick Kids, Toronto, Karen Wilson MD MPH, Children's Hospital Colorado, Samir Shah MD MSCE, Cincinnati

Children's Hospital, Shawn Rangel MD Children's Hospital Boston, as well as Lisa McLeod MD MSCE at CHOP and a team of biostatisticians and programmer analysts. During the 1st phase of the prioritization project, the team analyzed comprehensive hospital billing data from the Pediatric Health Information System (PHIS) which included all children age 1 month to 18 years who were hospitalized at one of 40 free-standing Children's Hospital Association (CHA, formerly Child Health Corporation of America) member children's hospitals during calendar year 2004-2009. Our statistical programmers assembled a list of primary discharge diagnoses that account for 80% of all costs and a list of primary discharge diagnoses that account for 80% of all admissions to CHA hospitals during this time period. Two investigators reviewed this list of diagnoses and grouped them into clinically sensible "conditions" – defined as diagnoses that share the same pathophysiology and initial management. For example, the various International Classification of Diseases (ICD) 9 codes for asthma exacerbations were grouped together as they are all managed initially with the same initial diagnostic tests and treatments. This list of discharge ICD9 codes sorted into conditions comprises our ICD9 code "grouper".

The team then divided the conditions into "medical", "surgical", or "medical/surgical" based on whether less than 20%, more than 80%, or between 20-80% of admissions for a particular condition had an ICD-9 CM principal procedure code for a surgery related to the condition. This resulted in 255 medical, 231 surgical and 16 medical/surgical conditions. The team used the ICD-9 codes that were reported for each encounter to further restrict the cohort of children within each condition. For medical and medical/surgical conditions they excluded children who had any procedures (surgical or non-surgical) that were unlikely to be related to the medical condition (e.g. laparoscopic appendectomy for child with primary diagnosis of asthma). For surgical conditions they only included children who had a procedure code for a surgery that was likely to be related to the condition (e.g. laparoscopic or open appendectomy for child with primary diagnosis of appendicitis). Eight pediatric hospitalist researchers that serve on the Executive Council of the Pediatric Research in Inpatient Settings research network determined which procedure codes to use to include or exclude children from the condition-specific cohorts.

Cost Master Index. Because the objective of the study is to compare inter-hospital variation in resource utilization using mean cost per admission as a surrogate for total resource utilization, the researchers decided to standardize the cost of individual items in the hospital bills in order to remove the often high inter-hospital variation in item costs as a contributor to the variation in total hospitalization costs. To calculate standardized costs for each item in the dataset, the team first tabulated the line-item charges and number of billed units for every Clinical Transaction Code (CTC) code in every hospital billing record. They then computed the cost per CTC for each line item using hospital and department specific ratios of cost to charges (RCCs), the CTC charge, and the number of billed CTC units. The charges listed in PHIS already adjust for the HCFA wage/price index (published annually in the Federal Register) for each hospital. All costs were then inflated to 2009 dollars using the medical component of the Consumer Price Index. Next, the researchers calculated the median cost for every CTC code within each hospital. Finally, they defined the standardized unit cost for each CTC code as the median of hospital median unit CTC costs. The standardized unit costs for a total of 20,903 CTC codes were then tabulated in a Cost Master Index (CMI) (available upon request).

Standardized Total Admission Costs. Using the standardized unit costs from the CMI, the team calculated the total hospitalization cost for every admission, by multiplying the CMI cost by the number of units for each CTC appearing in the hospital bill, and then summing the costs of each line item in every hospital bill. For each condition they evaluated the overall distribution of costs per encounter. Because some hospitals have a higher representation of children with complex chronic conditions who often utilize a lot more resources for reasons unrelated to their reason for admission, the team identified and excluded extreme cost outliers. For each condition, they calculated the mean, median and individual quintiles of cost per encounter. They used bin plots to demonstrate the number and proportion of patients at a particular hospital whose standardized cost per encounter was within one of the five quintiles (see Figure 1 for an example—acute appendicitis without peritonitis). They generated box plots to demonstrate the variation in mean cost/encounter for each condition (see Figure 2). To get a simple and easily interpretable estimation of the degree of variation in cost per encounter across hospitals, for each condition they counted the number of hospitals with more than 30% of their admissions in either the highest or lowest quintiles of cost per encounter. They summarized (and ranked) the degree of variation across each condition by calculating intra-class correlation coefficients (ICC) for the degree of variation in cost per encounter.

**Figure 1. Proportion of patients falling into each of five quintiles for cost per admission for Acute Appendicitis without Peritonitis at various PHIS hospitals.**

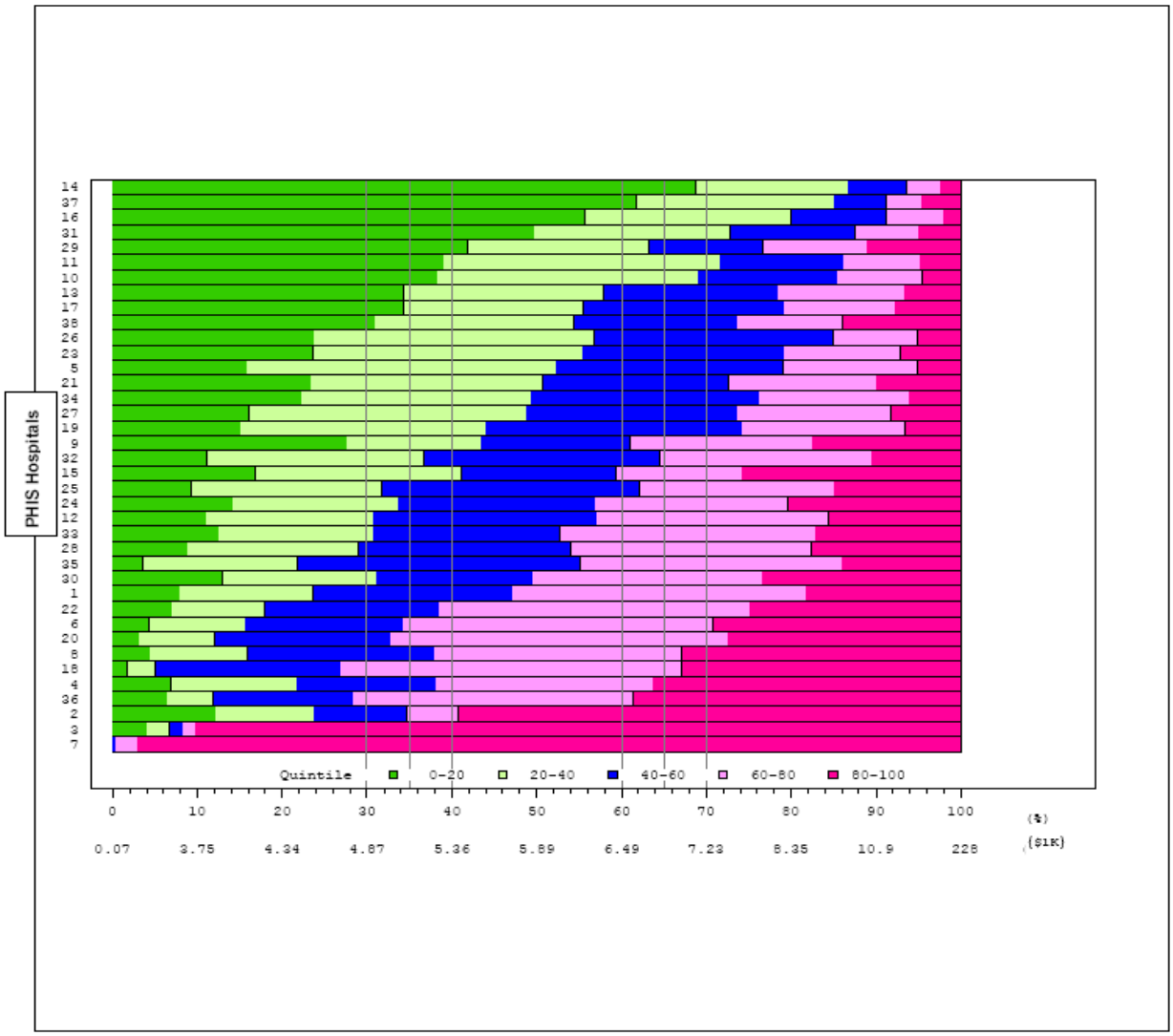
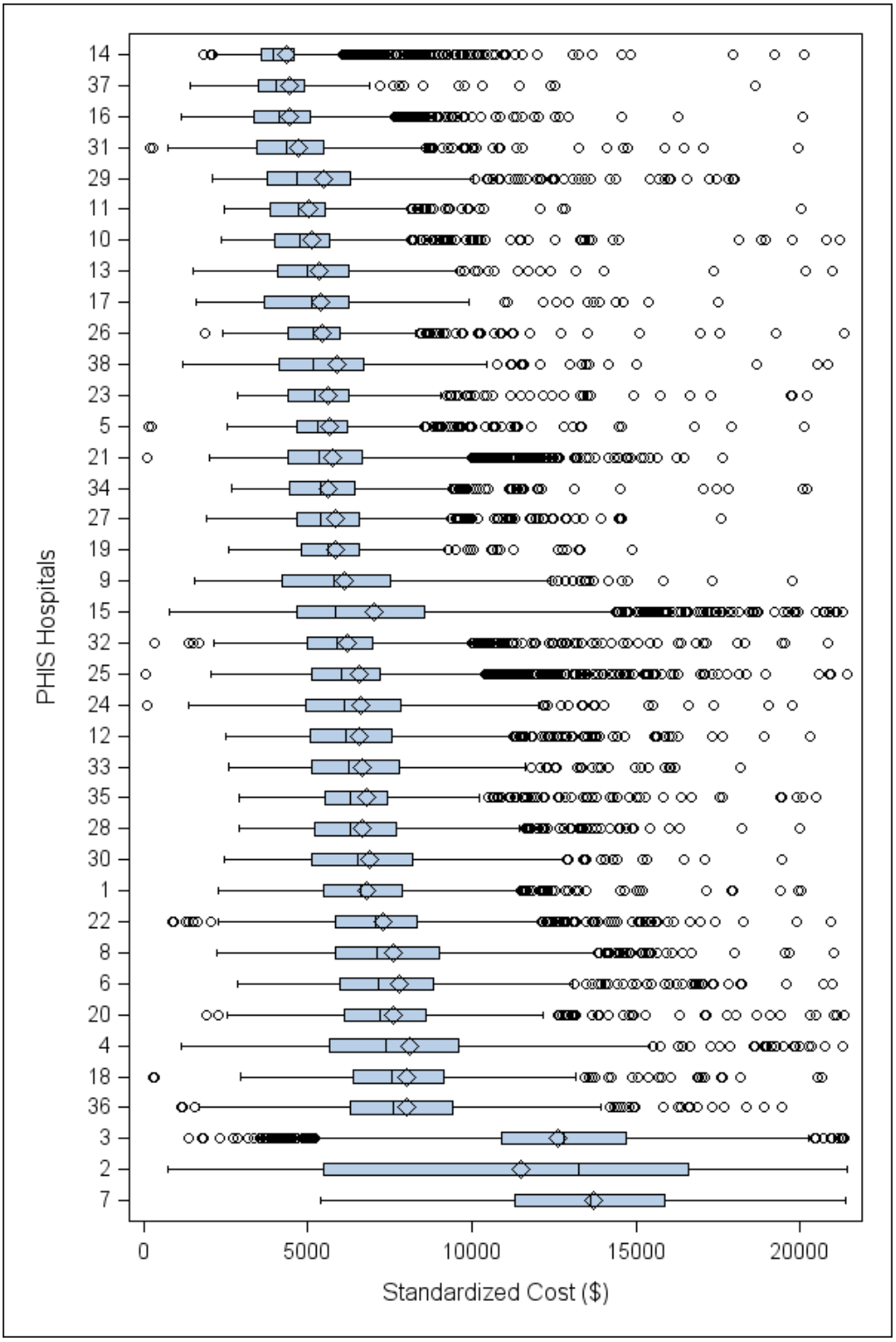


**Figure 2. Variation Across PHIS Hospitals for Acute Appendicitis without Peritonitis**



Data Issues. 43 hospitals contributed data to PHIS over the 6-year study period (2004-2009). The team identified and solved several issues affecting the completeness and quality of the data in the analysis, including:

a) Missing level 2 (line-item billing) data – 2 hospitals were excluded from the analysis because they did not submit billing data and another hospital was excluded because it submitted only one year's billing data during the 6 year project period. Data from an additional 13 quarters from various hospitals were excluded because more than 10% of the records were missing billing data.
b) Missing hospital/department specific RCCs – Hospital and year specific RCCs were used to convert charges into costs in each of 29 charge departments. Two hospitals were excluded from the analysis because they did not provide RCC information. For the remaining 38 hospitals, there were 7% department-specific RCCs missing. These RCCs were imputed using a formal RCC strategy.
c) CTC codes in some bills with non-integer units or unit counts that are unreasonably high or low – A manual review of these by the team determined that these reflected hospital-specific coding errors or idiosyncrasies. The line-item cost calculated by multiplying the number of units by CMI unit cost were replaced with the reported charge, multipled by the RCC, when the suspect cost was either more than 3 times or less than 1/3 of the replacement cost. This was necessary in fewer than 5% of billed items.

Findings

Table 1 shows the 50 most prevalent and 50 most costly conditions, sorted by cumulative standardized cost across hospitals. Conditions ranked high in cumulative cost because they were either very prevalent or very expensive on a cost per encounter basis. The 10 most expensive conditions accounted for 36% of all costs among the 495 conditions in the original sample. Of the 77 most prevalent and/or costly conditions, 26 had ICCs higher than .1 and five had ICCs higher than .3 after adjusting for patient demographic characteristics, presence of complex chronic conditions, all patient refined diagnosis related group severity level, and admission type. The ICC measures the amount of variation in costs across hospitals as a fraction of total variation in costs. An ICC approaches 0 when variation across hospitals is small and approaches 1 as hospitals begin to account for all variation of costs. For example, an ICC of .19, as in acute appendicitis without peritonitis, means that 19% of all variation in standardized cost per encounter can be attributed solely to the hospital in which these children happened to receive care. In an outlier analysis, the team identified many conditions for which a large number of hospitals had a high proportion of high or low-cost hospitalizations, including 10 conditions for which more than half of the hospitals had more than 30% of encounters with costs in either the lowest or highest quintile of overall costs.

Conditions that met all of the prioritization criteria (prevalent, high cost and high variation in interhospital cost per encounter) included: hypertrophy of the tonsils and adenoids requiring tonsillectomy and/or adenoidectomy, otitis media requiring tympanostomy tube placement, and acute appendicitis without peritonitis requiring appendectomy.

**Table 1**

**Table. Prevalence, Cost, and Variation in Standardized Cost for the 50 Most Prevalent and 50 Most Costly Pediatric Inpatient Conditions**

| Condition | Type | Rank | | Encounters, No. | Standardized Cost, $ | | | Standardized Cost for All 495 Conditions, % | | ICC[a] | Outlier Hospitals, No.[a] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cost | Prevalence | | Per Encounter | Total, Millions | Cumulative, Millions | Total | Cumulative | | Low-Cost | High-Cost |
| Respiratory distress syndrome in newborn | M | 1 | 37 | 16 806 | 72 923 | 1226 | 1226 | 6.49 | 6.49 | 0.07 | 12 | 4 |
| Pneumonia | M | 2 | 5 | 106 792 | 8293 | 886 | 2111 | 4.69 | 11.18 | 0.04 | 5 | 4 |
| Chemotherapy | M | 3 | 7 | 90 694 | 8746 | 793 | 2904 | 4.20 | 15.38 | 0.12 | 7 | 5 |
| Acute respiratory failure | M | 4 | 42 | 15 246 | 41 146 | 627 | 3532 | 3.32 | 18.70 | 0.05 | 2 | 4 |
| Scoliosis, idiopathic | S | 5 | 48 | 13 348 | 45 674 | 610 | 4141 | 3.23 | 21.92 | 0.37 | 7 | 10 |
| Asthma | M | 6 | 3 | 150 528 | 3799 | 572 | 4713 | 3.03 | 24.95 | 0.09 | 7 | 7 |
| Hypoplastic left heart syndrome | S | 7 | 63 | 5415 | 104 037 | 563 | 5277 | 2.98 | 27.93 | 0.07 | 5 | 7 |
| Bronchiolitis | M | 8 | 4 | 107 562 | 5225 | 562 | 5839 | 2.98 | 30.91 | 0.04 | 6 | 2 |
| Hypertrophy of tonsils and adenoids | S | 9 | 2 | 225 758 | 2468 | 557 | 6396 | 2.95 | 33.86 | 0.30 | 12 | 8 |
| Extreme immaturity, birth weight 500-749 g | M | 10 | 72 | 2302 | 199 808 | 460 | 6856 | 2.44 | 36.30 | 0.03 | 3 | 3 |
| Transposition of great vessels | S | 11 | 61 | 6530 | 66 344 | 433 | 7289 | 2.29 | 38.59 | 0.05 | 4 | 6 |
| Extreme immaturity, birth weight 750-999 g | M | 12 | 71 | 2318 | 177 915 | 412 | 7701 | 2.18 | 40.77 | 0.04 | 3 | 5 |
| Necrotizing enterocolitis | M/S | 13 | 68 | 2781 | 132 236 | 368 | 8069 | 1.95 | 42.72 | 0.04 | 3 | 5 |
| Tetralogy of Fallot | S | 14 | 62 | 6107 | 59 327 | 362 | 8431 | 1.92 | 44.64 | 0.08 | 5 | 7 |
| Cellulitis | M | 15 | 8 | 79 288 | 4532 | 359 | 8791 | 1.90 | 46.54 | 0.05 | 8 | 3 |
| Specified conditions originating in perinatal period, other | M | 16 | 43 | 14 973 | 23 199 | 347 | 9138 | 1.84 | 48.38 | 0.04 | 1 | 3 |
| Septicemia | M | 17 | 54 | 9496 | 35 506 | 337 | 9475 | 1.79 | 50.16 | 0.01 | 2 | 3 |
| Acute lymphoid leukemia without remission | M | 18 | 49 | 13 339 | 22 757 | 304 | 9779 | 1.61 | 51.77 | 0.09 | 9 | 11 |
| Otitis media, unspecified | S | 19 | 1 | 227 700 | 1322 | 301 | 10 080 | 1.59 | 53.36 | 0.22 | 9 | 12 |
| Coarctation of aorta or interrupted aortic arch | S | 20 | 59 | 6674 | 44 484 | 297 | 10 377 | 1.57 | 54.94 | 0.06 | 5 | 9 |
| Cystic fibrosis | M | 21 | 51 | 12 790 | 21 973 | 281 | 10 658 | 1.49 | 56.42 | 0.14 | 7 | 6 |
| Congenital anomalies of abdominal wall, other | S | 22 | 69 | 2775 | 98 057 | 272 | 10 930 | 1.44 | 57.86 | 0.09 | 8 | 6 |
| Gastroesophageal reflux and esophagitis | M/S | 23 | 10 | 59 139 | 4404 | 260 | 11 190 | 1.38 | 59.24 | 0.03 | 14 | 5 |
| Acute appendicitis without peritonitis | S | 24 | 16 | 40 142 | 6373 | 256 | 11 446 | 1.35 | 60.60 | 0.19 | 7 | 8 |
| Ventricular septal defect | S | 25 | 58 | 6869 | 36 839 | 253 | 11 699 | 1.34 | 61.94 | 0.11 | 4 | 8 |

**Table. Prevalence, Cost, and Variation in Standardized Cost for the 50 Most Prevalent and 50 Most Costly Pediatric Inpatient Conditions (continued)**

| Condition | Type | Rank | | Encounters, No. | Standardized Cost, $ | | | Standardized Cost for All 495 Conditions, % | | ICC[a] | Outlier Hospitals, No.[a] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cost | Prevalence | | Per Encounter | Total, Millions | Cumulative, Millions | Total | Cumulative | | Low-Cost | High-Cost |
| Mechanical complication of nervous system device, implant, and graft | S | 26 | 26 | 22 046 | 11 418 | 252 | 11 951 | 1.33 | 63.27 | 0.07 | 4 | 3 |
| Dental caries | S | 27 | 6 | 102 523 | 2398 | 246 | 12 197 | 1.30 | 64.57 | 0.22 | 5 | 13 |
| Sickle cell disease with crisis | M | 28 | 20 | 30 963 | 7769 | 241 | 12 437 | 1.27 | 65.85 | 0.09 | 5 | 7 |
| Endocardial cushion defects, other | S | 29 | 65 | 4180 | 55 038 | 230 | 12 667 | 1.22 | 67.06 | 0.07 | 4 | 10 |
| Infection and inflammation due to vascular device, implant, or graft | M/S | 30 | 52 | 10 914 | 20 656 | 225 | 12 893 | 1.19 | 68.26 | 0.05 | 2 | 6 |
| Neutropenia | M | 31 | 28 | 21 720 | 10 260 | 223 | 13 116 | 1.18 | 69.44 | 0.04 | 3 | 4 |
| Preterm infants, birth weight 1000-1249 g, other | M | 32 | 75 | 2083 | 104 755 | 218 | 13 334 | 1.16 | 70.59 | 0.12 | 3 | 5 |
| Urinary tract infection | M | 33 | 15 | 40 393 | 5399 | 218 | 13 552 | 1.15 | 71.75 | 0.06 | 7 | 4 |
| Acute myeloid leukemia without remission | M | 34 | 66 | 3521 | 61 176 | 215 | 13 767 | 1.14 | 72.89 | 0.11 | 10 | 8 |
| Seizures with and without intractable epilepsy | M | 35 | 19 | 31 009 | 6856 | 213 | 13 980 | 1.13 | 74.01 | 0.04 | 7 | 3 |
| Dehydration | M | 36 | 11 | 52 970 | 3753 | 199 | 14 179 | 1.05 | 75.06 | 0.07 | 9 | 6 |
| Other convulsions | M | 37 | 14 | 42 222 | 4693 | 198 | 14 377 | 1.05 | 76.11 | 0.06 | 9 | 3 |
| Aspiration pneumonia or pneumonitis | M | 38 | 55 | 8920 | 20 858 | 186 | 14 563 | 0.98 | 77.10 | 0.04 | 1 | 5 |
| Respiratory problems after birth, other | M | 39 | 53 | 9833 | 18 855 | 185 | 14 748 | 0.98 | 78.08 | 0.09 | 8 | 3 |
| Acute appendicitis with peritonitis | S | 40 | 41 | 15 606 | 11 824 | 185 | 14 933 | 0.98 | 79.06 | 0.14 | 5 | 6 |
| Congenital anomalies of skull and face bones | S | 41 | 56 | 8661 | 21 294 | 184 | 15 117 | 0.98 | 80.03 | 0.14 | 7 | 8 |
| Patent ductus arteriosus | S | 42 | 60 | 6597 | 27 102 | 179 | 15 296 | 0.95 | 80.98 | 0.19 | 8 | 8 |
| Congestive heart failure | M | 43 | 67 | 2990 | 57 911 | 173 | 15 469 | 0.92 | 81.90 | 0.05 | 4 | 7 |
| Anomalies of diaphragm, congenital | S | 44 | 76 | 1874 | 84 524 | 158 | 15 628 | 0.84 | 82.74 | 0.08 | 4 | 6 |
| Perinatal chronic respiratory disease | M | 45 | 70 | 2333 | 67 772 | 158 | 15 786 | 0.84 | 83.57 | 0.05 | 4 | 8 |
| Diabetic ketoacidosis | M | 46 | 22 | 25 352 | 6172 | 156 | 15 942 | 0.83 | 84.40 | 0.19 | 7 | 8 |
| Preterm infants, birth weight 1250-1499 g, other | M | 47 | 73 | 2204 | 70 742 | 156 | 16 098 | 0.83 | 85.23 | 0.11 | 5 | 3 |

