The association of type of surgical closure on length of stay among infants with gastroschisis born ≥ 34 weeks’ gestation

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ABSTRACT

Background/Purpose: The optimal surgical approach in infants with gastroschisis (GS) is unknown. The purpose of this study was to estimate the association between staged closure and length of stay (LOS) in infants with GS.

Design/Methods: We used the Children’s Hospital Neonatal Database to identify surviving infants with GS born ≥ 34 weeks’ gestation referred to participating NICUs. Infants with complex GS, bowel atresia, or referred after 2 days of age were excluded. The primary outcome was LOS; multivariable linear regression was used to quantify the relationship between staged closure and LOS.

Results: Among 442 eligible infants, staged closure occurred in 68.1% and was associated with an increased median LOS relative to odds ratio (OR): primary closure (37 vs. 28 days, p < 0.001). This association persisted in the multivariable equation (β = 1.35, 95% CI: 1.21, 1.52, p < 0.001) after adjusting for the presence of necrotizing enterocolitis, short bowel syndrome, and central-line associated bloodstream infections.

Conclusions: In this large, multicenter cohort of infants with GS, staged closure was independently associated with increased LOS. These data can be used to enhance antenatal and pre-operative counseling and also suggest that some infants who receive staged closure may benefit from primary repair.

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With an incidence between one in 2000–10,000 births, gastroschisis (GS) is a congenital disorder in which the abdominal viscera herniate through a para-umbilical abdominal wall defect [1,2]. Reduction of the viscera into the abdomen can be achieved either with primary reduction and closure shortly after birth or with staged reduction and delayed closure [3,4]. In the 1990’s, staged closure via bedside placement of pre-made, silastic, spring-loaded silos became more common in order to obviate potential complications secondary to increased intra-abdominal pressure after primary closure [5,6].

Oftentimes, infants with uncommon illnesses such as GS are referred to regional or level IV neonatal intensive care units (NICUs) [7,8]. However even in these regional NICUs, years may pass before amassing sufficient numbers of patients to analyze and to report representative outcomes [2,9]. In 2010, the Children’s Hospital Neonatal Database (CHND) began systematic data collection for all infants admitted to the participating NICUs in order to study the care and outcomes of infants with uncommon illnesses such as GS. The purposes of this study are to describe and quantify the short-term outcomes of a large multi-center cohort of infants with GS and to estimate the association between the types of surgical closure on length of stay (LOS) for these affected infants. We hypothesized that staged closure would be associated with a longer LOS [10,11] relative to primary closure in infants with GS [4,12,13].

1. Materials & methods

The CHND captures clinical data on all infants admitted to 27 participating regional NICUs. Variables were defined prospectively, and chart abstractors at each site undergo prospective training including review of clinical definitions, participation in web-based seminar tutorials, and case-based practice. Since 2010, both initial and semi-annual measurements of inter-rater agreement scores are calculated at each site; over 90% intra-site concordance in abstraction is required for initial and continued participation in the CHND [14].

For this study, the CHND was accessed on June 18, 2012 to identify surviving infants who had GS from January 2010 to April 2012. GS was differentiated from other abdominal wall defects during chart abstraction. In order to study a homogenous population and to reduce the chance that disease-severity from complicated presentations of GS contributed to an increased LOS, we excluded infants born <34 weeks gestation (GA) as their preterm birth independently predicts a longer LOS. Other infants were excluded from the analysis if they had surgical intervention prior to referral to the participating NICU, if they were admitted after 2 days of age, if they had other major congenital anomalies such as major cardiac or neuromuscular disease, if they died prior to discharge, or if any bowel atresia or other complex GS was present. Infants with GS [15] complicated with small bowel resection, ostomy creation, or repair of intestinal perforations [16] in the first three days of life were not included in the analysis. Finally, records were removed if the infant’s closure type was not documented.

The primary outcome measure was LOS in the CHND participating hospital. Secondary outcomes measured were the inter-center variation in LOS, the duration of parenteral nutrition (PN), the duration of prophylactic anti-microbial treatment, the rates of central-line utilization and associated bloodstream infections (CLABSI) [17]. The prevalence of necrotizing enterocolitis (NEC) [18] and short bowel syndrome/intestinal failure (SBS/IF) that became evident after closure [19] was also ascertained. SBS/IF was defined when infants had a major bowel resection such that <50% of the expected length or <75 cm of small bowel remained post-operatively [20] and with the subsequent receipt of ≥90 days of PN [21–23]. Assignment of IF required >90 days of PN when resection(s) was not done. This approach mimics an ‘intention-to-treat’ analysis and was utilized to quantify a serious intestinal morbidity evident after the closure specifically because SBS/IF cannot be reliably identified at the time of closure.

Eligible infants were stratified by whether they received primary or staged closure. Primary closure was defined as a single surgical procedure immediately after referral to reduce the abdominal contents and close fascia and/or skin [24,25]. Staged closure was defined as progressive reduction of abdominal contents postnatally with a final closure of skin/fascia at a later date [13]. In order to quantify the practice variability in the type of closure performed, the frequency of staged closure was reported after stratification by participating NICU with the proportion of final closures performed in the operating room described.

Selected perinatal and post-referral characteristics were reported and stratified by the type of surgical closure. Gender, mode of delivery, and multiple gestation as well as birth weight and the prevalence of infants born small for gestational age (SGA) ≤10th centile were reported both descriptively and graphically. For these plots, gender-specific birth weights in the infants with GS were graphed compared against the normative 10th, 50th/median, and 90th centiles in birth weights [26]. Post-referral, the considered variables were CLABSI, SBS/IF, and NEC.