**Table. Prevalence, Cost, and Variation in Standardized Cost for the 50 Most Prevalent and 50 Most Costly Pediatric Inpatient Conditions (continued)**

| Condition | Type | Rank | | Encounters, No. | Standardized Cost, $ | | | Standardized Cost for All 495 Conditions, % | | ICC[a] | Outlier Hospitals, No.[a] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cost | Prevalence | | Per Encounter | Total, Millions | Cumulative, Millions | Total | Cumulative | | Low-Cost | High-Cost |
| Inguinal hernia, unilateral or bilateral, nonobstructive | S | 48 | 9 | 61 645 | 2497 | 154 | 16 252 | 0.81 | 86.04 | 0.25 | 14 | 10 |
| Respiratory failure of newborn | M | 49 | 74 | 2144 | 71 695 | 154 | 16 406 | 0.81 | 86.86 | 0.05 | 3 | 7 |
| Partial anomalous pulmonary venous connection | S | 50 | 64 | 4304 | 35 312 | 152 | 16 558 | 0.80 | 87.66 | 0.06 | 3 | 5 |
| Fever | M | 51 | 18 | 33 056 | 4558 | 151 | 16 708 | 0.80 | 88.46 | 0.05 | 7 | 4 |
| Failure to thrive | M | 53 | 38 | 16776 | 8081 | 136 | 16 983 | 0.72 | 89.91 | 0.04 | 4 | 5 |
| Partial epilepsy with or without intractable epilepsy | M | 54 | 47 | 13 388 | 9345 | 125 | 17 108 | 0.66 | 90.57 | 0.04 | 2 | 4 |
| Abdominal pain | M | 56 | 13 | 43 127 | 2737 | 118 | 17 346 | 0.62 | 91.83 | 0.09 | 15 | 8 |
| Feeding difficulties and misman-agement | M | 57 | 50 | 13 300 | 8364 | 111 | 17 458 | 0.59 | 92.42 | 0.05 | 6 | 5 |
| Vesicoureteral reflux unspecified or without reflux nephropathy | S | 58 | 33 | 18 498 | 5645 | 104 | 17 562 | 0.55 | 92.98 | 0.23 | 7 | 6 |
| Supracondylar fracture of humerus | S | 59 | 21 | 26 473 | 3889 | 103 | 17 665 | 0.55 | 93.52 | 0.11 | 7 | 8 |
| Gastroenteritis, infectious | M | 60 | 24 | 24 246 | 4147 | 101 | 17 766 | 0.53 | 94.05 | 0.08 | 6 | 7 |
| Congenital hypertrophic pyloric stenosis | S | 61 | 39 | 16 755 | 5720 | 96 | 17 861 | 0.51 | 94.56 | 0.17 | 10 | 6 |
| Cleft palate or cleft lip | S | 62 | 40 | 16 368 | 5685 | 93 | 17 954 | 0.49 | 95.05 | 0.31 | 8 | 11 |
| Gastroenteritis and colitis, noninfectious | M | 63 | 25 | 23 198 | 3549 | 82 | 18 037 | 0.44 | 95.49 | 0.07 | 12 | 8 |
| Esotropia, exotropia, heterotropia, and hypertropia | S | 64 | 17 | 35 364 | 2201 | 78 | 18 115 | 0.41 | 95.90 | 0.34 | 6 | 9 |
| Hypospadias | S | 65 | 30 | 20 498 | 3624 | 74 | 18 189 | 0.39 | 96.30 | 0.37 | 10 | 8 |
| Redundant prepuce and phimosis | S | 66 | 12 | 43 754 | 1694 | 74 | 18 263 | 0.39 | 96.69 | 0.00 | 7 | 10 |
| Upper respiratory tract infection | M | 67 | 32 | 19 223 | 3848 | 74 | 18 337 | 0.39 | 97.08 | 0.06 | 6 | 6 |
| Constipation, unspecified | M | 68 | 31 | 20 378 | 3587 | 73 | 18 410 | 0.39 | 97.47 | 0.07 | 9 | 5 |
| Viral infection, unspecified | M | 69 | 34 | 17 794 | 4003 | 71 | 18 481 | 0.38 | 97.84 | 0.07 | 6 | 4 |
| Undescended testis | S | 70 | 23 | 25 082 | 2645 | 66 | 18 548 | 0.35 | 98.19 | 0.31 | 10 | 7 |
| Viral meningitis | M | 71 | 46 | 13 611 | 4672 | 64 | 18 611 | 0.34 | 98.53 | 0.09 | 5 | 6 |
| Gastritis, gastroduode-nitis, without hemorrhage, unspecified | M | 72 | 27 | 21 908 | 2582 | 57 | 18 668 | 0.30 | 98.83 | 0.13 | 17 | 13 |

**Table. Prevalence, Cost, and Variation in Standardized Cost for the 50 Most Prevalent and 50 Most Costly Pediatric Inpatient Conditions (continued)**

| Condition | Type | Rank | | Encounters, No. | Standardized Cost, $ | | | Standardized Cost for All 495 Conditions, % | | ICC[a] | Outlier Hospitals, No.[a] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cost | Prevalence | | Per Encounter | Total, Millions | Cumulative, Millions | Total | Cumulative | | Low-Cost | High-Cost |
| Neonatal hyperbilirubinemia | M | 73 | 35 | 17 774 | 3074 | 55 | 18 723 | 0.29 | 99.12 | 0.06 | 6 | 4 |
| Croup | M | 74 | 29 | 20 861 | 2381 | 50 | 18 772 | 0.26 | 99.38 | 0.08 | 13 | 4 |
| Vomiting alone | M | 75 | 45 | 13 671 | 3192 | 44 | 18 816 | 0.23 | 99.61 | 0.07 | 14 | 5 |
| Encounter for removal of internal fixation device | S | 76 | 44 | 14 591 | 2530 | 37 | 18 853 | 0.20 | 99.81 | 0.21 | 9 | 7 |
| Umbilical hernia without mention of obstruction or gangrene | S | 77 | 36 | 17 091 | 2108 | 36 | 18 889 | 0.19 | 100.00 | 0.27 | 9 | 9 |

Abbreviations" ICC, intraclass correlation coefficient; M, medical; S, surgical

[a]The ICCs and number of outlier hospitals were calculated from standardized costs adjusted for patient age (<30; ≥30 days and <1 year; ≥1 year and <5 years; ≥5 years and <13 years; ≥13 years and <17 years; ≥18 years), sex race (white, black, other), presence of a complex chronic condition,[12]all patient refined diagnosis related group severity level, and patient type (inpatient, ambulatory surgery, and observation status).

Aim 1b: Drill-down phase

Once the prioritization methodology phase was complete, focus shifted from identification of pediatric hospital conditions that are prevalent, costly and characterized by significant variation in resource utilization to 'drill-downs' that sought explanations for variation in selected high priority conditions. Drill-down condition criteria were established, methodology was developed and 5 drill-downs were conducted. Criteria for selecting conditions were prevalence, cost, amount of variation, homogeneity of patient population, availability of evidence and consensus regarding best practices, high morbidity, and quality of data available.

Drill-down #1: Diabetic Ketoacidosis (DKA). DKA is a short-term complication of type 1 diabetes and is a major cause of preventable hospitalization in children. DKA was selected for a drill-down due to a high degree of variability in resource utilization and a high number of outlier hospitals; because it is the leading cause of morbidity and mortality in Type 1 Diabetes Mellitus; and because there are established guidelines for management. The objective of the drilldown was to characterize variation in resource utilization for DKA admissions across US children's hospitals and to determine the clinically relevant processes of care that contribute to variation, as well as to assess the independent effects of resource utilization on readmission. The DKA drilldown team was led by Dr. Tieder. A retrospective cohort study of children with a diagnosis of DKA, ages 2-18 years, discharged from 38 CHA freestanding children's hospitals from 2004-2009 was conducted. Patients with a secondary discharge diagnosis of DKA who had a principal diagnosis indicating a diabetes-related condition or complication were also included. Children who did not have a billing code for intravenous or subcutaneous insulin were excluded, as insulin is necessary to treat DKA. Resource utilization as determined by standardized total cost per hospitalization, overall and non-ICU length of stay (LOS), and readmission for DKA within 30 and 365 days of discharge were the main outcome measures. The drill-down showed that, after applying exclusion criteria, there were 24,890 DKA admissions during the project period and 20.3% of those were readmissions within 1 year.

The CMI that was developed in the initial phase of the prioritization project was used to calculate standardized costs for the entire hospital visit, emergency room through discharge, by multiplying the units of each item in every record of the cohort by its standardized costs and then summing these in each hospital bill. The team analyzed variables for patient age, gender, primary insurance and presence or absence of complex chronic conditions and mental health conditions and classified patients my medical severity. Hospital characteristics including number of ICU and inpatient beds, annual DKA admissions, number of endocrinology attending physicians, and presence and size of endocrinology fellowship program were also examined.

Subsequent readmissions 30 and 365 days after discharge for DKA were identified using the same inclusion/exclusion criteria as for the index admission, and each hospitalization was considered an independent index admission. The top 1% of most frequently admitted patients were excluded. Patients readmitted within 30 days were included among the 365 day readmissions.

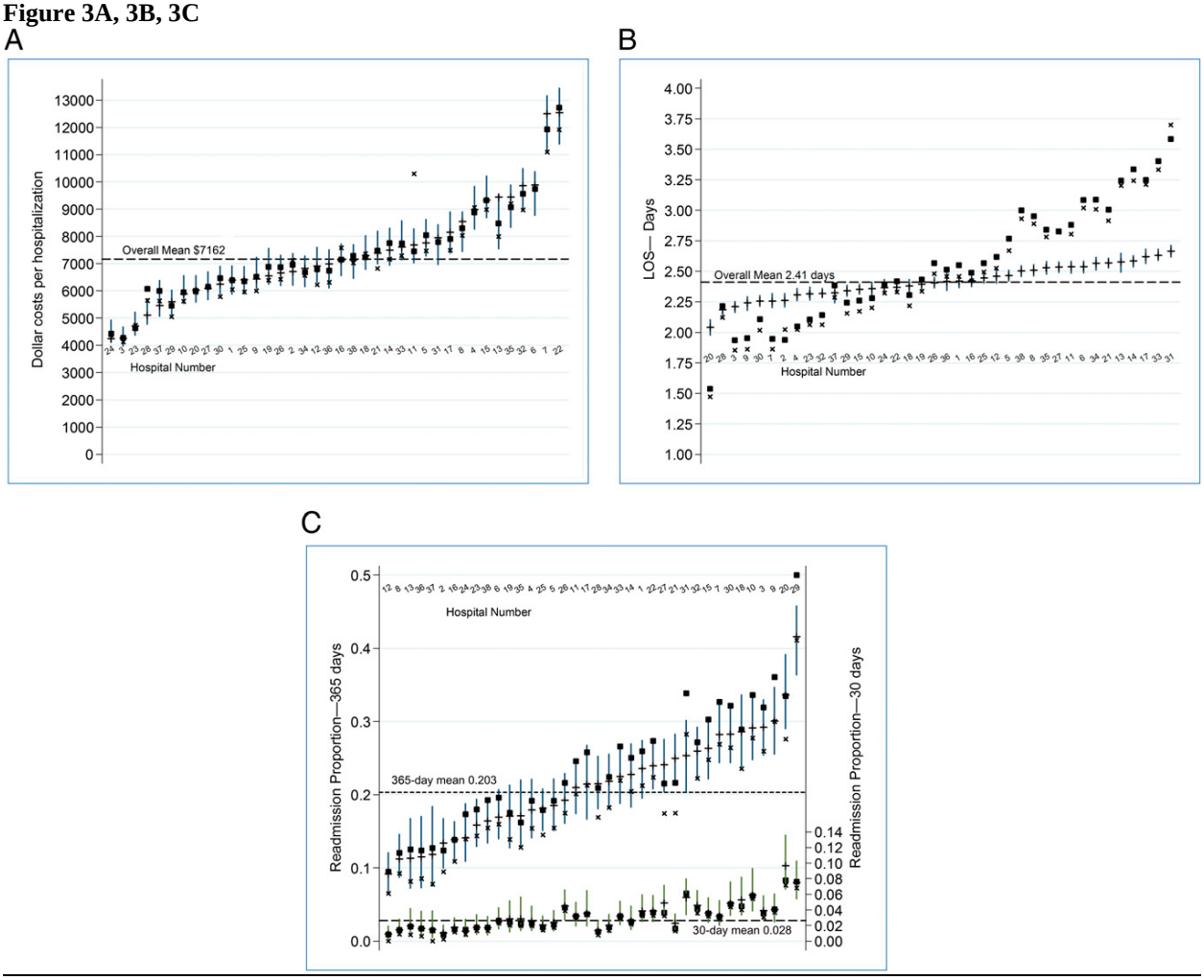
To model variation across hospitals, the team constructed mixed-effects linear and logistic regression models with hospital as a random intercept and patient-level factors as fixed effects, which produced an expected outcome, predicted outcome, and predicted vs expected ratios for each hospital. Ratios were then multiplied by the overall mean costs across all patients in all hospitals to represent the hospital-specific adjusted costs. For LOS, a log linear model was used and for readmission, a logit model was used, to fit patient-level factors and hospital-level effects together and over many iterations produced the distribution of hospital-specific estimates of each hospital's departure from average, after adjustment for patient-level factors. Each model was repeated to estimate hospital-specific average costs, LOS and risk of readmission, but without adjustment for patient-level factors. Results with and without adjustment were compared to determine if variation might change after controlling for case mix. A mixed-effects linear regression model with hospital as random intercept and cost category as fixed and random effects was used to estimate the relative contribution to the variability of total hospital standardized cost from each of the cost categories.

Findings

The analysis found little across-hospital variability in gender and age of patients. Hospital patient mix differed by race, government insurance, comorbidities and severity of illness. Hospitals differed in the number of available and ICU beds and in the mean number of inpatient and DKA admissions, but none of these factors were associated with outcomes. The mean hospital-level total standardized cost per DKA hospitalization was $7,142 with a wide range across hospitals from $4,125 to $11,916. Figure 3A depicts the variation in total standardized cost across hospitals. Hospital bed-days, in particular the non-ICU portion, accounted for the majority of total standardized cost per hospitalization, and accounted for 2$^{nd}$ most of the overall variability in total standardized cost. Mean hospital-level LOS was 2.5 days, with a range of 1.5 days to 3.7 days, and the non-ICU portion was 1.9 days, 0.7 days to 2.7 days. Figure 3B demonstrates the persistent and statistically significant across-hospital variation in in hospital LOS after adjusting for patient characteristics. Mean hospital level readmission within 365 days was 18.7% but also showed wide variability across hospitals (6.5%-41.1%). Within 30 days, mean readmission rate was 2.5% (0.0%-7.1%). Figure 3C demonstrates the hospital variability in readmission at 30 and 365 days. Variation across hospitals for total standardized cost per

admission, LOS and readmission rates was persistent and statistically significant, even after adjusting for patient and hospital characteristics. Adjustment for patient level factors did not tend to change the rankings of high vs low hospitals. Across hospitals, a statistically significant association between higher average cost and lower rates of readmission could not be shown, but within hospitals, patients with higher cost of hospitalization and patients with non-ICU length of stay >2 days had significantly lower odds of readmission at 30 days (OR 0.51, p<.001) and 365 days (OR 0.60, p<.001). The team concluded that at the system level, higher intensity care is not necessarily related to better outcomes and may represent ineffective spending; but that future research should focus on within hospital patient level interventions, such as patient education, to maximize the benefits of additional cost and hospital days.

**Figure 3A, 3B, 3C**




Unadjusted and adjusted variability in standardized costs, mean LOS, and readmission with 95% confidence intervals. Each figure reports hospital-level raw data (x), hospital estimates based on models that adjusted only for the instability of raw data (square symbols), and estimates that adjusted for patient-level factors (+): age group, gender, government insurance, mental health conditions (yes/no), CCCs(yes/no), and patient APR-DRG (v. 20) severity level (1 and 2 vs 3 and 4). The 95% confidence bounds reflect not only patient-level factors but also uncertainty of adjusted for patient-level factors and then comparing hospitals in a single model. Analyses were performed by using mixed-effects models: (A) linear with log transformed costs, (B) for negative binomial for LOS, and (C) logistic for readmission.

Summary

This study found that there are widespread differences in resource use, LOS and readmissions across children's hospitals for children admitted for DKA, and that readmission is common. Non-ICU bed utilization was a main component of variation as well as overall cost. The high rate of readmission found by the study demonstrates sub-optimal diabetes control and self-management, and suggests that hospital based-education programs, although they may extend LOS and add to cost, can improve the overall value of care by decreasing future DKA risk. The study highlights the need for future research to determine the most cost-effective strategies to improve self-management of diabetes.

Aim 1b, Drilldown #2: Hypertrophy of Tonsils and Adenoids

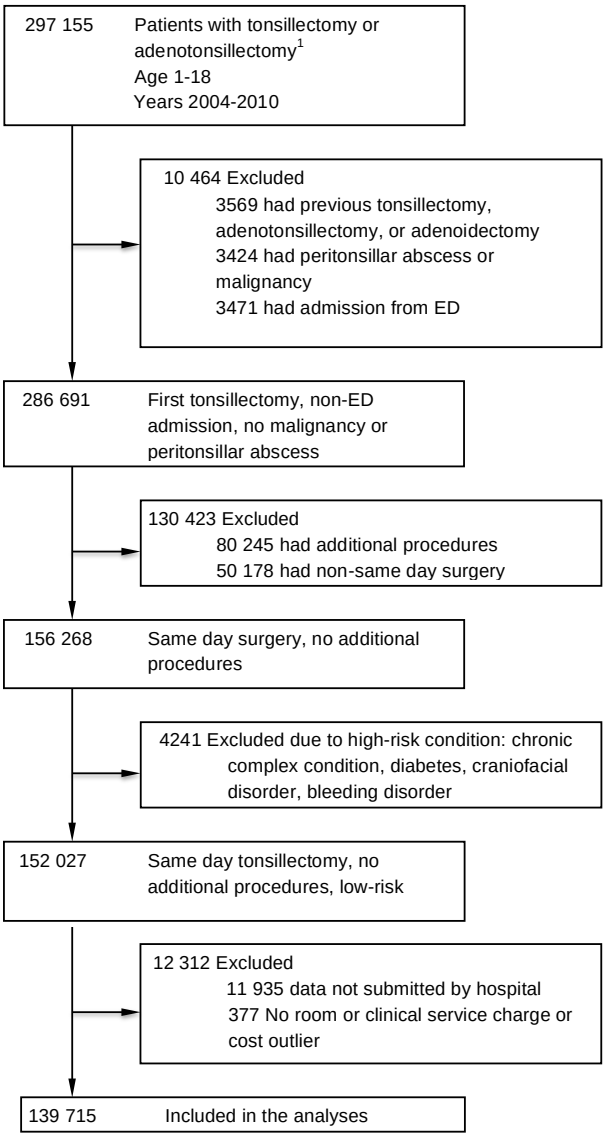
Tonsillectomy is one of the most common surgeries performed in children with over 500,000 performed yearly in the US. An analysis in US children's hospitals found that it was the second most commonly performed surgery and 9$^{th}$ most cumulatively expensive of all conditions. Despite how common and cumulatively expensive tonsillectomy is for the health care system, few studies have examined quality of care across hospitals. The goal of this work is to describe the quality of care for one aspect of tonsillectomy care: the perioperative phase. Specifically, we were interested in describing variations in processes and outcomes; examine the safety of dexamethasone, which is used in perioperative care; and to examine variations in resource utilization across hospitals. Dr. Mahant led this drilldown.

Drilldown #2, Study 1. Variation in Quality of Tonsillectomy Care

*Objective* The first study was a retrospective cohort study at children's hospitals, which examined the variation in the quality of perioperative care for children undergoing same day surgery at children's hospitals.

*Methods* The study used an administrative database as the data source – the Pediatric Health Information System (PHIS) – which collects data from member children's hospitals in the United States. The database contains information on demographics, diagnosis and procedure codes (ICD-9CM), service locations and their charges. The cohort consisted of 139,715 children, ages 1-18, who underwent same day tonsillectomy surgery at 36 children's hospitals from years 2004-2010 (see Figure 4 for cohort construction). Children who had tonsillectomy in the previous 2 years; a peritonsillar abscess or malignancy; additional procedures (including tympanostomy tubes); a complex chronic conditions, diabetes, or a disorder in hemostasis; or those who were admitted from the emergency department were excluded.

**Figure 4. Cohort Flow Diagram**




[1]Includes inpatient, ambulatory, observation and ED patient types in the PHIS database

Quality of care was measured by assessing process measures and outcomes. Evidence based process measures evaluated were the use of dexamethasone on the day of surgery, recommended by national guidelines to reduce postoperative nausea and vomiting based on randomized control trial evidence, and the use of antibiotics on the day of surgery, which is not recommended by national guidelines based on a lack of effectiveness in randomized control trials. Although these trials were published prior to the current study period, the national guidelines were published after the study period. Thus any variation in these process measures should be regarded as opportunities for improvement rather than non-compliance with guidelines. The primary outcome measure was tonsillectomy related revisits to hospital, either emergency department or hospital admission, in the first 30 days after surgery for complications: total and reason specific complications (bleeding, vomiting & dehydration, pain, infections, respiratory problems, and

other causes). Only revisits that were related to tonsillectomy were included. For example if a child came back to hospital for a fracture of the humerus this revisit was excluded.

To estimate the hazards of revisits over time from surgery we used reason-specific discrete time failure models using logistic regression. We estimated the hazards of revisits as a function of in-hospital processes (dexamethasone, antibiotics), the day post discharge, patient level covariates, and hospital. We also estimated the risk of revisit at 30 days, using logistic regression with a covariate for each hospital to adjust for confounding by hospital. Results from logistic regression were standardized, using predictive margins, by patient level covariates, as well as hospital and year of admission to produce adjusted probabilities with 95% confidence intervals. Finally, we estimated the variation across hospitals in the risk for revisit at 30 days, and the relative rankings of hospitals using mixed effects logistic regression.

*Results* Table 2 describes the study population. The mean age was 7.0 years and 91.0% had a tonsillectomy with adenoidectomy vs. tonsillectomy alone (9.0%). The most common reason for tonsillectomy was for airway obstruction (58.4%) followed by infection (33.4%).

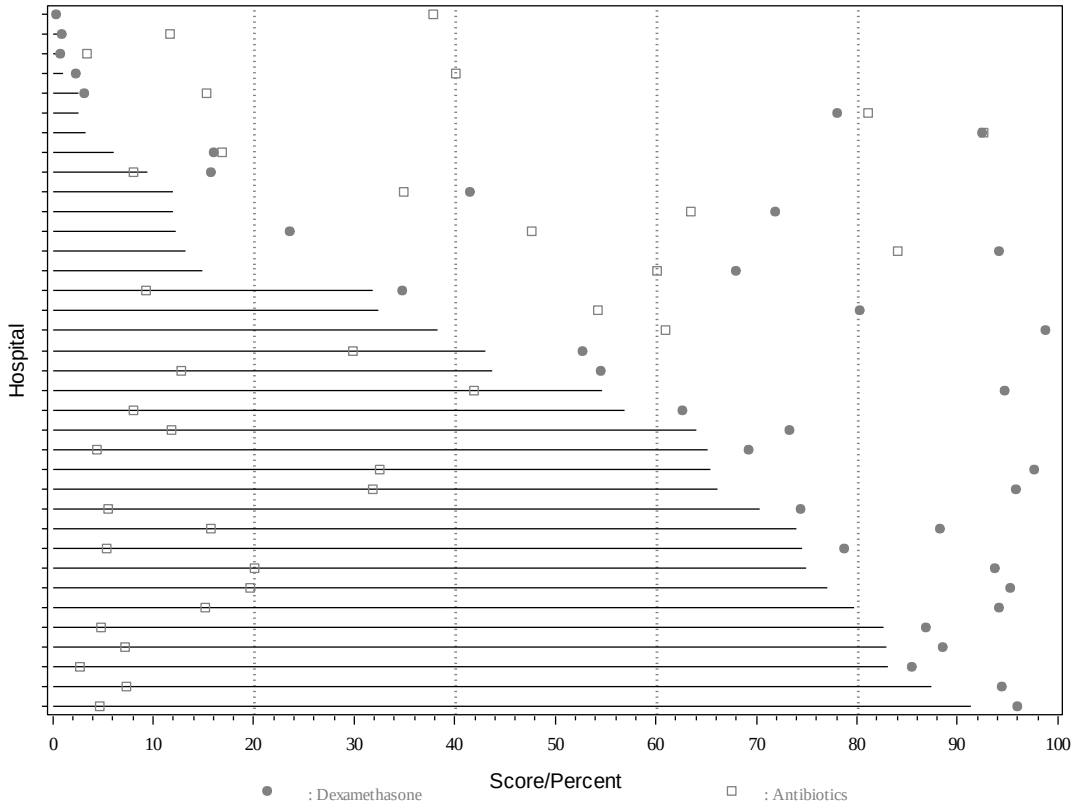
**Table 2: Study Population**

| Patient Characteristics | No. (%) of Patients (N=139 715) |
|---|---|
| Surgery Type | |
| Tonsillectomy with adenoidectomy | 127 147 (91.0) |
| Tonsillectomy | 12 568 (9.0) |
| Sex | |
| Female | 72 280 (51.7) |
| Age, y | |
| mean (SD) | 7.0 (3.8) |
| 1-3 | 22 146 (15.9) |
| 4-9 | 86 764 (62.1) |
| 10-18 | 30 805 (22.0) |
| Payer | |
| Government | 50 339 (36.0) |
| Race | |
| White | 98 739 (70.7) |
| Black | 18 549 (13.3) |
| Other | 22 427 (16.0) |
| Asthma | 13 975 (10.0) |
| APR-DRG Severity | |
| Minor | 131 366 (94.0) |
| Non-minor | 8349 (6.0) |
| | |
| Indication Diagnosis Codes | |
| Airway Obstruction | 81 656 (58.4) |
| Infection | 46 695 (33.4) |
| Both infection and airway obstruction | 10 145 (7.3) |
| Other | 1219 (0.9) |
| | |
| **Hospital Characteristics (N=36)** | |
| Region | **No. (%) of Hospitals** |
| Midwest | 10 (27.8) |
| North East | 5 (13.9) |
| South | 13 (36.1) |
| West | 8 (22.2) |
| Tonsillectomy Volume per year | **Median No. (range)** |
| 2004 | 483 (154,1980) |
| 2005 | 535 (108,2013) |
| 2006 | 528 (85,2149) |
| 2007 | 555 (136,2235) |
| 2008 | 560 (130,2020) |
| 2009 | 682 (125,1761) |
| 2010 | 707(113,1679) |

*Process Measures* We found significant variation in the use of dexamethasone and antibiotics across hospitals (Figure 5). At the hospital level, the median percentage of patients who received dexamethasone was 76.2% (range 0.3%-98.8%) and antibiotics was 16.3% (range 2.7%-92.6%).

Overall in the entire cohort across hospitals, 69.6% received dexamethasone and 31.1 % received antibiotics.

Figure 5. Variation in perioperative dexamethasone and antibiotic use across 36 children's hospitals

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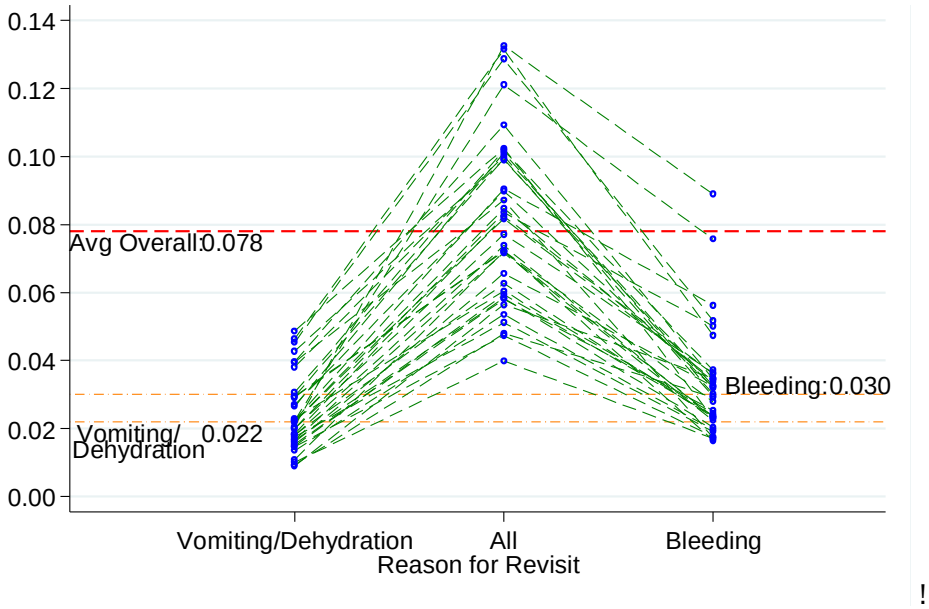
Legend: Each hospital's dexamethasone use, antibiotic use, and summary score is indicated by a shaded circle, open square, and horizontal line respectively. The dexamethasone use indicates the percentage of patients in each hospital that received perioperative dexamethasone. The antibiotic use indicates the percentage of patients in each hospital that received perioperative antibiotics. The summary score is the number of times a hospital performed the appropriate action i.e. the number of times a hospital administered dexamethasone but not antibiotics to an individual child, divided by the number of children who had a tonsillectomy at the hospital, multiplied by one hundred

*Outcome* Of the 139,715 children, 10,868 (7.8%) had a revisit to hospital within 30 days of surgery. The most common reason for a revisit was for bleeding, 4182 (3.0%), vomiting and dehydration, 3011 (2.2%), followed by pain (0.8%, infections (0.8%), respiratory problems (0.5%), and other reasons (0.7%).

At the hospital level, the median 30 day total revisit rate was 7.8% but this varied from 3.0 to 12.6% (Figure 6). The median revisit rate for bleeding was 3.0% (range 1.0-8.8%) and for vomiting and dehydration was 1.9% (range 0.3%-4.4%). The variability in all these outcomes was significant after standardizing for patient-level covariates and year.

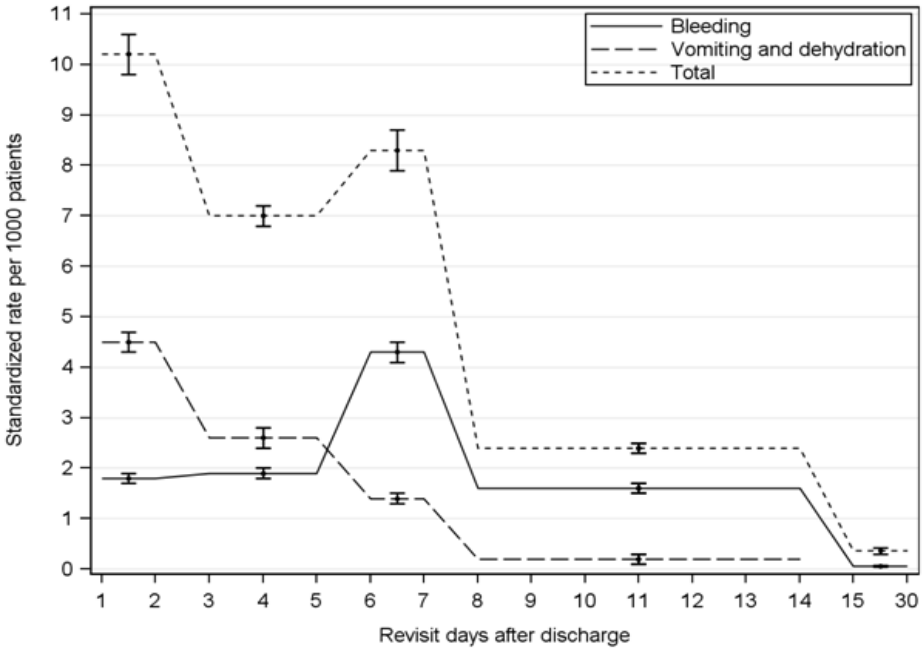
**Figure 6. Variation in 30-day probability of revisits across 36 children's hospitals**




Legend: Variation in 30-day probability of revisits by reason for revisit (all reasons, bleeding, or vomiting and dehydration) across 36 children's hospitals after adjusting for patient-level factors. A dark circle indicates each hospital's 30-day probability of revisit by reason. The dashed lines connecting the three probabilities (all reasons, bleeding, and vomiting and dehydration) indicates values from a single hospital. Probabilities were estimated using mixed effects logistic regression models with a random intercept for hospital and with fixed effects for patient age, race, insurance (government or private), diagnosis of asthma, indication for admission, and year of admission to account for possible differences across hospitals and over time in types of patients treated. Probabilities are further adjusted to improve prediction (of these probabilities), and to avoid overstating the degree of inter-hospital variation, via a weighted average of hospital-specific estimates and the overall estimates of all hospitals. For all revisits, and those from bleeding and dehydration/vomiting the dispersion across hospitals of these adjusted probabilities was significantly greater (P<0.001) than expected at random.

Most revisits (93.8%) occurred within 15 days after surgery. The time to event analysis revealed distinct patterns of revisits for the two most common reasons. The highest rate of revisits for vomiting and dehydration was on days 1 and 2 (4.52 per 1000 days of follow-up [95% CI 4.27-4.77]). In contrast the highest rate of revisits for bleeding was on days 6 and 7 (4.32 per 1000 days of follow-up [95% CI 4.08-4.56)] (Figure 7).

**Figure 7. Standardized rates of revisit by reason for revisit between days 1 through 30 post discharge**

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Legend: Standardized rates of revisit between days 1 through 30 post discharge per 1000 patient days of observation and 95% confidence bounds by reason for revisit. Rates were estimated separately for each reason for revisit using discrete time failure model implemented using logistic regression and with time of revisit categorized by day (1-2, 3-5, 6-7, 8-14, and 15-30) to allow for the effect of time to vary without the restriction of a particular parametric form (such as a linear trend). Adjacent days with similar rates of revisits were groups to avoid instability of estimates from small sample sizes. All rates are marginally standardized by patient characteristics (age, gender, race, severity (APR-DRG), indication for tonsillectomy, insurance (government or private), year of admission, and hospital to represent within-hospital adjusted rates and avoid confounding by these factors or by hospital characteristics.

Age was the covariate that was most associated with standardized risk of revisits for the most common reasons for revisits. Older age, relative to youngest age (1-3 years) was associated with an increased risk of revisits for bleeding and a reduced risk of revisits for vomiting and dehydration.

*Association between process measures and revisit rates* There was no significant association between dexamethasone or antibiotic use and 30-day cumulative risk of total revisits (Table 3).

**Table 3. Antibiotic and Dexamethasone use and 30-day Cumulative Risk of Total Revisits[a]**

| Treatment ! | No. (N=139 708)! | 30-day Cumulative Risk of Total Revisits (95% CI) | Risk difference (95%CI) | P Value | Adjusted OR (95% CI) |
|---|---|---|---|---|---|
| Antibiotic | 43 425! | 7.6 (7.3-7.8)! | -0.3 (-0.7-0.1) | 0.12 | 0.96 (0.91-1.01) |
| No antibiotic | 96 283 | 7.9 (7.2-7.9) | | | |
| Dexamethasone | 97 242! | 7.9 (7.7-8.1)! | 0.3 (-0.1-0.8) | 0.12 | 1.02 (0.90-1.15) |
| No Dexamethasone | 42 466 | 7.5 (7.2-7.9) | | | |

[a]Cumulative risk per 100 patients and odds ratios standardized (adjusted) for patient level covariates (age, gender, severity level, asthma, race, payer, indication), year of admission, and hospital using logistic regression and predictive margins.!

*Limitations* It should be noted that this study addresses one aspect of tonsillectomy care and not the entire spectrum. We were unable to assess surgical appropriateness or other outcomes such as resolution of sleep-disordered breathing, recurrent infections, or quality of life. Our data are representative of children's hospitals and may not be generalizable to other settings. We were unable to track patients to hospitals outside the 36 children's hospitals. Although unlikely, it is possible to children and families sought care at other hospitals, leading to an underestimation of revisit counts. Given that we used an administrative data source, there may be misclassification in measures due to coding differences across hospitals.

*Implications* We observed substantial variation across children's hospitals in the quality of tonsillectomy care, measured in terms of perioperative process measures (use of dexamethasone and antibiotics) and outcomes (standardized revisits to hospitals) in this large multicenter low-risk cohort of children undergoing same day tonsillectomy.

Our data highlights the need for further work on reducing this variation for one of the most common surgeries performed in children. Investigation is necessary to understand the reasons for the substantial variation in process measures in outcomes. It is unlikely the health status accounted for the observed variation as we limited our cohort to a healthy one suitable for discharge the same day of surgery. With 36 hospitals in our cohort, we had limited statistical power to examine hospital factors associated with better performance. Further work into understanding this variation should focus on understanding differences in processes of care during the index hospitalization (e.g. surgical technique, anesthesia, pain management, discharge education) and in the post discharge period (e.g. follow-up care, pain management).

Our data on tonsillectomy related revisits can be used to inform quality measurement around tonsillectomy care. Our results suggest that 15 days is an appropriate time frame to measure revisits as 90% occurred within 15 days. Our data on patient level covariates reveal that age is an important variable for risk adjustment when reporting revisit rates. Furthermore, attention to quality measurement around reason specific revisits, bleeding and vomiting and dehydration, is important to provide hospitals with detailed data which is actionable as reduction of these reasons for revisits have different solutions.

Quality improvement initiatives are needed to implement current evidence into practice and to understand and disseminate the practices of high performing hospitals. Quality improvement collaboratives may be one approach to improving care across hospitals.

Drilldown #2, Study #2 – Dexamethasone and risk of revisits for bleeding in tonsillectomy for children

*Objective* The objective of this study was to determine whether dexamethasone use in children undergoing tonsillectomy is associated with increased risk of postoperative bleeding.

Current national guidelines suggest routine use of dexamethasone on the day of surgery to prevent postoperative nausea and vomiting, which occurs in 70% of children. This recommendation is based on small randomized controlled trials over the past 20 years which showed that for every 5 children given dexamethasone one child would be prevented from experiencing nausea and vomiting. Furthermore dexamethasone reduces pain and increases the proportion of children that are eating postoperatively.

However, several small trials that were not designed to examine bleeding, found that the bleeding risk was increased with dexamethasone use. Meta-analysis has shown that the risk is not increased, however, the estimates are not precise due to a lack of bleeding events in the pooled small trials. A large randomized control trial of at least 5,000 children would be needed to detect a 1.5% difference in bleeding rates, which has been suggested as a clinically important difference, between dexamethasone and placebo.

With the large observational cohort constructed from study 1, we had the opportunity to examine the risk of revisits for bleeding associated with dexamethasone use in this real world setting.

*Methods* We used the same cohort of 139,715 children across 36 children's hospitals as in study 1. The primary outcome of interest was revisits for bleeding within 30 days. Two of the investigators reviewed all ICD-9-CM principal diagnoses for revisits and classified them as bleeding related or unrelated. The primary exposure of interest was dexamethasone use on the day of surgery which was defined by the presence of a pharmacy charge. Covariates that were included were age category (1-3,4-9,10-18), sex, race, insurance type, asthma diagnosis, antibiotic administration and patient illness severity. The minimal clinically important difference in bleeding risk was 1.5% based on published consensus from experts in the field.

To estimate the risk of revisits for bleeding over time we used a time-to-event analysis using discrete time failure models. We constructed models using logistic regression to estimate the hazard of revisit as a function of in-hospital dexamethasone treatment standardizing for the day post-discharge, perioperative antibiotics, the patient-level covariates, and hospital. We divided the 30 days into five day categories (1-2, 3-5, 6-7, 8-14, 15 or more) to allow for identification of distinct periods of risk and to facilitate stable estimates or risk of events within categories.

We also estimated the risk of revisits for bleeding at 30 days. We used logistic regression with a covariate for each hospital to adjust for confounding by hospital arising out of the differences across hospitals in the risk of revisit and the concomitant variation in the utilization of treatments, such as dexamethasone, across hospitals. Results from logistic regression were standardized, using predictive margins, by other patient-level covariates, antibiotic treatment, and also by hospital and year of admission to produce adjusted probabilities and their 95% confidence bounds of revisit according dexamethasone treatment.

*Results.* Of the 139,715 children studied, 4,182 (3.0%) had a revisit for bleeding within 30 days. Characteristics of children who received dexamethasone vs. those who did not are summarized in Table 4.

**Table 4. Patient characteristics according to use of dexamethasone**

| Characteristic | Treatment Group | |
|---|---|---|
| | Dexamethasone (N=97 247) | No Dexamethasone (N=42 468) |
| **Surgery Type** | | |
| Tonsillectomy with adenoidectomy | 88 731 (91.2) | 38 416 (90.5) |
| Tonsillectomy | 8516 (8.8) | 4052 (9.5) |
| **Sex** | | |
| Female | 50 741 (52.2) | 21 539 (50.7) |
| **Age, years** | | |
| Mean (SD) | 7.0 (4.0) | 7.0 (4.0) |
| 1-3 | 15 406 (15.8) | 6740 (15.9) |
| 4-9 | 60 198 (61.9) | 26 566 (62.6) |
| 10-18 | 21 643 (22.3) | 9162 (21.6) |
| **Payer** | | |
| Government | 34 596 (35.6) | 15 743 (37.1) |
| **Race** | | |
| White | 71 811 (73.8) | 26 928 (63.4) |
| Black | 12 704 (13.1) | 5845 (13.8) |
| Other | 12 732 (13.1) | 9695 (22.8) |
| **Asthma** | 3443 (8.1) | 10 532 (10.8) |
| **APR-DRG Severity** | | |
| Minor | 91 216 (93.8) | 40 154 (94.6) |
| Non-minor | 6031 (6.2) | 2314 (5.5) |
| **Indication Diagnosis Codes** | | |
| Airway Obstruction | 55 622 (57.2) | 26 034 (61.3) |
| Infection | 33 792 (34.8) | 12 904 (30.4) |
| Both airway obstruction and infection | 6944 (7.1) | 3200 (7.5) |
| Other | 889 (0.9) | 330 (0.8) |
| **Perioperative Antibiotics** | 33 381 (34.3) | 10 045 (23.7) |

Figures are numbers (percentages) unless stated otherwise.
P<0.001 for all comparisons of dexamethasone exposed versus unexposed except for age categories which is p<0.05

The 30-day cumulative standardized risk of revisits for bleeding was higher among children who received dexamethasone (3.11%, [95% CI, 2.99%-3.23%]) vs. those who did not (2.71%, [95% CI, 2.50%-2.91%]) (standardized difference 0.40% [95% CI, 0.13%- 0.67%]; P=0.003). For every 250 children treated with dexamethasone, one more child had a revisit for bleeding

(number needed to harm, 250; [95% CI, 149-769]). Although standardized risk of revisits for bleeding in both treatment groups increased with increasing age, absolute risk increases in revisits for bleeding associated with dexamethasone were small across all age strata: the upper limit of the 95% CI for this risk difference was 0.42% in the age category 1-3 years, 0.58% in ages 4-9, and 1.09% in ages 10-18 (Table 5).

**Table 5. 30-day Cumulative Risk of Revisit for Bleeding by Age and Dexamethasone Treatment Group***

| | | Treatment Group | | | |
|---|---|---|---|---|---|
| Age, y | No. | Dexamethasone (N=97 242) | No Dexamethasone (N=42 466) | Difference (95% CI) | P value |
| 1-3 | 22 146 | 1.92 (1.73-2.12) | 1.67 (1.46-1.87) | 0.25 (0.08-0.42) | 0.003 |
| 4-9 | 86 758 | 2.66 (2.53-2.79) | 2.31 (2.13-2.50) | 0.35 (0.12-0.58) | 0.003 |
| 10-18 | 30 804 | 5.13 (4.84-5.41) | 4.48 (4.10-4.85) | 0.65 (0.21-1.09) | 0.003 |
| All (1-18) | 139 708 | 3.11 (2.99-3.23) | 2.71 (2.50-2.91) | 0.40 (0.13-0.67) | 0.003 |

*Cumulative risk per 100 patients standardized for sex, gender, race, government insurance, asthma, APR-DRG severity status, year of surgery, antibiotic use, and hospital using logistic regression and predictive margins.

In addition, when we examined the standardized rates of revisits for bleeding by post-discharge time period, there was a small increased rate of revisits associated with dexamethasone for days 1-2 (standardized difference 0.44 revisits per 1000 days of follow-up [95% CI, 0.09-0.78;P=0.01] and days 3-5 (standardized difference 0.76 revisits per 1000 days of follow-up [95% CI, 0.47-1.05];P<0.001). Of note, there was no increased rate of revisits associated with dexamethasone use for day 6-7 which had the highest rate of revisits for bleeding (Table 6 and Figure 8).

**Table 6. Standardized Rates of Revisits for Bleeding by Post Discharge Tim Period and Dexamethasone Treatment Group***

| | Treatment Group | | | |
|---|---|---|---|---|
| Postdischarge Time Period, days | Dexamethasone (N=97 242) | No Dexamethasone (N=42 466) | Difference (95% CI) | P value |
| 1-2 | 1.97 (1.76-2.16) | 1.52 (1.25-1.80) | 0.44 (0.09-0.78)[§] | 0.01 |
| 3-5 | 2.15 (1.98-2.32) | 1.39 (1.17-1.61) | 0.76 (0.47-1.05) | <0.001 |
| 6-7 | 4.41 (4.10-4.72) | 4.11 (3.62-4.59) | 0.30 (-0.30-0.91) | 0.33 |
| 8-14 | 1.62 (1.52-1.72) | 1.59 (1.42-1.76) | 0.03 (-0.18-0.24) | 0.76 |
| 15-30 | 0.06 (0.05-0.07) | 0.05 (0.03-0.07) | 0.01 (-0.01-0.03) | 0.33 |

*Rates per 1000 days of follow-up from days 1 through 30 after discharge, standardized for sex, age, gender, race, government insurance, asthma, APR-DRG severity status, antibiotic use and hospital, and 95% confidence intervals using discrete time failure models implemented in logistic regression. These are fixed effects estimates that represent within-hospital estimates averaged across 36 hospitals.[§]Interpreted as "for children treated with dexamethasone, there is a 0.44 increase in the standardized rate of revisits for bleeding during days 1-2 postdischarge per 1000 days of follow-up".

**Figure 8**

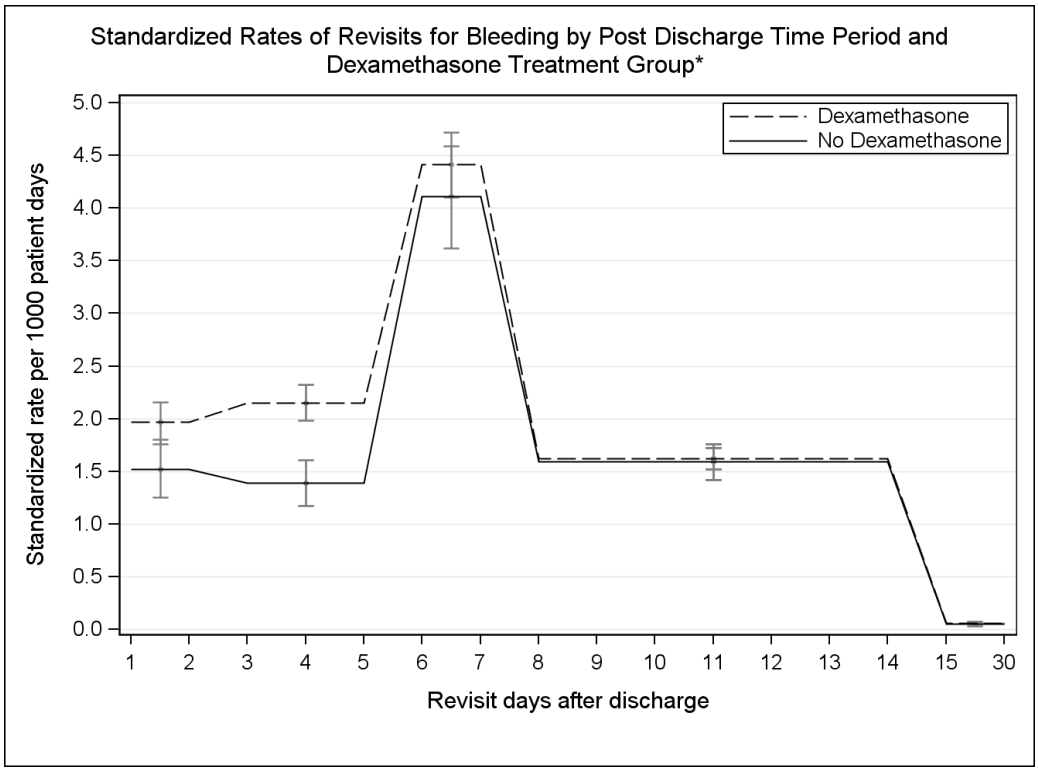



Figure 8. Standardized rates of revisits for bleeding by post discharge time period and dexamethasone treatment group
*Rates per 1000 days of follow-up from days 1 through 30 after discharge, standardized for sex, age, gender, race, government insurance, APR-DRG severity status, antibiotic use and hospital, and 95% confidence intervals using discrete time failure models implemented in logistic regression. These are fixed effects estimates that represent within-hospital estimates averaged across 36 hospitals.

*Limitations*

We were not able to assess surgical technique, which has been associated with bleeding risk. However, for surgical technique to have biased our results it would need to be associated with both dexamethasone use and postoperative bleeding. To our knowledge, there is no statistical association between surgical technique and dexamethasone use. We were not able to assess NSAID or steroid use after discharge. Although NSAIDs have been associated with increased bleeding risk in a few RCTs, a recent meta-analysis concluded that they are not associated with increased bleeding. Parents and children would likely return to the same hospital for bleeding complications, however, they may have sought follow up health care at different hospitals. Our data did not allow for tracking of children across different hospitals. Although a data quality program exists across institutions to ensure consistency of coding, misclassification in measures with this administrative data source may have occurred. Finally, given the observational design of this study there may be residual confounding.

*Implications*

We observed that dexamethasone was not associated with a clinically important increased risk of revisits for bleeding in a real-world practice setting across multiple centers. Our study adds to the current evidence base by providing more precise estimates of the risk of bleeding associated with

dexamethasone use. Postoperative nausea and vomiting occurs in more than 70% of children who do not receive prophylactic antiemetics and might result in prolonged hospital stay. A meta-analysis found that routine dexamethasone use in five children would result in one less experiencing postoperative vomiting. Dexamethasone was also associated with an increased likelihood of advancing diet and reducing pain. In considering the larger body of evidence on benefits and harms, the AAO-HNS guidelines make a strong recommendation for routine dexamethasone use without a role for patient preference because of a preponderance of benefit over harm and the value associated with the benefits to patients and the health care system. Our large observational study combined with this body of evidence from small RCTs support the safety of dexamethasone and these recommendations for the routine use of dexamethasone in children.

Drilldown #2, Study 3. Examining variation in resource utilization for children undergoing tonsillectomy

The objectives of this study were to determine (a) whether there is substantial variation in resource utilization, as measured by standardized cost, across hospitals for children undergoing same day tonsillectomy, (b) the major source of variability in resource utilization and (c) whether resource utilization is associated with risk of revisits for complications. This study is still in progress with the final analysis pending. We plan to submit this work to a peer reviewed journal.

Aim 1b, Drilldown #3: Appendectomy

Our third drill-down, using normalized costing for comparative analysis focused on a cohort of 37,469 children treated with low-severity appendicitis (non-perforated) at 39 PHIS hospitals from 2007 to 2012. This drilldown was co-led by Dr. Rangel and Dr. Shah.

The goal of the drill-down was to characterize the magnitude of cost variation across hospitals and to identify aspects of management that were associated with the greatest relative cost in the treatment of this disease.

Cost variation between hospitals, both overall and associated with specific management areas, was analyzed. Solutions were developed for all data quality issues, including a novel method for assigning room-associated costs based on three levels of acuity. This approach was devised to address inconsistencies between hospitals in how patients are assigned and charged for facility services (room cost).

Key findings from the analysis included a greater than two-fold difference among hospitals in overall median treatment-related cost, as well as significantly different treatment-related cost within the cohort for each of the individual management areas examined (Figure 9). Operating room costs were found to be the greatest driver of cost variation overall and among most hospitals, while facility costs were a close second for both overall cost and inter-hospital variation (Figure 10). A manuscript is currently in preparation.

**Figure 9:** Variation in treatment-related cost in the management of uncomplicated appendicitis at 39 freestanding children's hospitals.

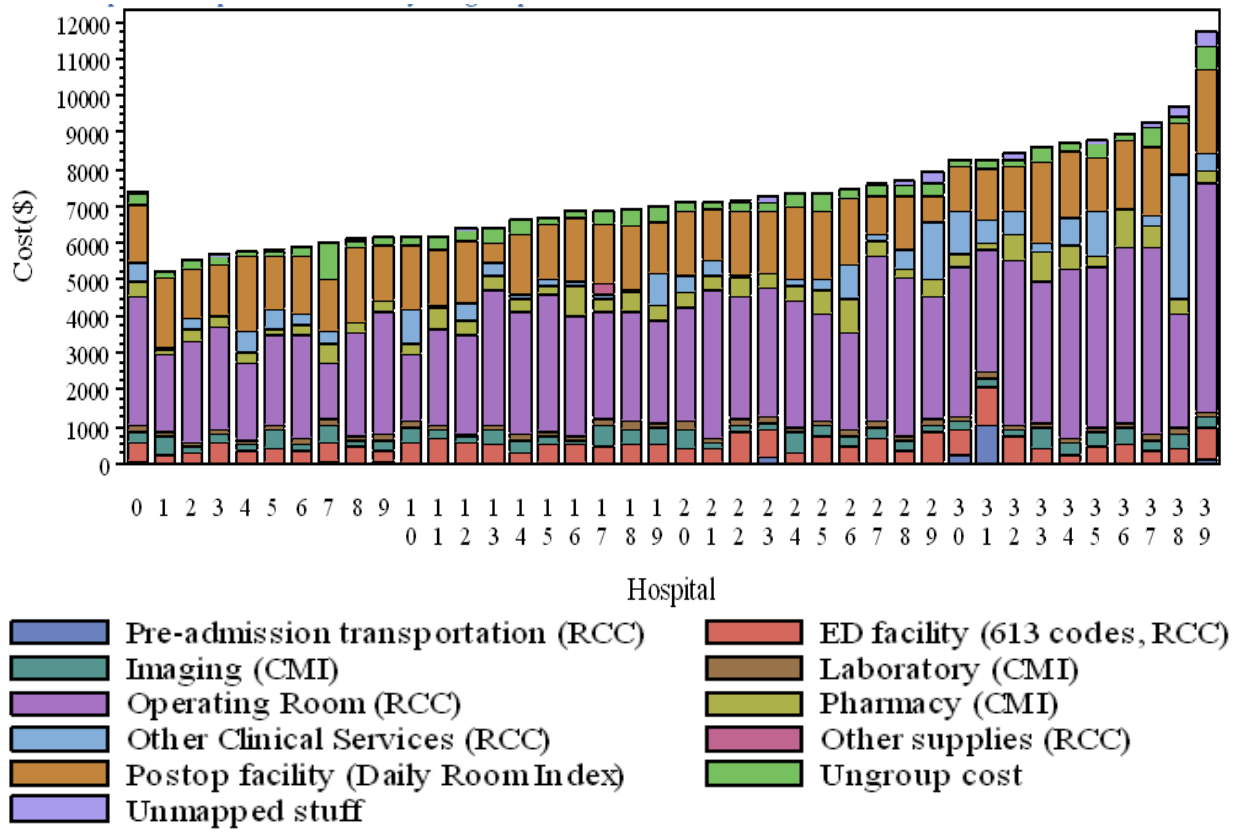
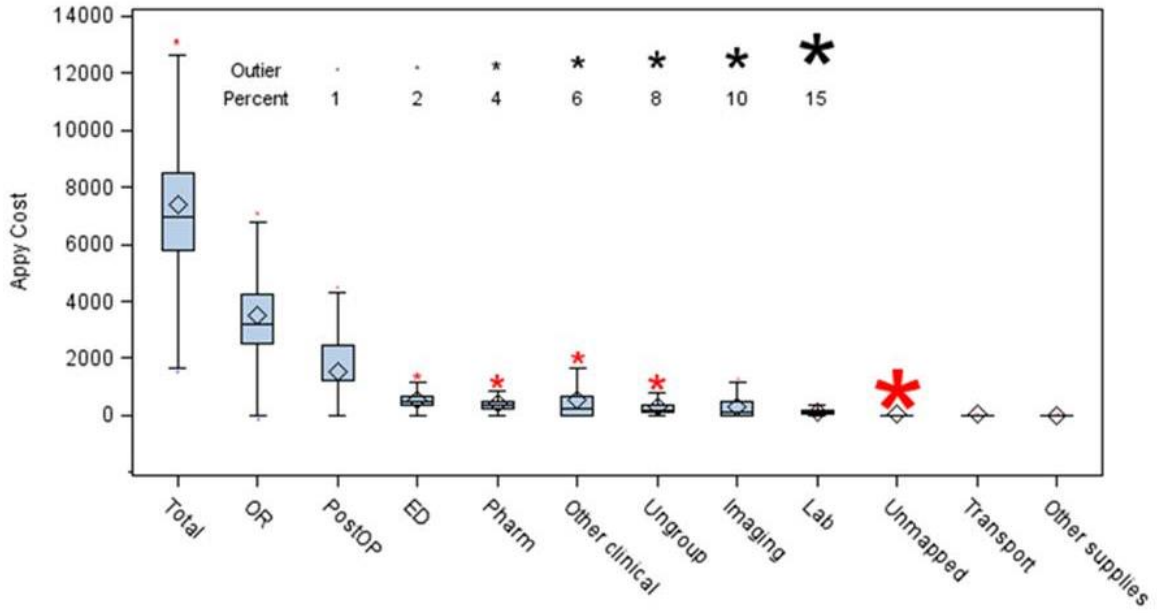



**Figure 10:** Relative contribution and cost-variation of different management areas in the treatment of uncomplicated appendicitis in children.



In the next phase, the team explored the relationship between standardized overall cost (and cost related buckets) and readmission/revisit rates as a framework for identifying high-value hospitals, with a goal to set the stage for a collaborative quality improvement network where best practices can be identified and disseminated from hospitals that are positive outliers for both case-related standardized costs and revisit rates. Hospital readmission and resource utilization have been increasingly targeted as markers for quality of care although the relationship between these measures has not been well characterized in the context of defining value-based care. The objective of this phase of the project was to characterize variation in resource utilization and inpatient readmission associated with treatment of uncomplicated appendicitis at children's hospitals and to examine the relationship between these measures as a framework for establishing benchmarks for comparative analysis and value-based care.

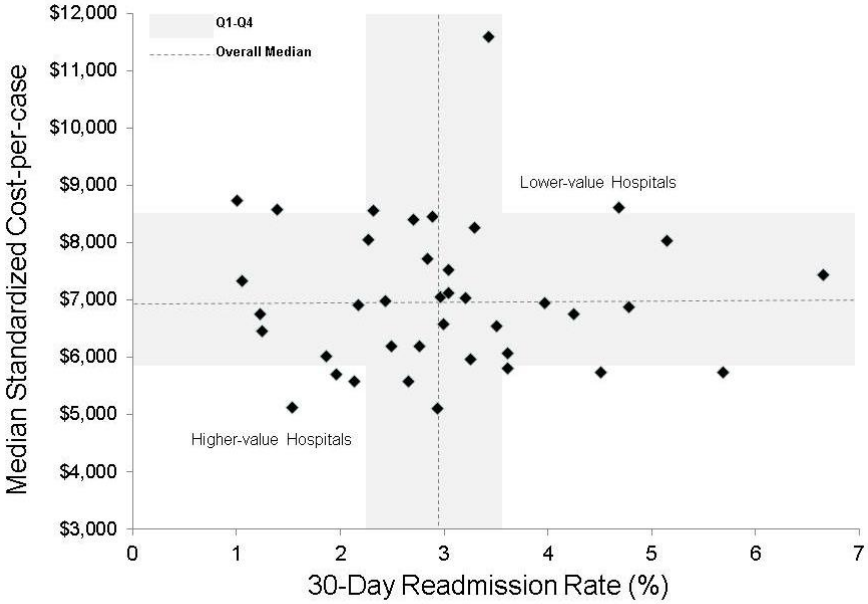
A retrospective cohort study was done using the same cohort of 37,469 patients as above. The main outcome measures were median standardized cost per case (as a surrogate for resource utilization) and thirty-day standardized postoperative readmission rate.

Results

The median standardized cost per case was $6,985 and this differed by more than two-fold across hospitals (range: $5,103 to $11,588, $p<0.001$). The overall 30-day readmission rate was 3.0% and this varied nearly seven-fold across hospitals (range: 1.0% to 6.7%, $p<0.0001$). Fifteen (38%) hospitals were identified as outliers by median cost (9 low-cost and 6 high-cost) and 16 (41%) were outliers by readmission rate (11 with low rates and 5 with high rates). Poor agreement was found between quartile-based hospital rankings based on readmission rates and median cost (weighted Kappa=-0.102 [95% CI: -0.227 to 0.201]), and increased resource utilization was not associated with lower readmission rates (figure 11). Three (8%) hospitals were found to be high-performers for both measures.

CONCLUSIONS: There is poor correlation between resource utilization and readmission following treatment of uncomplicated appendicitis at children's hospitals, and increased resource utilization does not lead to better outcomes. Dissemination of best-practice guidelines from "high-value" hospitals may provide an effective strategy to facilitate cost-containment without sacrificing quality of care for children with this disease.

**Figure 11.**




Aim 1b, Drilldown #4: Pneumonia

The 4th drilldown, which explored pediatric pneumonia, was led by Dr. Wilson.
Pediatric pneumonia is the 5th most common cause of pediatric hospitalization, and is associated with significant morbidity, including need for surgical intervention and intensive care utilization. The total standardized cost of pneumonia at 43 PHIS institutions was almost $900,000,000 over 6 years. There is a significant amount of variability between hospitals in diagnostic testing for children with pneumonia, and an increase in testing was associated with an increased length of stay. We now have a guideline for the treatment and management of community acquired pneumonia is children > 3 months, and thus the ability to measure the variability in resource utilization in the context of adherence to the recommended guidelines.

Pneumonia is a clinical and radiologic diagnosis which often coexists with a diagnosis of asthma; however it is unclear how concomitant asthma impacts the variability in resource utilization and guideline adherence for pneumonia, and whether the guidelines are useful in shaping our diagnosis and treatment of these more complex conditions. In this study, we examined the relationship between resource utilization, guideline adherence, and outcomes, for children with pneumonia, pneumonia + acute asthma exacerbation, and pneumonia + asthma history.

The specific aims of this project are:

1. To understand the extent of and factors associated with *variability in resource utilization* for community acquired pneumonia (CAP) and pneumonia + acute asthma (CAP + asthma), in children's hospitals
2. To determine the association between adherence to pneumonia guideline recommendations and *resource utilization* in children with pneumonia (PNA) and CAP + asthma.
3. To determine the relationship between pneumonia guideline adherence and *outcomes* in children with PNA, and CAP + asthma.

The pneumonia drill-down team began work in October 2012. Since that time, work has been done to define the patient cohort and create our two subgroups. We identified and excluded inappropriate cases based on diagnoses, and outlier for costs. We have completed the initial round of statistical analyses, and are in the process of transitioning the final analytics to our epidemiologist in Denver.

Our timeline has been extended by about 6 months because of complications in the data cleaning and analysis; the final analyses will be completed by our epidemiologist, Dr. Michelle Torok. In the next 3 months we will finish the data analysis and write up the results for publication. We anticipate submitting the manuscript to *Pediatrics*.

Methods

The team used administrative data from 42 children's hospitals in the PHIS Database. We identified subjects with CAP from ICD-9 codes using a validated approach. We excluded children with non-CAP antibiotics, age<2 years, viral pneumonia, and significant comorbidities. Patients with a diagnosis of asthma and code for albuterol treatment were considered CAP+asthma. Costs were standardized using the Cost Master Index. Geometric means were used for cost and length of stay (LOS), and t-tests, chi-square statistics, and regression analyses were used to compare the CAP and CAP+asthma groups.

Findings

The final cohort included 30,558 patients; 24,039 patients (79%) with CAP only, and 6,519 patients (21%) with CAP+asthma. Patients with CAP+asthma were more likely than those with pneumonia alone to be <5 years of age (51% vs. 49% p<.001) and to have government insurance (45% vs. 41%; p<.001). They also had a longer mean LOS (2.18 days vs. 2.03 days; p<.001) and higher mean of total standardized costs ($5259 vs. $4838; p<.001). The range among hospitals for mean LOS for pneumonia was 1.4-2.6 days, while the mean length of stay range for CAP+asthma was 1.5-2.8. The geometric mean cost range for pneumonia was $3129-$6525, while for CAP+asthma it was $3711-$8146. There were significant differences by metrics [table 7]. In multivariate models, CAP+asthma predicted increased cost for non-ICU patients, but not LOS.

*Table 7: CAP guideline metric adherence by CAP vs. CAP+asthma*

| **Metrics** | CAP only N (%) | CAP+asthma N (%) | p-value |
|---|---|---|---|
| % **with** CXR | 18998 (81.88) | 5126 (84.28) | <.0001 |
| % **with** blood culture | 11951 ( 51.51) | 2700 (44.39) | <.0001 |
| % **without** CBC | 8517 (36.71) | 2569 ( 42.24) | <.0001 |
| % **with** respiratory viral panel testing | 7128 (30.72) | 1992 ( 32.75) | 0.0023 |
| % **with** macrolide **with** mycoplasma testing | 1576 (6.79) | 428 (7.04) | 0.5007 |

Conclusions

About 20% of children hospitalized with CAP also have asthma. Asthma was associated with higher costs among non-ICU patients. The ambiguity in treating two diagnoses may lead to treatment uncertainty and increased resource utilization.

Aim 1b, Severe Asthma Pathway Project

In the prioritization phase of the project, asthma was identified as the third most common and the sixth most costly reason for hospital admission within the CHA hospital network. That analysis also revealed moderate variability in costs for asthma admission (ICC= 0.09) prompting us to further investigate the potential reasons for variability in asthma care and costs. Given the lack of granularity with regard to frequency and duration of inpatient therapies within the PHIS dataset, we initiated a pilot investigation using data from the electronic medical record at The Children's Hospital of Philadelphia (CHOP), a high volume asthma center. Dr. Chen Kenyon MD MSHP. Dr. Kenyon was added to the grant in July 2013, replacing Dr. McLeod.

Methods

In this retrospective cohort study, we sought to investigate how demographic, clinical presentation, or treatment factors contributed to individual level outcomes, such as prolonged therapy, ICU transfer, adverse medication effects and length of stay, using a dataset developed from the CHOP Data Warehouse.

Results

We identified 4921 patients admitted to CHOP for asthma over a two year interval, 3003 of whom met our study criteria. We found that children treated for severe asthma with continuous aerosolized albuterol (CAA) had higher rates of transfer to the ICU, as well as lengths of stay that were approximately 17 hours longer than for those children treated with intermittent therapy (57.0 vs 40.2, $p<.001$). 25% of patients who received CAA therapy were treated with this modality for more than 24 hours and preliminary cost estimates indicate that prolonged CAA therapy leads to nearly twice the amount of hospital charges and insurance payments.

Next Steps

We hypothesize that treatment with continuous albuterol, as well as prolonged treatment – which may reflect the severity of asthma exacerbation, contributes substantially to cost variation, which should be investigated in future multicenter analyses. Additionally, this analysis identified factors associated with prolonged therapy and failure of therapy, which will be used to help predict these outcomes and initiate enhanced therapies earlier in the hospital course.

**Specific Aim 2: Volume-Quality-Outcome Relationships in Treating Pediatric Hospital Conditions**

Numerous studies in the adult and surgical worlds have shown that for many conditions higher provider and hospital volume is associated with higher compliance with best practices and improved outcomes, proving the old adage that "practice makes perfect". However, very little is known about whether this is true for pediatric conditions and the mechanisms through which increased volumes produce better care.

Aim 2a: To examine the relationship of provider and hospital patient volume of gastroenteritis, asthma and bronchiolitis admissions with adherence to disease-specific quality indicators—process measures drawn from nationally endorsed practice guidelines and systematic reviews

Hypothesis 2a: There will be a positive relationship between hospital and provider patient volume and adherence to disease-specific quality indicators.

The researchers, led by Dr. McLeod, conducted a retrospective cohort study using administrative data from the Premier database to analyze the relationship between volume of acute gastroenteritis (AGE) admissions and adherence to quality indicators derived from established guidelines published by the American Academy of Pediatrics (AAP) and Centers for Disease Control (CDC). Quality indicators included blood testing, stool studies, use of antibiotics, and use of non-recommended anti-emetic or anti-diarrheal medications (NRGIs). Between 2007 and 2009, a total of 12,604 patients ages 3 months to 10 years of age were admitted to 280 hospitals with at least one ICD-9 diagnosis code for AGE. Characteristics of the sampled hospitals closely matched AHA national discharge statistics (Table 8). Most children in the study sample were between the ages of 3 months and 3 years (80%), admitted from the emergency department (58%), cared for in hospital by pediatricians (79%), had a length of stay between 1-3 days (92%), and were rated as minor severity at discharge (78%). Relevant patient characteristics were balanced across volume categories. Analyses were performed using multilevel logistic regression, adjusting for hospital and patient characteristics and accounting for clustering of patients within hospitals.

**Table 8:** Hospital Characteristics Overall and Across Categories[a] of Average AGE Admissions per Year

| **Characteristics** | **Overall(n=280)** | **Small (n=98)** | **Medium (n=89)** | **Large (n=93)** |
|---|---|---|---|---|
| Providers n | 4089 | 566 | 1115 | 2409 |
| Patients n | 12,604 | 972 | 2744 | 8888 |
| Hospital Admits: Total[b] median/yr (range) | 1758 (22-10160) | 787 (22-6250) | 1707 (130-6076) | 3401 (514-10160) |
| Hospital Admits: Gastroenteritis median/yr (range ) | 13 (1-174) | 4 (1-7) | 13 (7-18) | 30 (18-174) |
| Attending Admits: Gastroenteritis median/yr (range) | 1 (1-35) | 1 (1-5) | 1 (1-8) | 1 (1-35) |
| Pts/Attending: Total 2007-09[b,c] | 67 (1-335) | 56 (6-204) | 66 (8-194) | 81 (13-335) |
| Pts /Attending: Gastroenteritis 2007-09 | 4 (1-20) | 2 (1-10) | 2 (1-19) | 5 (1-20) |
| Hospitals in Database All 3yrs, n (%) | 249(89) | 85(87) | 79(89) | 85(91) |
| Region/Location[c], n (%) | | | | |
| South/urban | 90(32) | 23(23) | 23(26) | 44(47) |
| South /Rural | 45(16) | 18(18) | 18(20) | 9(10) |
| West /urban | 35(13) | 13(13) | 10(11) | 12(13) |
| West/rural | 13(5) | 11(11) | 2(2) | 0(0) |
| Midwest/urban | 44(16) | 15(15) | 19(21) | 10(11) |
| Midwest/rural | 19(7) | 8(8) | 7(8) | 4(4) |
| Northeast/urban | 31(11) | 9(9) | 9(10) | 13(14) |
| Northeast/rural | 3(1) | 1(1) | 1(1) | 1(1) |
| Teaching Hospital Admissions[c], n (%) | 78(28) | 13(13) | 22(25) | 43(46) |
| Payer-mix[b,] , mean (sd) | 0.48(.18) | 0.51(.17) | 0.45(.17) | 0.47(.18) |
| Case-Mix[b,c] , mean (sd) | 1.3(.17) | 1.2(.10) | 1.3(.12) | 1.4(.19) |

[a] Hospital size categories were determined by dividing all hospitals into terciles of average gastroenteritis admissions/year; [b] Total variables constructed using all children 0-10 years of age admitted to each hospital over the 3 year study period; [c] Bivariable regression using clustered survey methods to compare distribution of covariate across continuous measure of volume is significant with $p<.01$.

Misuse of Care. Use of NRGIs was generally low (6%), and varied by location and region, ranging from 1.5% in Northeastern urban hospitals to 16% in Southern rural hospitals. Twenty-six percent of the children received antibiotics. Use was higher if bacterial gastroenteritis was

diagnosed (63% vs. 23%), and ranged from 14% at Northeastern urban hospitals to 37% at Southern rural hospitals. After adjustment for patient- and hospital-level covariates, higher AGE and total admission volumes were associated with less frequent use of NRGIs and antibiotics (Table 9). Marginal probabilities estimated from adjusted analyses indicated that children admitted to hospitals at the 25$^{th}$ versus the 75$^{th}$ percentile of AGE volume had a 30% and 10% increased chance of receiving NRGIs and antibiotics, respectively.

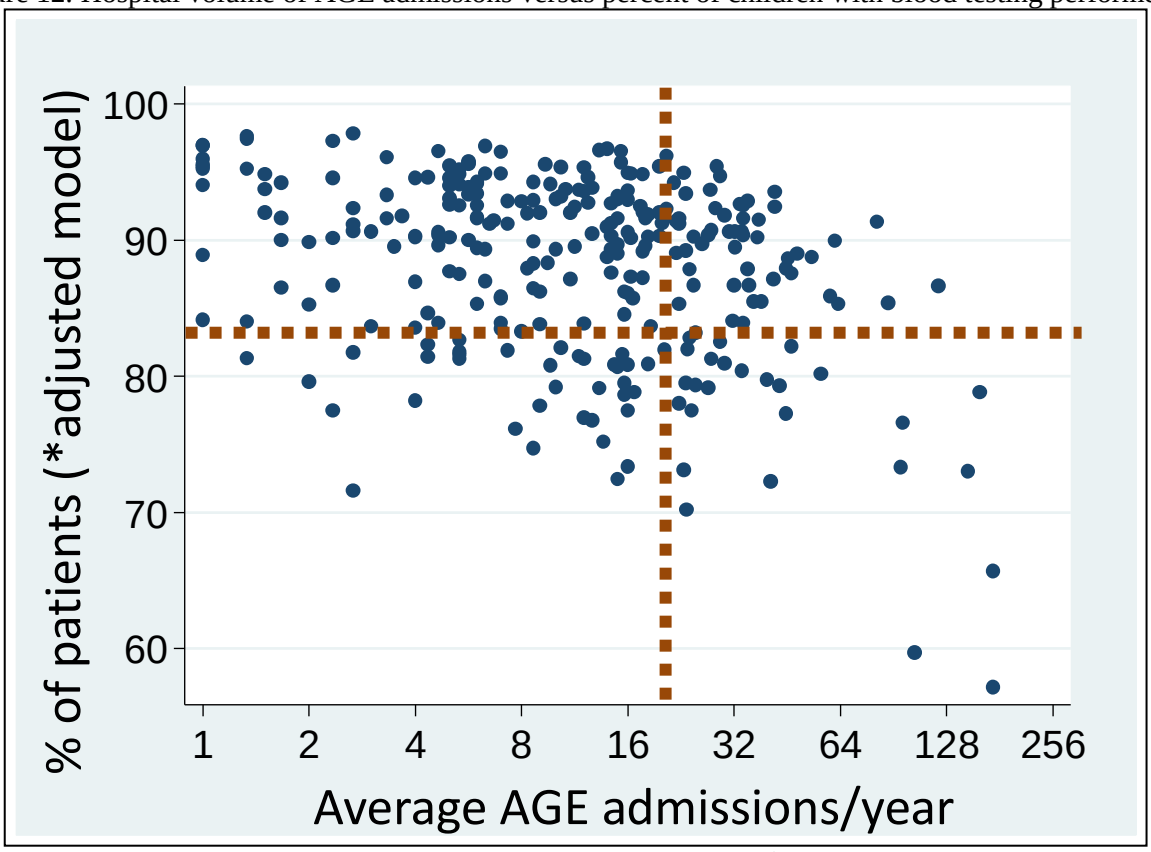
**Table 9:** Adjusted Odds of Outcomes Across Avg Annual AGE Admissions and Avg Total Admissions of Patients Ages 0-10 Yr

| **Misuse of Care** | **AGE Admissions (OR (95% CI) p-value)** | **Total Admissions (OR (95% CI) p-value)** |
|---|---|---|
| Antiemetic/Antidiarrheal Medications | 0.84 (0.76-0.93) p<.001 | 0.81 (0.71-0.92) p<.001 |
| Antibiotics | 0.93 (0.86-1.0) p=.04 | 0.88 (0.81-0.97) p=.01 |
| **Overuse of Care** | | |
| Blood Tests | 0.72 (0.59-0.88) p<.001 | 0.60 (0.48-0.76) p<.001 |
| Stool Studies | 0.95 (0.85-1.05) p=.35 | 0.89 (0.78-1.01) p=.07 |
| Rotavirus Testing | 1.13 (0.99-1.28) p=.06 | 0.99 (0.95-1.17) p=.98 |

[a]Patient-level covariates (age, gender, race, payer, severity, year/quarter, bacterial gastroenteritis, admitting attending, admission source), and fixed hospital-level covariates (location, region, teaching status, physician to patient ratio) tested in each model.

Overuse of Care. Blood tests were performed in 80% of children, ranging from 76% at Northeast urban hospitals to 94% at Southern rural facilities. Stool and rotavirus testing occurred in 46% and 56% of children, respectively, with less variation in testing across regions and locations. In adjusted analyses, higher AGE and total admission volumes were associated with less frequent use of blood testing (Table 9). Odds ratios for the association between AGE and total volume and stool or rotavirus testing did not achieve statistical significance in any model. Marginal probabilities estimated from adjusted analyses indicated that children admitted to hospitals at the 25$^{th}$ versus the 75$^{th}$ percentile of AGE volume had a 10% increased chance of having blood tests performed. Excluding children with bacterial AGE did not change the direction or significance of the associations, and adjusting for physician AGE volume had no effect on the estimates. Finally, volume-quality associations were not homogenous within volume strata (Figure 12).

Figure 12: Hospital volume of AGE admissions versus percent of children with blood testing performed.




*(Each point represents one hospital. Dotted lines represent the avg volume and avg percent of patients with blood testing across all hospitals)*

Conclusion. Using a nationally representative sample of hospitals that care for children with gastroenteritis, higher admission volumes were associated with greater adherence to established guidelines. The association was heterogeneous within volume strata indicating that higher quality could not be attributed solely to experiential learning. More research is needed to identify structural and organizational characteristics that drive quality for common pediatric conditions, regardless of hospital size.

Aim 2b: To examine the relationship of provider and hospital patient volume of gastroenteritis, asthma and bronchiolitis admissions with outcomes, such as length of stay (LOS), readmission, resource utilization and transfer to higher level of care.

Hypothesis 2b: Higher hospital and provider patient volume will be associated with shorter LOS, less frequent readmission, lower costs, and less frequent transfer to ICU. A portion of these associations will be mitigated by controlling for adherence to quality indicators.

Aim 2b, Study 1

Based on the list of high priority conditions identified in Aim #1, researchers chose spinal fusion procedures as the condition of interest to explore the volume/outcomes relationship for aim 2b. Spinal fusion operations for scoliosis in particular were chosen by researchers as an important condition to explore due to the high cost, high variation and surprisingly high prevalence. Studying variation in spinal fusion processes and outcomes was also seen as a high priority due

to the clinical impact on children with complex chronic conditions and the opportunity to study issues related to continuity of care, healthcare regionalization, and medical home models of care. Researchers designed a retrospective cohort study using administrative data from the PHIS database to analyze the relationship between hospital characteristics including procedure volume, processes variation, and outcomes. Outcomes included all cause readmission within 30 days of discharge from the index procedure, any ICD9 code indicating a complication, any diagnosis code indicating a surgical site or blood stream infection, and any reoperation within 30 days. As perioperative antibiotic choice is often a component of surgical site infection prevention protocols, the root mean squared error (RMSE) for categories of prophylactic antibiotic use was used as a marker for intra-hospital process variation. A total of 15,105 patients ages 6 months to 10 years were admitted to 40 major children's hospitals with (1) an ICD9 procedure code indicating a clean spinal fusion procedure, (2) an ICD9 diagnosis code indicating a non-traumatic, non-oncologic spinal deformity, and (3) look-back and follow up periods of > 6 months. Ninety-two percent of children were >10 years old at the time of their initial procedure. Just greater than half of the surgeries involved healthy adolescent children with idiopathic scoliosis (AIS), with 24% and 20% involved children with neuromuscular scoliosis (NMS), and children with other non-neuromuscular congenital deformities, respectively. Procedure volumes and the proportion of procedures performed on children with NMS and other congenital deformities varied remarkably across hospitals (Figure 13). Comparing the more homogenous NMS and AIS subgroups, children with NMS had slightly longer median lengths of stay (7 v. 6), higher rates of readmission at 30d (8% v. 1.8%), were more likely to have a discharge code indicating an adverse outcome (48% v. 12%), and more likely to have a reoperation within 30d (4.7% v. 1.4%). Similarly, choice of prophylactic antibiotics varied both across and within hospitals, and did not correlate with procedure volume. Both inter- and intra-hospital variation in antimicrobial prophylaxis as well as rates of broad spectrum antibiotic use were highest in the NMS cohort (Figure 14). In order to determine the independent effects of procedure volume and process variation on adverse outcomes, researchers performed multilevel logistic regression, adjusting for hospital and patient characteristics and accounting for clustering of patients within hospitals. All models with the exception of the healthy AIS subcohort, were adjusted for patient insurance, specific technology dependence, diagnosis of neuromuscular disease, diagnosis of spina bifida, age category, prior admissions, gender, and discharge year.

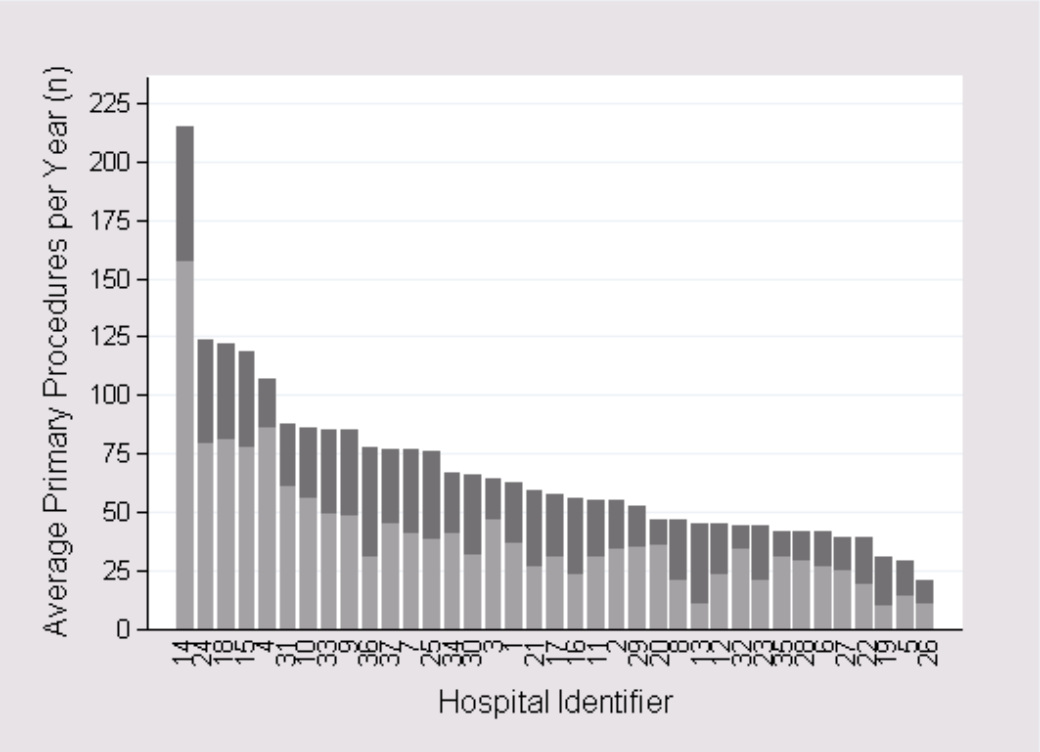



**Figure 13:** Average annual primary procedures involving children with AIS (light gray segments) and NMS (dark gray segments) performed across 37 US children's hospitals. Each bar represents a single hospital. Height of each bar is the total number of procedures performed at a particular hospital per year.

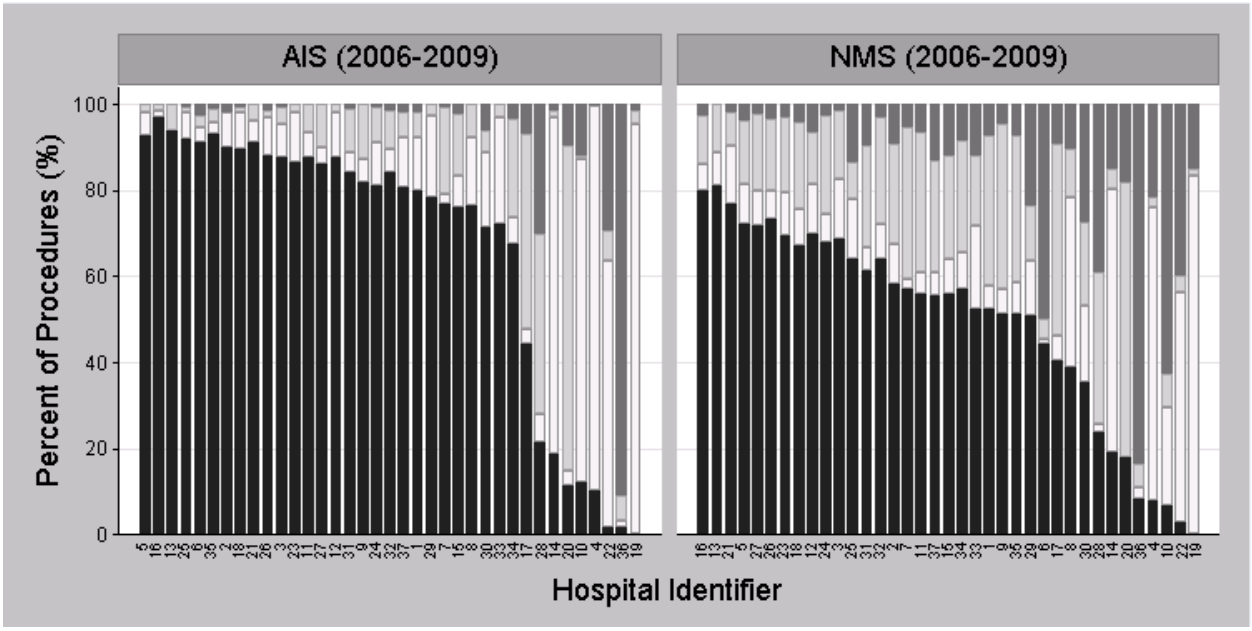



**Figure 14:** Patterns in prophylactic antibiotic choice for AIS and NMS procedures performed at 37 children's hospitals from 2006 to 2009. Each bar represents a single hospital. Bar segments represent the percent of procedures for which each antibiotic regimen was ordered, including: (1) cefazolin only (black), (2) addition of MRSA coverage with vancomycin or clindamycin (white), (3) addition of broad spectrum gram-negative coverage (light gray), or (4) addition of both MRSA coverage *and* broad spectrum gram-negative coverage (dark gray). Bar height equals the 100%.

Results. The occurrence of any complication as defined by ICD9 coding, rates of reoperation, rates of readmission at 30 days, and variation in antibiotic use, had no significant association with annual hospital volume, subgroup (AIS or NMS) volume, or proportion of procedures involving children with neuromuscular disease. Process variation, as represented by the RMSE for categories of antibiotic use, was not associated with the occurrence of complications or early reoperations, but was significantly associated with 30 and 60 day readmissions in the NMS subgroup (OR 1.8, 95% CI 1.2-2.6, $p<0.01$ for overall RMSE; OR 2.3, 95% CI 1.3-4.0, $p<0.01$ for NMS RMSE). The same process variation-outcomes relationships were not observed for the total cohort or AIS subcohort.

Conclusion. Using a sample of non-competing US children's hospitals, the team identified a high degree of variation in procedure volume, prophylactic antibiotic use, and adverse outcomes. Preliminary risk-adjusted analyses did not identify any statistically significant associations between procedure volume or process variation, and coded complications or early reoperations. However, among children with NMS, higher degrees of process variation were associated with increased odds of readmission in 30 and 60 days.

Aim 2b, study 2

Given the above results indicating that volume was not associated with outcomes such as readmission, reoperation, or surgical site infection (SSI), the team continued to pursue other risk factors that may be contributing to poor outcomes within and/or across hospitals. After exploring prophylactic antibiotic use, focus was turned to a second identified risk factor of blood loss and blood conservation strategies, primarily the use of pharmacologic agents that inhibit clot breakdown (Antifibrinolytic agents, or AF agents). The team designed a retrospective cohort study using administrative data from the PHIS database to analyze the relationship between the use of AF agents (ε-aminocaproic acid (EACA), tranexamic acid (TXA) and aprotinin (APR)) and blood loss. The primary outcome was blood transfusions during the procedural admission. The team selected all children ages 0-18 discharged from PHIS hospitals between 1/1/06-9/30/09, for which a spinal fusion procedure was performed for scoliosis. Patients with diagnoses indicating malignancy or coagulation disorders, as well as cases in which patient blood was collected and autotransfused during the procedure were excluded. Sub-cohorts of patients with Neuromuscular Scoliosis (NMS) and Adolescent Idiopathic Scoliosis (AIS) were selected, using procedure and diagnosis algorithms previously published by the research group. Analyses comparing the effectiveness of each drug were performed for each sub-cohort separately. To determine the relationship between antifibrinolytic use and blood transfusion procedures, the researchers performed multilevel logistic regression controlling for factors that were significantly associated with antifibrinolytic use or significantly associated with blood transfusions. The team then estimated the average treatment effect of antifibrinolytic use in patients with similar characteristics undergoing similar surgeries, under the assumption that there is no residual confounding by unmeasured factors. In both sub-cohorts, which consisted of 2,722 operations for AIS and 1,517 operations for NMS, the proportion of children in the treated group increased over time (13%-42%), while transfusion rates remained stable. Children with the greatest medical complexity, children undergoing a posterior only procedure, and children with >9 vertebrae fused were more likely to be treated. Of the AF agents, EACA was used most frequently (15%), followed by TXA (7%), and APR (2.2%). The median hospital-specific red cell transfusion rate was 24% (IQR 5-44%) for children with AIS and 43% (IQR 14-63%) for children with NMS.

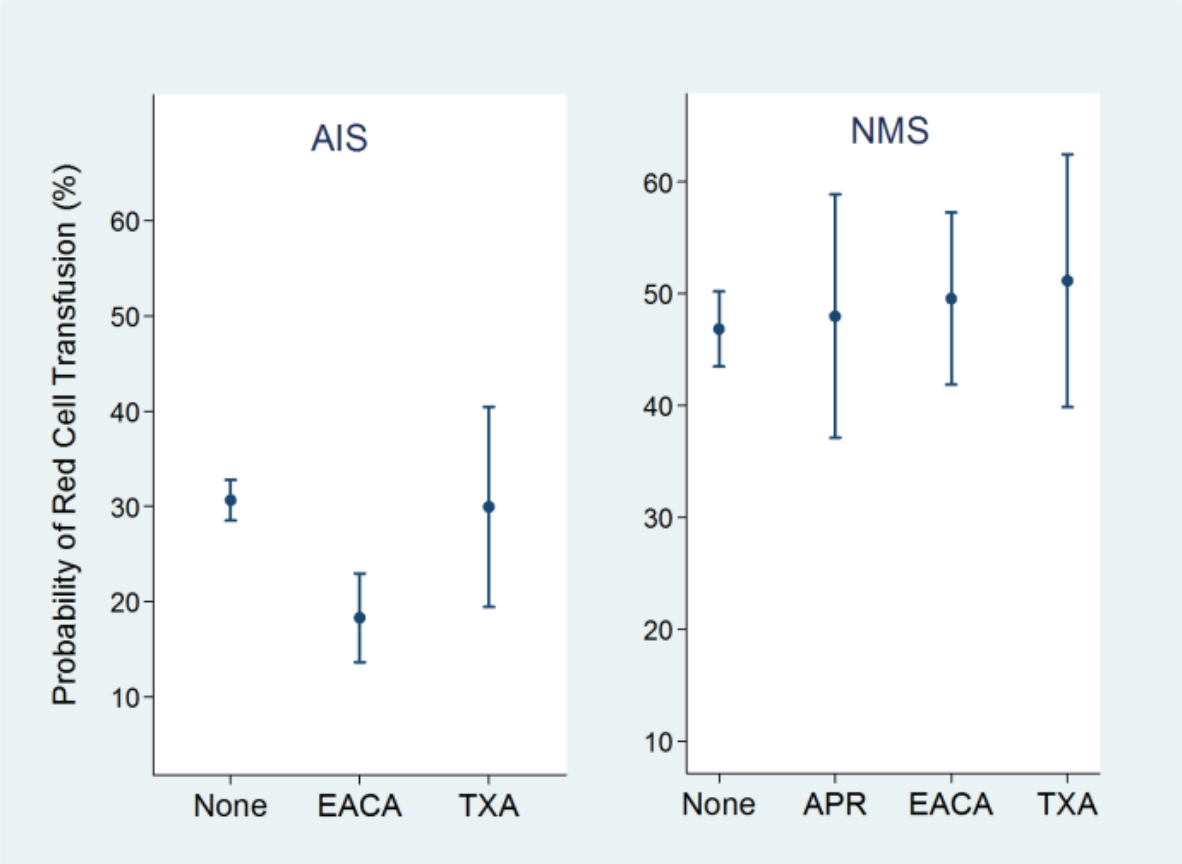
Across hospitals, rates of antifibrinolytic use were not correlated with unadjusted mean transfusion rates. For AIS operations, only EACA use was associated with a significant reduction in odds of transfusion (0.42, p<0.001; Table 10), and the reduction in probability of transfusion for patients in the treated vs. untreated groups was 13% (95% CI, 0.08-0.18), corresponding to a number needed to treat (NNT) of between 8 and 13 children (Figure 15). However, there was no association between red cell transfusions and the use of EACA (OR 1.2, p=0.5), TXA (OR 1.3, p=0.4), or APR (OR 1.2, p=0.7; Table 10). The team concluded that (1) use of these agents was highly variable and increasing over time with no significant changes in transfusion rates, (2) EACA may be an important component of blood conservation in children undergoing spinal fusion surgery for AIS, and (3) use of all of these drugs should be prospectively studied in order to account for factors such as dosing and concurrent practices for blood conservation which may vary by institution.

**Table 10:** Odds ratios (OR) and 95% confidence intervals (CI) for the association between red cell transfusion and ε-aminocaproic acid (EACA) or tranexamic acid (TXA) use in AIS and NMS procedures

| | **AIS Procedures n=2,722** | **NMS Procedures n=1,547** |
|---|---|---|
| EACA, OR (95% CI) | 0.42 (0.26,0.67)[a] | 1.2 (0.73, 1.9) |
| TXA, OR (95% CI) | 1.0 (0.48,1.9) | 1.3 (0.68,2.4) |

[a] *p<0.001*

**Figure 15:** Standardized (adjusted) probabilities (point estimates with 95% CI) for receiving a blood transfusion in AIS (Left) and NMS (Right) procedures with and without use of antifibrinolytics, as estimated from multivariable analyses (EACA=ε-aminocaproic acid, TXA=tranexamic Acid, APR=aprotinin).



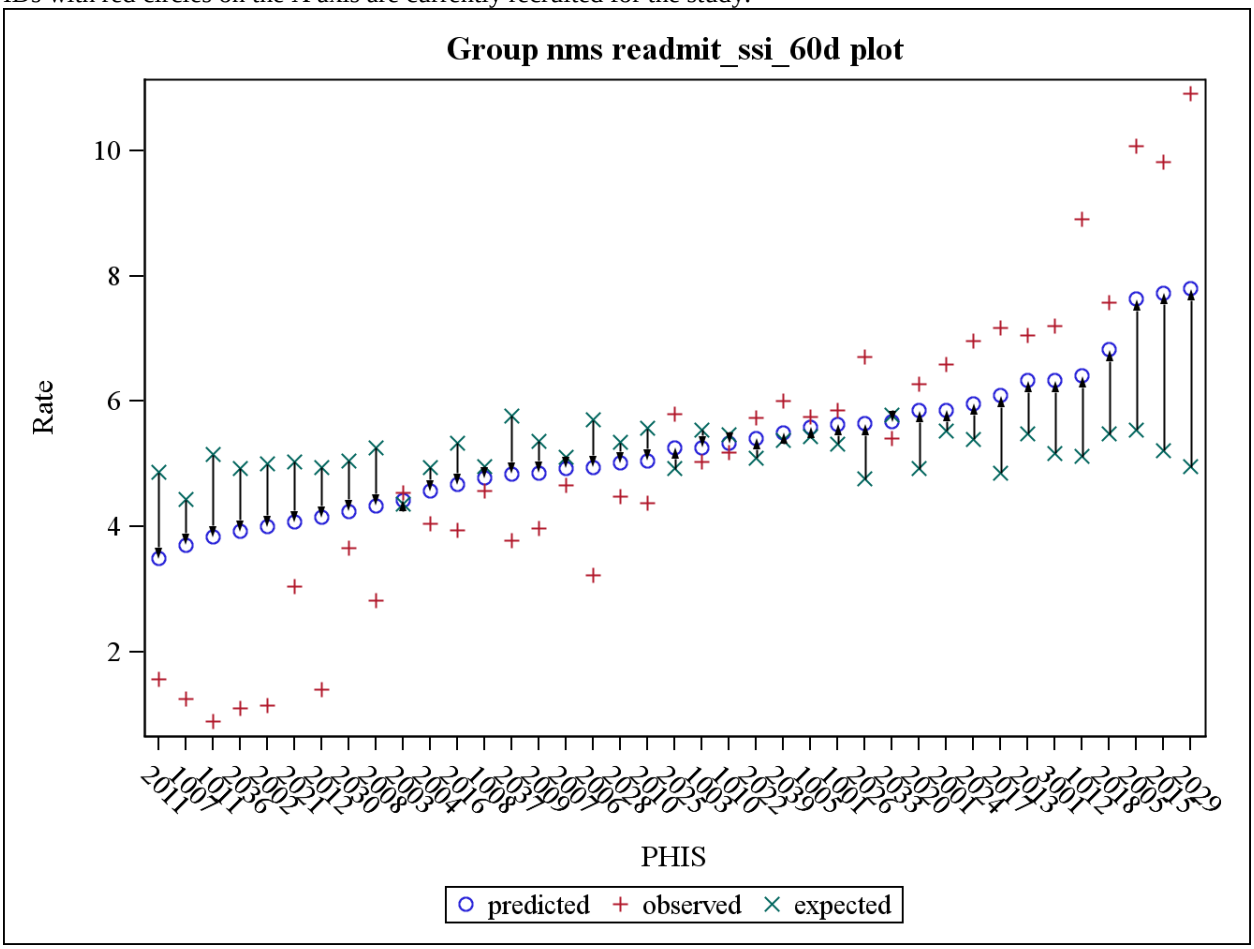

Next, researchers completed complex adjusted analyses demonstrating significant outcomes variation for children undergoing spinal fusion procedures. Administrative data from the PHIS was used to first identify hospitals that were high and low outliers for adjusted rates of surgical site infection (SSI). Children ages 10-18 years who had undergone an elective spinal fusion procedure for either adolescent idiopathic (AIS) or neuromuscular scoliosis (NMS) between 2007-2012 were selected from the database using a previously described algorithm.

The final cohort included 13,112 children with AIS and 7,560 children with NMS. Multivariable logistic regression was used to determine the rates of SSI, reoperation, and readmission at 14, 30, 60, and 365 days post-discharge, adjusted for patient medical and surgical comorbidities, age, and year of procedure. Statistical analyses for determining Predicted vs. Expected ratios (*pe)* were then performed to determine the deviation of each hospital's adjusted rate of SSI from what would be expected for all patients with similar combinations of characteristics across all hospitals. Examples of plots illustrating the unadjusted and adjusted outcomes rates, as well as the deviations of hospital rates from what would be expected for the hospitals given case-mix are shown in Figure 16.

Variation across hospitals in unadjusted rates of SSI at 60 days was significantly greater in the NMS vs. AIS population, ranging from 1.6-10.9%. As shown in Figure 16, 17 hospitals had

better than expected outcomes (*pe* <1.0), and 15 hospitals had worse than expected outcomes (*pe* <1.0). A manuscript reporting these results is currently in progress.

**Figure 16:** Observed, expected, and predicted SSI rates across 39 children's hospitals from 2007-2012. Red plus signs represented unadjusted SSI rates for the NMS population, blue circles represent the predicted (adjusted) rates of SSI, and green x's represent the expected rates of SSI based on each hospital's particular case mix. Arrows show the deviation of each hospital's adjusted SSI rates from what would be expected from their given case mix. Hospital IDs with red circles on the X axis are currently recruited for the study.




Aim 2c: For conditions that demonstrate a strong volume-quality relationship, to identify hospital structures and processes in hospitals that are exceptions to the rule—those that demonstrate high quality (defined in terms of adherence to disease-specific quality indicators and avoidance of therapies shown to be ineffective) despite relatively low patient volumes, and those that exhibit poor quality despite high patient volumes.

Hypothesis 2c: Hospitals that demonstrate high quality relative to patient volume for particular conditions will be more likely to have structures such as robust electronic medical records with decision support, and processes such as clinical practice guidelines, systematic tracking of outcomes, and root cause analyses of safety events.

Aim 2c

Aim 2c has not been completed. The team determined that in order properly explore this aim, more preliminary data and resources were needed. Therefore the team chose to use the DOH funding to generate more data focusing on aims 2a and 2b in order to design a higher yield, higher impact study of structural and organizational factors that may influence variation in processes and outcomes (see info about additional funding in response to question #11 above).

Dr. McLeod's salary was removed from the DOH grant in March 2013 when she moved from CHOP to Colorado Children's Hospital. However, Dr. McLeod continued her participation on the project.

**Specific Aim 3: Evaluation of an Early Warning Scoring System**

The aim 3 portion of the project was led by Christopher Bonafide, MD MSCE, at CHOP. The project had 3 sub-aims as follows.

**Aim 3a:** To evaluate the effect of the implementation of a Rapid Response System on clinical outcomes and costs among children urgently transferred to the ICU.

The first of the two aspects of Subaim 3a, the impact on clinical outcomes, has been completed and published, resulting in 2 papers (as listed in question 20). Abstracts are below.

ABSTRACT #1(*Development of a pragmatic measure for evaluating and optimizing rapid response systems*)

OBJECTIVES: Standard metrics for evaluating rapid response systems (RRSs) include cardiac and respiratory arrest rates. These events are rare in children; therefore, years of data are needed to evaluate the impact of RRSs with sufficient statistical power. We aimed to develop a valid, pragmatic measure for evaluating and optimizing RRSs over shorter periods of time.

METHODS: We reviewed 724 medical emergency team and 56 code-blue team activations in a children's hospital between February 2010 and February 2011. We defined events resulting in ICU transfer and noninvasive ventilation, intubation, or vasopressor infusion within 12 hours as "critical deterioration." By using in-hospital mortality as the gold standard, we evaluated the test characteristics and validity of this proximate outcome metric compared with a national benchmark for cardiac and respiratory arrest rates, the Child Health Corporation of America Codes Outside the ICU Whole System Measure.

RESULTS: Critical deterioration (1.52 per 1000 non-ICU patient-days) was more than eightfold more common than the Child Health Corporation of America measure of cardiac and respiratory arrests (0.18 per 1000 non-ICU patient-days) and was associated with .13-fold increased risk of in-hospital death. The critical deterioration metric demonstrated both criterion and construct validity.

CONCLUSIONS: The critical deterioration rate is a valid, pragmatic proximate outcome associated with in-hospital mortality. It has great potential for complementing existing patient safety measures for evaluating RRS performance.

ABSTRACT #2(*Impact of rapid response system implementation on critical deterioration events in children*)

Importance: Rapid response systems aim to identify and rescue deteriorating hospitalized patients. Previous pediatric rapid response system implementation studies have shown variable effectiveness in preventing rare, catastrophic outcomes such as cardiac arrest and death.

Objective: To evaluate the impact of pediatric rapid response system implementation inclusive of a medical emergency team and an early warning score on critical deterioration, a proximate outcome defined as unplanned transfer to the intensive care unit with noninvasive or invasive mechanical ventilation or vasopressor infusion in the 12 hours after transfer.

Design, Setting, and Participants: Quasi-experimental study with interrupted time series analysis using piecewise regression. At an urban, tertiary care children's hospital in the United States, we evaluated 1810 unplanned transfers from the general medical and surgical wards to the pediatric and neonatal intensive care units that occurred during 370,504 non–intensive care patient-days between July 1, 2007, and May 31, 2012.

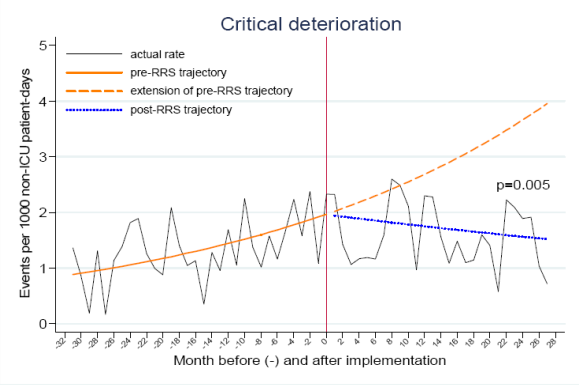
Interventions: Implementation of a hospital-wide rapid response system inclusive of a medical emergency team and an early warning score in February 2010.

Main Outcomes and Measures: Rate of critical deterioration events, adjusted for season, ward, and case mix.

Results: Rapid response system implementation was associated with a significant downward change in the pre-intervention trajectory of critical deterioration and a 62% net decrease relative to the pre-intervention trend (adjusted incidence rate ratio = 0.38; 95% CI, 0.20-0.75) as shown in Figure 17 below. We observed absolute reductions in ward cardiac arrests (from 0.03 to 0.01 per 1000 non–intensive care patient-days) and deaths during ward emergencies (from 0.01 to 0.00 per 1000 non–intensive care patient-days), but these were not statistically significant (P = .21 and P = .99, respectively). Among all unplanned transfers, critical deterioration was associated with a 4.97-fold increased risk of death (95% CI, 3.33-7.40; P < .001).

Conclusions and Relevance: Rapid response system implementation reversed an increasing trend of critical deterioration. Cardiac arrest and death were extremely rare at baseline, and their reductions were not statistically significant despite using nearly 5 years of data. Hospitals seeking to measure rapid response system performance may consider using valid proximate outcomes like critical deterioration in addition to rare, catastrophic outcomes.

**Figure 17**




Analysis for the second of the two aspects of Subaim 3a, the impact on cost outcomes, has been completed and a manuscript is in development. In this aim, we gathered data on 1,396 patients and determined the excess cost associated with critical deterioration events compared with other

unplanned transfer events that did not meet critical deterioration criteria. We then performed a cost-benefit analysis of rapid response system operation. We found that, after adjustment for potential confounders, patients not meeting critical deterioration criteria generated an average of $85,278 in costs, and patients meeting critical deterioration criteria generated an average of $185,052 in costs (difference of $99,773 per patient, 95% CI $69,431 – $130,116, P<.001). In cost-benefit analysis, we provided an example scenario of a hospital with 300 unplanned transfers from ward to ICU per year and a 30% critical deterioration proportion, and demonstrated that reducing that rate to 20% (from 90 to 60 critical deterioration events/year) would result in reducing critical deterioration costs by $2,993,190 per year, for a net savings of $687,732 when that reduction occurs using a freestanding rapid response team, and a net savings of $2,416,825 when that reduction occurs using a team with other clinical responsibilities.

**Aim 3b:** To validate the test properties of an early warning scoring system for identifying children on general inpatient wards who are clinically deteriorating. Aim 3b was not completed as focus was given to other aspects of Aim 3.

**Aim 3c:** To identify factors that contribute to false-positive and false-negative early warning scores using qualitative methods and evaluate the impact of a rapid response system on the hierarchical and cultural barriers relevant to patient safety. This subaim is complete. The findings are summarized in four manuscripts; one has been published and three are in press

Aim 3C -ABSTRACT #1(*Beyond statistical prediction: Qualitative evaluation of the mechanisms by which pediatric early warning scores impact patient safety*)
Background: Early warning scores (EWSs) assign points to clinical observations and generate scores to help clinicians identify deteriorating patients. Despite marginal predictive accuracy in retrospective datasets and a paucity of studies prospectively evaluating their clinical effectiveness, pediatric EWSs are commonly used.
Objective: To identify mechanisms beyond their statistical ability to predict deterioration by which physicians and nurses use EWSs to support their decision making.
Design: Qualitative study.
Setting: A children's hospital with a rapid response system.
Participants: Physicians and nurses who recently cared for patients with false-positive and false-negative EWSs (score failures).
Intervention: Semi-structured interviews.
Measurement: Themes identified through grounded theory analysis.
Results: Four themes emerged among the 57 subjects interviewed: (1) The EWS facilitates safety by alerting physicians and nurses to concerning changes and prompting them to think critically about deterioration. (2) The EWS provides less-experienced nurses with vital sign reference ranges. (3) The EWS serves as evidence that empowers nurses to overcome barriers to escalating care. (4) In stable patients, those with baseline abnormal physiology, and those experiencing neurologic deterioration, the EWS may not be helpful.
Conclusions: Although pediatric EWSs have marginal performance when applied to datasets, clinicians who recently experienced score failures still considered them valuable to identify deterioration and transcend hierarchical barriers. Combining an EWS with a clinician's judgment may result in a system better equipped to respond to deterioration

than retrospective data analyses alone would suggest. Future research should seek to evaluate the clinical effectiveness of EWSs in real-world settings.

Aim 3c-ABSTRACT #2(*Physician attitudes toward family-activated medical emergency teams for hospitalized children*)

Introduction: Medical emergency teams activated by clinicians have been shown to reduce in-hospital mortality. Some hospitals now enable family members to bypass clinicians and activate medical emergency teams directly. We aimed to explore physicians' viewpoints on (1) the ways in which families currently facilitate the identification of deteriorating children, and (2) the possibility of enabling families to independently activate a medical emergency team in the future.
Methods: We conducted semi-structured interviews with 30 physicians from a tertiary care children's hospital without a family-activated medical emergency team.
Results: Physicians described the important role of families in explaining their child's baseline and identifying subtle changes in their child's condition. However, physicians cited concerns that prevented them from endorsing family-activated medical emergency teams including misuse of the team, inappropriately asking parents to make assessments without clinical training, undermining therapeutic relationships, and burdening families. They also noted that evidence of family-activated medical emergency team effectiveness was needed before they could support implementation.
Conclusions: Physicians believed that families play an important role in detecting clinical deterioration, yet they viewed family-activated medical emergency teams as unproven interventions that may have unintended consequences. Future research should focus on optimizing shared decision-making between families and clinicians in the care of hospitalized children at risk of deterioration, capitalizing upon the strengths of families in recognizing subtle changes, and the expertise of clinicians in identifying the need for intensive care.

Aim 3c – ABSTRACT #3 (*Barriers to calling for urgent assistance that exist despite implementation of a comprehensive pediatric rapid response system)*

Background: Rapid response systems (RRSs) aim to identify and rescue deteriorating hospitalized patients before respiratory or cardiac arrest occurs. Previous studies of RRS implementation have shown variable effectiveness, which may be attributable in part to barriers preventing staff from activating the system.
Objective: To proactively identify barriers to calling for urgent assistance that exist despite recent implementation of a comprehensive RRS in a children's hospital.
Methods: Qualitative study using open-ended, semi-structured interviews of 27 nurses and 30 physicians caring for patients on general medical and surgical wards.
Results: The following themes emerged: (1) Self-efficacy in a) recognizing deterioration and b) activating the medical emergency team (MET) were considered strong determinants of whether or not care would be appropriately escalated for deteriorating children. (2) Intra- and inter-professional hierarchies were sometimes challenging to navigate, and led to delays in care for deteriorating patients. (3) Expectations of adverse interpersonal or clinical outcomes from MET activations and intensive care unit (ICU) transfers could strongly shape escalation of care behavior. This included reluctance among subspecialty attending physicians to transfer patients to the ICU for fear of inappropriate management.

Conclusions: The results of this study provide an in-depth description of the barriers that may limit RRS effectiveness. By recognizing and addressing these barriers, hospital leaders may be able to improve the RRS safety culture and thus enhance the impact of the RRS on rates of cardiac arrest, respiratory arrest, and mortality outside the ICU.

An additional aspect of subaim 3c was a video monitoring project which studied the feasibility and acceptability of a video method to study false physiologic monitor alarms and their consequences in children with heart and/or lung failure. This study is complete and the findings are presented in a manuscript in press (*Video methods for evaluating physiologic monitor alarms and alarm responses*)

Aim 3C –ABSTRACT #4 (*Video methods for evaluating physiologic monitor alarms and alarm responses*)
Introduction: False physiologic monitor alarms are extremely common in the hospital environment. High false alarm rates have the potential to lead to alarm fatigue, leading nurses to delay their responses to alarms, ignore alarms, or disable them entirely. Recent evidence from the FDA and Joint Commission has demonstrated a link between alarm fatigue and patient deaths. Yet, very little scientific effort has focused on the rigorous quantitative measurement of alarm fatigue in the hospital setting.
Methods: We developed a system using multiple temporarily-mounted, minimally-obtrusive video cameras (as shown in Figure 18 below) in hospitalized patients' rooms to characterize physiologic monitor alarms and measure nurse response time as a proxy for alarm fatigue. This allowed us to efficiently categorize each alarm's cause, technical validity, actionable characteristics, and determine the nurse's response time. Figure 19 below shows an example of the video alarm interface. We describe and illustrate the methods we used to acquire the video, synchronize and process the video, manage the large digital files, integrate the video with data from the physiologic monitor alarm network, archive the video to secure servers, and perform expert review and annotation using alarm "bookmarks." We discuss the technical and logistical challenges we encountered, including the root causes of hardware failures as well as issues with consent, confidentiality, protection of the video from litigation, and Hawthorne-like effects.
Conclusion: The description of this video method may be useful to multidisciplinary teams interested in quantitatively measuring alarm fatigue and other patient safety issues in clinical settings.

Figure 18. Examples of camera mounting options. Clockwise from upper left: GoPro suction cup mount attached to window, use of wireless viewfinder with camera facing down mounted on top of patient's clear-top crib, Articulating Magic Arm with Super Clamp attached to GE Dash 3000 monitor handle, Kupo Max Arm attached to television wall mount.


Figure 19. Example of alarm video review interface. Clockwise from upper left, the monitor screen, a close-up view of the patient, and a wide view of the room including the door and window.

Preliminary results for evaluating alarm fatigue:

We performed a total of 40 video sessions for a total of 210 hours of footage among 20 heart and/or lung failure patients in the pediatric ICU, and 20 medical patients on the wards monitored due to risk of cardiovascular or respiratory deterioration. Using our operational definition of

"true alarms" as those that are both valid and actionable, 86.7% of alarms in heart and lung failure patients were false, and 99.0% of alarms in ward patients were false.
We found that response time increased as the number of false alarms the nurse was exposed to for the same patient over the preceding 120 minutes increased (See figure 20 below).

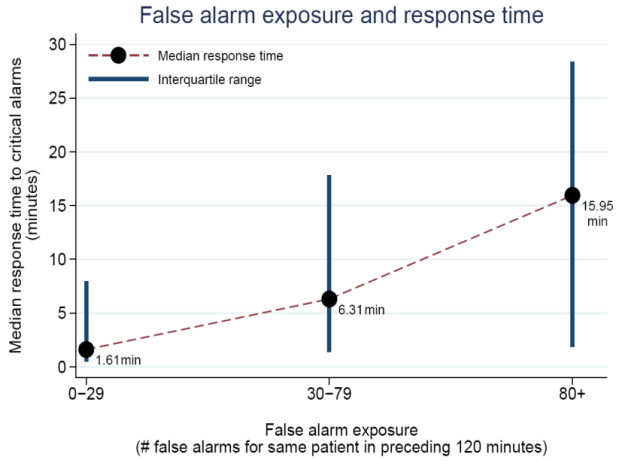



Figure 20. Relationship between number of false alarms over preceding 120 minutes (x axis) and response time to critical alarms (y axis). With increasing false alarm exposure, we observed a statistically significant increase in response time (p=0.001).

If a nurse experienced an alarm that required an intervention to be made on the same patient earlier in the session, median response time was 18 seconds faster among heart and lung failure patients, and more than 8 minutes faster among monitored ward patients.

**Abstracts, Poster Presentations and Scientific Meeting Presentations Resulting from the Pediatric Quality, Safety and Cost Project**

Srivastava R, Keren R, Luan X, Localio R, Dai D, McLeod M, Hall M, for the PRIS Network A Strategy for Prioritizing Pediatric Inpatient Comparative Effectiveness Research, Pediatric Academic Societies Annual Meeting, Platform presentation, May 2011, Denver CO

Srivastava R, Prioritizing Pediatric Conditions for Research and Quality Improvement, Child Health Corporation of America Quality and Safety Leaders Forum, May 18 2011, St Petersburg FL

Keren R, Srivastava R, Children's Hospital Association (CHA) Webcast Presentation of Hospital Specific Reports based on Prioritization Project Findings. Presented to CHA Quality and Safety Leaders and CMOs, March 20 2012

Tieder J, McLeod L, Luan X, Keren R, Localio R, Shah SS, Wilson KM, Srivastava R, Variation in Resource Utilization and Adverse Outcomes for Children Hospitalized for Diabetic Ketoacidosis, Pediatric Academic Societies Annual Meeting, Platform session, April 29, 2012, Boston MA

Tieder J, McLeod L, Luan X, Keren R, Localio R, Shah SS, Wilson KM, Srivastava R, Variation in Resource Utilization and Adverse Outcomes for Children Hospitalized for Diabetic Ketoacidosis. Endocrine Society 2012 Annual Meeting. Poster Presentation. June 25, 2012, Houston TX

Mahant S, Keren R, Localio R, Luan X, McLeod L, Mohamad Z, Shah SS, Song Lihai, Tieder JS, Wilson KM, Srivastava R. Improving the care of children undergoing tonsillectomy:

Variation in Process, Clinical Outcomes and Cost. Pediatric Hospital Medicine Meeting, Cincinnati OH, July 2012 PA (poster)

Mahant S**,** Keren R, Localio R, Luan X, McLeod L, Mohamad Z, Shah SS, Song Lihai, Tieder JS, Wilson KM, Elden L, Srivastava R. Tonsillectomy Perioperative Care and Outcomes in US Children's Hospitals. Pediatric Academic Societies Meeting, Washington D.C., May 2013 PA (platform)

C-Suite Vantage Point Webcast: Reducing Variation for Better Care + Lower Cost: Tonsillectomy. Children's Hospital Association. January 2013 (Srivastava R, Mahant S, Keren R)

Improving Tonsillectomy Perioperative Care in Children's Hospitals. Children's Hospitals Association Chief Financial Officers Meeting. New York, NY. June 2012

Paediatric Outcomes Research Team (PORT) Rounds, Division of Paediatric Medicine, Department of Paediatrics, 'Tonsillectomy Care and Outcomes in United States Children Hospitals' The Hospital for Sick Children, University of Toronto, February 2013

Opportunities to improve efficiency and outcomes in children's hospitals: The PRIS-CHA Prioritization Project. Appropriateness Care Committee, The Hospital for Sick Children, University of Toronto, October 2012

Opportunities to improve efficiency and outcomes in children's hospitals: The PRIS-CHA Prioritization Project. SickKids 8th Annual Paediatric Patient Safety Symposium Optimizing Quality in the Era of Efficiency, Department of Paediatrics, The Hospital for Sick Children, University of Toronto, June 2012

Wilson KM, Shah SS, Luan X, Localio R, Torok M, Mohamad Z, Srivastava R. Variability in care for children with community acquired pneumonia and asthma. Pediatric Academic Societies Annual Meeting, Submitted Nov 2013/under review for May 3-6, 2014 Annual Meeting, Vancouver, Canada

McLeod L, French B, Localio R, Dai D, Keren R. The Volume-Quality Relationship in the Care of Children Hospitalized with Acute Gastroenteritis. Pediatric Academic Societies Annual Meeting, Platform presentation. May 2011. Denver CO

McLeod L, Song L, Flynn J, Dormans J, Keren R. Antibiotic Use in the Surgical Management of Pediatric Scoliosis Remains Highly Variable. Pediatric Academic Societies Annual Meeting, Poster Session, April 28 2012. Boston MA

McLeod LM, French B, Flynn J, Dormans J, Keren R. Should Antifibrinolytic Use in Pediatric Scoliosis Surgery Be Standard of Care? Pediatric Academic Societies Annual Meeting. Poster Session. May 5, 2013. Washington DC

McLeod LM, French B, Flynn J, Dormans J, Keren R. Should Antifibrinolytic Use in Pediatric Scoliosis Surgery Be Standard of Care? Pediatric Orthopedic Society of North America annual meeting, Platform panel presentation. May 1-4, 2013, Toronto, Canada

Bonafide C, Nadkarni V, Weirich C, Localio R, Keren R. Impact of Rapid Response System Implementation on Critical Deterioration. Platform Session. Pediatric Academic Societies Annual Meeting. May 4, 2013. Washington DC

Bonafide C, Nadkarni V, Weirich C, Localio R, Keren R. Impact of Rapid Response System Implementation on Critical Deterioration. Platform session. 8th International Conference on Rapid Response Systems and Medical Emergency Teams in May 13, 2013

Kenyon CC, Fieldston ES, Luan X, Keren R, Zorc JJ. Safety and Effectiveness of Continuous Aerosolized Albuterol in the Non-intensive Care Setting. Pediatric Academic Societies Annual Meeting, Submitted Nov 2013/under review for Annual Meeting May 3-6 2014, Vancouver, Canada.

Rangel S, Hall M. Children's Hospital Association (CHA) Webcast Series: Improving Care for Children with Appendicitis through Comparative Reporting, November 2013-April 2015. Series of 6 webcasts. Introductory webcast, November 12, 2013.

Rangel S, Variation in Pediatric Surgical Care, Defining the role of value and positive deviance in establishing best surgical practices. CHA Leadership/Surgeon-in-Chief's Annual Conference, October 14, 2013

**18. Extent of Clinical Activities Initiated and Completed**. Items 18(A) and 18(B) should be completed for all research projects. If the project was restricted to secondary analysis of clinical data or data analysis of clinical research, then responses to 18(A) and 18(B) should be "No."

18(A) Did you initiate a study that involved the testing of treatment, prevention or diagnostic procedures on human subjects?

___ Yes
____x__No

18(B) Did you complete a study that involved the testing of treatment, prevention or diagnostic procedures on human subjects?

_____Yes
__x____No

**If "Yes" to either 18(A) or 18(B), items 18(C) – (F) must also be completed.** (Do NOT complete 18(C-F) if 18(A) and 18(B) are both "No.")

18(C) How many hospital and health care professionals were involved in the research project?

_____Number of hospital and health care professionals involved in the research project

18(D) How many subjects were included in the study compared to targeted goals?

_____Number of subjects originally targeted to be included in the study
_____Number of subjects enrolled in the study

**Note**: Studies that fall dramatically short on recruitment are encouraged to provide the details of their recruitment efforts in Item 17, Progress in Achieving Research Goals, Objectives and Aims. For example, the number of eligible subjects approached, the number that refused to participate and the reasons for refusal. Without this information it is difficult to discern whether eligibility criteria were too restrictive or the study simply did not appeal to subjects.

18(E) How many subjects were enrolled in the study by gender, ethnicity and race?

Gender:
_____Males
_____Females
_____Unknown

Ethnicity:
_____Latinos or Hispanics
_____Not Latinos or Hispanics
_____Unknown

Race:
_____American Indian or Alaska Native
_____Asian
_____Blacks or African American
_____Native Hawaiian or Other Pacific Islander
_____White
_____Other, specify:_____
_____Unknown

18(F) Where was the research study conducted? (List the county where the research study was conducted. If the treatment, prevention and diagnostic tests were offered in more than one county, list all of the counties where the research study was conducted.)

**19. Human Embryonic Stem Cell Research.** Item 19(A) should be completed for all research projects. If the research project involved human embryonic stem cells, items 19(B) and 19(C) must also be completed.

19(A) Did this project involve, in any capacity, human embryonic stem cells?

_____Yes

____x__ No

19(B) Were these stem cell lines NIH-approved lines that were derived outside of Pennsylvania?

_____Yes

_____ No

19(C) Please describe how this project involved human embryonic stem cells:

**20. Articles Submitted to Peer-Reviewed Publications**.

20(A) Identify all publications that resulted from the research performed during the funding period and that have been submitted to peer-reviewed publications. Do not list journal abstracts or presentations at professional meetings; abstract and meeting presentations should be listed at the end of item 17. **Include only those publications that acknowledge the Pennsylvania Department of Health as a funding source** (as required in the grant agreement). List the title of the journal article, the authors, the name of the peer-reviewed publication, the month and year when it was submitted, and the status of publication (submitted for publication, accepted for publication or published.). Submit an electronic copy of each publication or paper submitted for publication, listed in the table, in a PDF version 5.0.5 (or greater) format, 1,200 dpi. Filenames for each publication should include the number of the research project, the last name of the PI, and an abbreviated title of the publication. For example, if you submit two publications for Smith (PI for Project 01), one publication for Zhang (PI for Project 03), and one publication for Bates (PI for Project 04), the filenames would be:

Project 01 – Smith – Three cases of isolated

Project 01 – Smith – Investigation of NEB1 deletions

Project 03 – Zhang – Molecular profiling of aromatase

Project 04 – Bates – Neonatal intensive care

If the publication is not available electronically, provide 5 paper copies of the publication.

**Note:** The grant agreement requires that recipients acknowledge the Pennsylvania Department of Health funding in all publications. Please ensure that all publications listed acknowledge the Department of Health funding. If a publication does not acknowledge the funding from the Commonwealth, do not list the publication.

| Title of Journal Article: | Authors: | Name of Peer-reviewed Publication: | Month and Year Submitted: | Publication Status (check appropriate box below): |
|---|---|---|---|---|
| Prioritization of comparative | Keren R, Luan X, Localio R, Hall M, McLeod L, Dai D, | Archives of Pediatric and Adolescent | December 2012 | ☐Submitted<br>☐Accepted<br>✓Published |

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|---|---|---|---|---|
| effectiveness research topics in hospital pediatrics | Srivastaa R, Pediatric Research in Inpatient Settings (PRIS) Network) | Medicine | | |
| Variation in resource use and readmission for diabetic ketoacidosis in children's hospitals | Tieder JS, McLeod L, Keren R, Luan X, Localio R, Mahant S, Malik F, Shah SS, Wilson KM, Srivastava R, Pediatric Research in Inpatient Settings Network | Pediatrics | August 2013 | ☐Submitted<br>☐Accepted<br>✓Published |
| Variation in Quality of Tonsillectomy Perioperative Care and Revisit Rates in Children's Hospitals | Mahant S, Keren R, Localio R, Luan X, Song L, Shah S, Tieder J, Wilson K, Elden L, Srivastava R. | Pediatrics | Submitted June 2013; published on-line Jan 20, 2014 | ☐Submitted<br>☐Accepted<br>✓Published |
| Safety and Effectiveness of Continuous Aerosolized Albuterol in the Non-intensive Care Setting | Kenyon, CC, Fieldston, ES, Luan, X, Keren, R, Zorc, JJ. | Pediatrics | March 4, 2014 | ✓Submitted<br>☐Accepted<br>☐Published |
| Patient Volume and quality of care for young children hospitalized with acute gastroenteritis | McLeod L, French B, Dai D, Localio R, Keren R | Archives of Pediatric and Adolescent Medicine | Sept 2011 | ☐Submitted<br>☐Accepted<br>✓Published |
| Perioperative antibiotic use for spinal surgery procedures in US children's hospitals | McLeod LM, Keren R, Gerber J, French B, Song L, Sampson NR, Flynn J, Dormans JP | Spine | April 2013 | ☐Submitted<br>☐Accepted<br>✓Published |
| Antifibrinolytic Use and Blood Transfusions in Pediatric Scoliosis Surgeries Performed | McLeod LM, French B, Flynn JM Dormans JP, Keren R | J Spinal Disorders and Techniques | October 2013 | ☐Submitted<br>☐Accepted<br>✓Published |

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| at US Children's Hospitals | | | | |
| Development of a pragmatic measure for evaluating and optimizing rapid response systems | Bonafide CP, Roberts KE, Priestley MA, Tibbetts KM, Huang E, Nadkarni VM, Keren R | Pediatrics | April 2012 | ☐Submitted<br>☐Accepted<br>✓Published |
| Impact of rapid response system implementation on critical deterioration events in children | Bonafide CP, Localio AR, Roberts KE, Nadkarni VM, Weirich CM, Keren R | JAMA Pediatrics | Nov 2013 | ☐Submitted<br>☐Accepted<br>✓Published |
| Beyond statistical prediction: Qualitative evaluation of the mechanisms by which pediatric early warning scores impact patient safety | Bonafide CP, Roberts KE, Weirich CM, Paciotti B, Tibbetts KM, Keren R, Barg FK, Holmes JH | Journal of Hospital Medicine | May 2013 | ☐Submitted<br>☐Accepted<br>✓Published |
| Physician attitudes toward family-activated medical emergency teams for hospitalized children | Paciotti B, Roberts KE, Tibbetts KM, Weirich C, Keren R, Barg FK, Holmes JH, Bonafide CP | The Joint Commission Journal on Quality and Patient Safety | In press | ☐Submitted<br>✓Accepted<br>☐Published |
| Barriers to calling for urgent assistance that exist despite implementation of a comprehensive pediatric rapid response system | Roberts KE, Bonafide CP, Weirich CM, Paciotti B, Tibbetts KM, Keren R, Barg FK, Holmes JH | American Journal of Critical Care | In press | ☐Submitted<br>✓Accepted<br>☐Published |
| Video methods for evaluating physiologic monitor alarms and alarm responses | Bonafide CP, Zander M, Graham CS, Weirich CM, Rock W, Rich A, Roberts KE, Fortino-Mullen M, Nadkarni VM, Lin R, Keren R | Biomedical Instrumentation and Technology | In press | ☐Submitted<br>✓Accepted<br>☐Published |
| Dexamethasone and risk of bleeding in children undergoing | **Mahant S,** Keren R, Localio R, Luan X, Song L, Shah | Otolaryng Head Neck Surg | Feb 2014 | ☐Submitted<br>☐Accepted<br>✓Published |

| | | | | |
|---|---|---|---|---|
| tonsillectomy | SS, Tieder JS, Wilson KM, Elden L, Srivastava R; | | | |

20(B) Based on this project, are you planning to submit articles to peer-reviewed publications in the future?

Yes___x_____ No_____

If yes, please describe your plans:
-2 manuscript submissions are planned for the appendectomy drilldown work, one describing the differences across hospitals in treatment related costs and another describing the relationship between resource utilization and readmissions for children hospitalized with appendicitis.
-A manuscript submission is planned on variability in care for children with community acquired pneumonia and asthma.
-A publication is planned describing variation in resource utilization for children undergoing tonsillectomy
-A publication is planned describing the relationship between patient false alarms and care team response time.
-A manuscript is being developed reporting the results of the analysis demonstrating outcomes variation for children undergoing spinal fusion procedures.

**21. Changes in Outcome, Impact and Effectiveness Attributable to the Research Project.**
Describe the outcome, impact, and effectiveness of the research project by summarizing its impact on the incidence of disease, death from disease, stage of disease at time of diagnosis, or other relevant measures of outcome, impact or effectiveness of the research project. If there were no changes, insert "None"; do not use "Not applicable." Responses must be single-spaced below, and no smaller than 12-point type. DO NOT DELETE THESE INSTRUCTIONS. There is no limit to the length of your response.

The Pediatric Quality Safety and Cost Project has impacted clinicians' ability to deliver safe, high-quality cost effective care in multiple ways. The prioritization project provided a methodology for prioritizing conditions for comparative effectiveness research. This methodology and the results of the prioritization analysis can be used by other organizations to develop research and funding priorities. The drilldown analyses have been used to inform hospital leaders and care providers at CHA hospitals and to drive improvements in resource use and outcomes. Hospital specific report cards, showing how hospitals rank for overall resource utilization, and identifying conditions in which each hospital ranks high or low compared to other hospitals, have been developed and distributed. Hospital reports for specific conditions, such as DKA and appendectomy, have been or are in the process of being developed.

The DKA drilldown demonstrated widespread differences in resource use, LOS and readmissions across children's hospitals for children admitted for DKA, and that readmission is common. The data models can be used to drive local opportunities for improvement in

effective resource use and outcomes. The high rate of readmission found by the study demonstrates sub-optimal diabetes control and self-management, and suggests that hospital based-education programs, although they may extend LOS and add to cost, can improve the overall value of care by decreasing future DKA risk. The study highlights the need for future research to determine the most cost-effective strategies to improve self-management of diabetes.

The tonsillectomy drilldown highlighted the need for further work on reducing variation for one of the most common surgeries performed in children, focusing on understanding differences in processes of care during the index hospitalization and in the post discharge period. The data generated on tonsillectomy related revisits will inform quality measurement around tonsillectomy care. Our results suggest that 15 days is an appropriate time frame to measure revisits as 90% occurred within 15 days. Our data on patient level covariates reveal that age is an important variable for risk adjustment when reporting revisit rates. Furthermore, attention to quality measurement around reason specific revisits, bleeding and vomiting and dehydration, is important to provide hospitals with detailed data which is actionable as reduction of these reasons for revisits have different solutions. Quality improvement initiatives are needed to implement current evidence into practice and to understand and disseminate the practices of high performing hospitals. This drilldown also added to the current evidence base by providing more precise estimates of the risk of bleeding associated with dexamethasone use, supporting the safety of dexamethasone and recommendations for its routine use in children hospitalized for tonsillectomy. The publication of the first manuscript based on this work earlier this month generated a significant amount of media coverage. Stories highlighting the study's findings regarding variation in revisit rates and adherence to guidelines were featured in USA today, NBC News and CNN Health among others, demonstrating the potential this work has to impact clinical practice.

The appendectomy drilldown work has resulted in a webcast series for leaders and providers of CHA hospitals, "Improving Care for Children with Appendicitis through Comparative Reporting" in progress from November 2013-April 2015. The project will have additional impact on patient care through the 2 "next steps" projects noted above in response to question #12. This work will increase our ability to effectively identify surgical procedures (or groups of procedures) that are most in need of QI prioritization, and will also provide a more accurate means of identifying hospitals that are providing high-value care (for comparative analysis, value-based benchmarking & dissemination of best practices).

The pneumonia drilldown work will result in increased awareness of the impact of multiple diagnoses on guideline adherence and resource utilization, and potentially lead to additional guidelines that explicitly address a co-diagnosis of asthma and pneumonia.

The severe asthma pathway project provided a granular description of the variation in treatment of asthma exacerbations that occurs within an institution with a high volume of asthma admissions, which is likely a principal driver of variation in cost. With appropriate severity stratification, future research could help delineate whether this variation in treatment – and the corresponding costs – are appropriate.

The research performed on the pediatric volumes and quality of care project has resulted in the dissemination of valuable information on variation in processes and outcomes of care for children undergoing spinal fusion operations. These findings have led to joint efforts among the hospitalist and surgical communities to explore better organizational strategies for improving hospital outcomes for these children. Partnerships with national quality improvement bodies have also created an opportunity to involve hospitals across the nation in a multi-center AHRQ-funded project evaluating how care is delivered to children undergoing spinal fusion procedures – something that had not been accomplished prior to this work.

For the rapid response system project, the main impacts have been to (1) provide evidence of the effectiveness and cost benefits of pediatric rapid response systems to support their development and refinement, which have the potential to reduce rates of in-hospital critical deterioration and save lives, and (2) provide some of the first actual evidence of alarm fatigue existing in the hospital in order to drive further research and innovation to prevent alarm fatigue, a phenomenon that has been blamed for hundreds of deaths in the United States.

**22. Major Discoveries, New Drugs, and New Approaches for Prevention Diagnosis and Treatment**. Describe major discoveries, new drugs, and new approaches for prevention, diagnosis and treatment that are attributable to the completed research project. If there were no major discoveries, drugs or approaches, insert "None"; do not use "Not applicable." Responses must be single-spaced below, and no smaller than 12-point type. DO NOT DELETE THESE INSTRUCTIONS. There is no limit to the length of your response.

The severe asthma pathway project team created a template data collection structure for auditing and evaluating asthma clinical pathways, which are increasingly used to standardize care for inpatient asthma. Up to this point, our data collection infrastructure was not sufficiently sophisticated or structured to collect this data and inform modifications in the pathway problems that we identify. Because this is all done within an EPIC framework, this data infrastructure could be imported to other institutions to provide enhanced audit and feedback support to inpatient asthma care at other institutions.

The rapid response project team developed several new tools to improve care for patients at risk for heart and/or lung failure:

- Metric to evaluate and optimize rapid response systems
- Qualitative methodology/guide for evaluating rapid response system implementation
- Video method useful to multidisciplinary teams interested in quantitatively measuring alarm fatigue and other patient safety issues in clinical settings.

**23. Inventions, Patents and Commercial Development Opportunities.**

23(A) Were any inventions, which may be patentable or otherwise protectable under Title 35 of the United States Code, conceived or first actually reduced to practice in the performance of work under this health research grant? Yes_____ No___x_____

If "Yes" to 23(A), complete items a – g below for each invention. (Do NOT complete items a - g if 23(A) is "No.")

a. Title of Invention:

b. Name of Inventor(s):

c. Technical Description of Invention (describe nature, purpose, operation and physical, chemical, biological or electrical characteristics of the invention):

d. Was a patent filed for the invention conceived or first actually reduced to practice in the performance of work under this health research grant?
Yes_____ No____

If yes, indicate date patent was filed:

e. Was a patent issued for the invention conceived or first actually reduced to practice in the performance of work under this health research grant?
Yes_____ No____
If yes, indicate number of patent, title and date issued:
Patent number:
Title of patent:
Date issued:

f. Were any licenses granted for the patent obtained as a result of work performed under this health research grant? Yes_____ No____

If yes, how many licenses were granted?_____

g. Were any commercial development activities taken to develop the invention into a commercial product or service for manufacture or sale? Yes___ No____

If yes, describe the commercial development activities:

23(B) Based on the results of this project, are you planning to file for any licenses or patents, or undertake any commercial development opportunities in the future?

Yes_____ No___x _____

If yes, please describe your plans:

**24. Key Investigator Qualifications.** Briefly describe the education, research interests and experience and professional commitments of the Principal Investigator and all other key investigators. In place of narrative you may insert the NIH biosketch form here; however, please limit each biosketch to 1-2 pages. *For Nonformula grants only – include information for only those key investigators whose biosketches were not included in the original grant application.*

**Ron Keren MD MPH, Principal Investigator** is Professor of Pediatrics and Epidemiology at the Perelman School of Medicine at the University of Pennsylvania and an experienced academic pediatric hospitalist, Director of the Center for Pediatric Clinical Effectiveness, Co-Director of the Clinical Pathways Program and a Co-Director of the Pediatric Hospital Epidemiology and Outcomes Research Training Program (PHEOT) at the Children's Hospital of Philadelphia (CHOP). Dr. Keren has recently been named Vice President of Quality and Chief Quality Officer at CHOP. He earned a BA is Philosophy from Princeton University in 1989, an MD from New York University School of Medicine in 1994 and his MPH from Harvard School of Public Health in 2001. Dr. Keren studies the efficacy and cost-effectiveness of treatments for common diseases of childhood, such as neonatal jaundice, influenza, and urinary tract infections. His research has been funded by NIH, AHRQ, CDC, as well as other foundation grants. He is currently the principal investigator (PI) on a Patient-Centered Outcomes Research Institute (PCORI) grant comparing the effectiveness of oral versus intravenous antibiotic therapy for children who have been hospitalized with one of 3 serious bacterial infections: perforated appendicitis, complicated pneumonia, or osteomyelitis.

**Christopher P Bonafide MD MSCE** is Assistant Professor of Pediatrics at the Perelman School of Medicine at the University of Pennsylvania and an attending physician at The Children's Hospital of Philadelphia. He is a faculty member of the Section of Clinical Informatics, a Senior Fellow at the Leonard Davis Institute of Health Economics, an Associate Member of the Institute for Translational Medicine and Therapeutics and a faculty member of CHOP's Center for Pediatric Clinical Effectiveness (CPCE). Dr Bonafide obtained his BA in Psychology from Colby College in 2000, his MD from Penn State University in 2004 and his MSCE from the University of Pennsylvania in 2011. He completed a residency and chief residency at CHOP from 2004-2008, and an Academic Pediatrics Fellowship, also from CHOP, in 2010. Dr. Bonafide's research interest is in evaluating the effectiveness and unintended consequences of systems intended to improve patient safety for hospitalized children. Specific areas of focus include: Rapid Response Systems; Medical Emergency Teams; Early Warning Scores; Physiologic Monitoring Systems; Alarm Fatigue; Electronic Health Records; Mobile Health (mHealth) Interventions. In addition to the Pennsylvania Department of Health Research Formula Award, Dr. Bonafide's current research is funded by the National Institutes of Health (NIH) Pediatric Research Loan Repayment Program, the CPCE Pilot Grant, the Center for Medicare and Medicaid Services CHIPRA Quality Demonstration Grant, and the CHOP Department of Pediatrics Chair's Initiative.

**Lisa McLeod MD MSCE is** an Academic Instructor in Pediatrics at the University of Colorado School of Medicine and a general pediatric hospitalist and clinical epidemiologist with the Children's Hospital of Colorado (CHCO) Section of Hospital Medicine. Dr. McLeod earned her

BS in Microbiology from the University of Pittsburgh, her MD from Harvard Medical School and her MSCE from the University of Pennsylvania Center for Clinical Epidemiology and Biostatistics. Her research focus involves evaluating the impact of the structures, processes, and organization of pediatric inpatient care on the safety and value of the care we provide as hospitalists. Her ongoing studies are related to the prevention of surgical site infections (SSIs) in children undergoing complex spinal procedures. She has recently been awarded a Patient Centered Outcomes Research K99/R00 award from the Agency for Healthcare Research and Quality to study the organizational barriers and facilitators to effective interventions for SSI prevention in this population. She is a former member of the Children's Hospital of Philadelphia Center for Pediatric Clinical Effectiveness and current affiliate of the CHCO Children's Outcomes Research Program (COR). She has extensive expertise in quantitative research, contributing to several manuscripts related to processes of care for SSI prevention.

**Chen Kenyon MD MSHP** is an Instructor in Pediatrics at the Perelman School of Medicine at the University of Pennsylvania, a Pediatric Hospitalist at CHOP and a Senior Fellow at the Leonard Davis Institute of Health Economics at Penn. He earned a BA in Mathematics from the University of Rochester, and MD from the Boston University School of Medicine and an MSHP from the Perelman School of Medicine at Penn. Dr. Kenyon's research is focused primarily on identifying risk factors for prolonged and repeat hospitalization for children with asthma using analyses of secondary datasets, including the Pediatric Health Information System, Medicaid Analytic Extract files and electronic health data from local institutions. Through his research, he has gained technical skills developing and cleaning analytic datasets, applying different research methodologies, and coordinating research teams. He has also developed content expertise in understanding which factors are associated with prolonged hospitalization and reliance on rescue care and barriers to care for "high risk" populations. His clinical work affords him more granular insight into the challenges that "high risk" families encounter, from differential access to quality primary and specialty care to outright distrust of the values and competence of traditional medical providers. These research and clinical pursuits, along with his community connections through the Robert Wood Johnson Clinical Scholars program, led Dr Kenyon to systems improvement work through the Asthma Care Committee at the CHOP) and to an informal partnership with the Community Asthma Prevention Program (CAPP). His local asthma work focuses on improving CHOP's care systems for children with severe asthma and his work with CAPP has focused on enhancing outreach efforts to currently unreached vulnerable communities.

**Russell Localio MA MPH MS PhD** is Associate Professor of Biostatistics in Biostatistics and Epidemiology at the University of Pennsylvania Perelman School of Medicine and a Senior Scholar at the Center for Clinical Epidemiology and Biostatistics. He has served as a teacher, mentor and collaborator to many CHOP researchers in the Department of Pediatrics and has been co-investigator on NIH, AHRQ and HRSA-funded projects. He has worked with investigators in General Pediatrics and Infectious Diseases as well as other sub-specialties on a broad range of topics including, among others, attributable outcomes of neonatal candidiasis; incidence, complications, and risk factors for prolonged stay in children hospitalized with community-acquired influenza; utilization and outcomes of antibiotic use among children across hospitals; corticosteroids use in Henoch Schönlein Purpura during hospitalization; placement stability and mental health costs for children in foster care; operative management of pediatric splenic injury; effectiveness of computerized reminders for immunizations for children; and trends in the

incidence of pediatric hospitalizations. Dr. Localio received his BA in economics from Columbia University, and his MPH and MS in Biostatistics from the Harvard School of Public Health. In 2005, he received his PhD in Epidemiology from the University of Pennsylvania School of Medicine. He is an associate editor of *Annals of Internal Medicine*. His teaching responsibilities include a full semester class on Statistical Methods in Epidemiological Research and he regularly provides formal mentoring to young investigators in designing, executing, analyzing and publishing research projects.

**Rajendu Srivastava MD MPH** is Associate Professor of Pediatrics at the University of Utah, a hospitalist at Primary Children's Medical Center, Utah, and a Fellow of the Institute of Health Care Delivery Research at Intermountain Health Care. Dr. Srivastava earned his MD from the University of Toronto in 1994 and his MPH from the Harvard School of Public Health in 2000. He is the PI or Co-I on several NIH-funded grants and multi-center studies and has published over 50 peer-reviewed articles in journals such as BMJ and Pediatrics. Dr. Srivastava's research focuses on how to measure and improve pediatric inpatient quality of care. He serves as chair for the Pediatric Research in the Inpatient Setting (PRIS) network.

**Joel Tieder MD MPH** is an Assistant Professor of Pediatrics in the Division of Inpatient Medicine at the University of Washington and the Manager of the Maintenance of Certification (MOC) Portfolio Program at Seattle Children's Hospital. He is an Executive Council Member of the PRIS research network. Dr. Tieder earned his BS in Biochemistry from University of Georgia in 1996 and his MD in 1999 from the Medical College of Georgia. He also earned an MPH from the University of Washington in 2006. Dr. Tieder's background includes formal training in Epidemiology, Health Services Research, Improvement Science, and Team Leadership. As Manager of the MOC Program, he manages a portfolio of quality improvement projects and participants seeking an educational opportunity in quality improvement across 15 specialties. He is responsible for the development of Seattle Children's Hospital Clinical Effectiveness Training Program and led the training of 85 physicians, nurses, and ancillary staff about guideline development, adaptation, dissemination, implementation, and improvement. Dr. Tieder's background in health services research has focused on improving the outcomes of care for children with acute and chronic diseases by changing how care is delivered in large healthcare systems with the development, dissemination, and implementation of evidence-based care. He has led studies and national guideline development for Apparent Life Threatening Events (ALTE) and has conducted a study that measured guideline adherence to the Center for Disease Control's 2003 guideline on acute gastroenteritis guideline. He is currently PI for a series of studies using administrative data to accurately identify common infectious conditions in children for the purposes of measuring quality of care.

**Sanjay Mahant MD MSc** is an Associate Professor at the University of Toronto and Project Investigator at the Research Institute of the Hospital for Sick Children. Dr. Mahant earned his MD from the University of Toronto and his MSc in Health Research Methodology from McMaster University. He is an Executive Council Member of the PRIS research network. Dr. Mahant's background in clinical research with training in clinical epidemiology and health services research has allowed him to study issues related to diagnosis, prognosis, and effectiveness of interventions in pediatric hospital care. His areas of research focus around both acute and chronic care relevant to hospital medicine (1) decision-making and outcomes of

feeding interventions in children with neurologic impairment (2) common conditions in the inpatient hospital setting and (3) collaborations with members of the PRIS research network in multi-center patient based research. Furthermore, his work has focused on understanding practice and variations in care at a systems level and at the individual clinical level.

**Shawn Rangel MD MSCE** is an Instructor in Surgery at Harvard Medical School, a staff surgeon in the Department of Surgery at Brigham & Women's Hospital and Boston Medical Center, and an Assistant in Surgery in the Department of Surgery at Children's Hospital Boston. Dr. Rangel earned a BS in Biology in 1993, his MD from University of California at San Francisco in 1998 and an MS in Clinical Epidemiology from Stanford University in 2000. Dr. Rangel has been the American Pediatric Surgical Association Surgical Quality Improvement Project (P-NWQIP) site director (surgeon champion) at Boston Children's Hospital for four years, currently serves as the vice-chair (chair-elect) of the P-NSQIP National Executive Steering Committee, is chair of P-NSQIP's Measurement & Evaluations Committee, and is the director of the national P-NSQIP Appendicitis Pilot Project. Furthermore, Dr. Rangel is a member of the American Pediatric Surgical Association's (APSA) Clinical Outcomes Committee, vice-chair (chair-elect) of APSA's Quality & Safety Committee, and currently serves as chair of the American Academy of Pediatrics Committee for the Delivery of Surgical Care (Section on Surgery).He is also a PRIS Executive Council Member.

**Karen Wilson MD MPH** is Associate Professor of Pediatrics at the University of Colorado School of Medicine and Section Head for Pediatric Hospital Medicine at the Children's Hospital of Colorado. She serves as a PRIS Executive Council Member. Dr. Wilson received her BS in psychology from Saint Lawrence University, New York, in 1990 and her MPH (1995) and MD (2004) from the University of Rochester. Her primary research interests are in understanding the relationship between secondhand tobacco smoke exposure and severity of illness in children hospitalized for respiratory illness, and how to improve outcomes in hospitalized children. Dr. Wilson is one of the Principal Investigators of the AAP/Julius B. Richmond Center of Excellence, which is dedicated to eliminating children's exposure to tobacco and secondhand smoke. She serves as a PRIS Executive Council Member.