The age at which enteral feeds were initiated and the duration of parenteral nutrition were recorded and stratified by the type of surgical closure. In addition, the age at which infants reached “full” feedings (defined as 100 kcal/kg/day) was included in the analysis.

1.1. Data analyses

Frequencies and percentages were reported for categorical variables, and median and interquartile range (IQR) were shown for continuous variables after stratification of the infants by the type of closure. Bivariable analysis was performed using Wilcoxon rank sum and chi-squared tests for continuous and categorical variables, respectively. Interactions between the main predictor and the covariates of interest were evaluated through mean plots. Then, a multivariable generalized linear model was used with a generalized estimating equation method to determine the significant predictors of infants’ hospital LOS after clustering on hospitals to account for inter-center variation [27]. Since a log transformation of the LOS variable did not mirror a normal distribution, the gamma distribution with logit link was applied. Backward selection of variables was used to identify and retain significant variables. Odds ratios (OR) and their 95% confidence intervals (CI) were reported.

Statistical analyses were performed using SAS v.9.3 (SAS Institute, Cary, NC) and significance was defined as α = 0.05. The Children’s Healthcare of Atlanta Institutional Review Board approved this study on March 12, 2012. Also, each participating hospital retained IRB and/or administrative oversight for participation in the CHND.

2. Results

Of the 28,299 infants in the CHND, 602 had GS during the study period. After sequentially excluding those born <34 weeks’ gestation (n = 66), those admitted after their second day of life (n = 10) and those who died (n = 3), we then omitted those with major congenital heart disease (n = 3), congenital neurological disorders (n = 4), bowel atresia (n = 39), other markers of complex GS (n = 10), and those without data available on the type of received closure (n = 25). Of the infants who died, one had bilateral renal agenesis and died of NEC. The other two infants died secondary to extra-intestinal complications (congenital heart disease and a central nervous system anomaly). Thus, there were 442 infants who were eligible and included in the analysis.

Staged closure was performed in the majority (68.1%) of the eligible infants, and this approach varied significantly between participating
centers (median 66.7%; inter-quartile range (IQR): 50%, 87.5%, range: 25.0% to 100%, p = 0.001). Four centers performed staged closure exclusively (n = 35). The vast majority of these closures occurred in the operating room, and this proportion significantly differed by the type of closure that was performed (75% of the primary closures; 86% of the final staged closures, p = 0.005). Additionally, inter-center variation in LOS was also observed (median LOS 36 days; (IQR 30, 38 days); range: 23.5–56 days, p < 0.001).

Few significant differences were observed in the demographic or medical characteristics of the cohort after stratifying by the type of closure performed (Table 1). Late preterm birth defined from 34\textsuperscript{6/7} to 36\textsuperscript{6/7} weeks' gestation occurred in 57.4% and 55.8% of the infants who received primary and staged closure, respectively. None of the infants who had received a greater duration of mechanical ventilation, prophylactic/empiric antibiotics, and PN and also had enteral feedings initiated and ductus technique.

Multivariable analysis demonstrated that infants' LOS was associated with staged closure (OR 1.35, 95% CI: 1.21–1.52, p < 0.001) independent of the presence of NEC, SBS/IF after closure, and CLABSI (Table 2), each of which is associated with longer LOS. The LOS related to staged closure was 10 days greater relative to infants who received primary closure. The prevalence of NEC, SBS/IF, and CLABSI was not associated with the type of closure. None of the infants who had primary closure subsequently developed abdominal compartment syndrome. In addition, late preterm birth (34\textsuperscript{6/7} to 36\textsuperscript{6/7} weeks' gestation) was not a risk factor for LOS in this analysis.

With regard to secondary outcomes, infants with staged closure received a greater duration of mechanical ventilation, prophylactic/empiric antibiotics, and PN and also had enteral feedings initiated and ductus technique.

### Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Primary Staged</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>141</td>
<td>301</td>
</tr>
<tr>
<td>Mean gestational age at birth (weeks)</td>
<td>36 ± 1.3</td>
<td>36 ± 1.5</td>
</tr>
<tr>
<td>Late preterm birth (n, %)</td>
<td>81 (57.4%)</td>
<td>168 (55.8%)</td>
</tr>
<tr>
<td>Mean birth weight (g)</td>
<td>2519 ± 506.7</td>
<td>2432 ± 1494.2</td>
</tr>
<tr>
<td>SGA ≤ 10th centile (n, %)</td>
<td>22 (15.6%)</td>
<td>54 (17.9%)</td>
</tr>
<tr>
<td>Female gender (n, %)</td>
<td>72 (51.1%)</td>
<td>142 (47.2%)</td>
</tr>
<tr>
<td>Multiple gestation (n, %)</td>
<td>3 (2.1%)</td>
<td>8 (2.7%)</td>
</tr>
<tr>
<td>Cesarean delivery (n, %)</td>
<td>72 (51.1%)</td>
<td>142 (47.2%)</td>
</tr>
<tr>
<td>Post-birth referral from another institution (n, %)</td>
<td>125 (88.7%)</td>
<td>277 (92.0%)</td>
</tr>
<tr>
<td>Median age at referral (IQR, h)</td>
<td>2.4 (1.3, 3.2)</td>
<td>2.4 (1.3, 3.4)</td>
</tr>
<tr>
<td>Mean admission weight (g)</td>
<td>2522 ± 505.8</td>
<td>2494 ± 469.9</td>
</tr>
<tr>
<td>NEC (n, %)</td>
<td>3 (2.1%)</td>
<td>12 (4.0%)</td>
</tr>
<tr>
<td>SBS/IF after closure (n, %)</td>
<td>1 (0.7%)</td>
<td>4 (1.3%)</td>
</tr>
<tr>
<td>CLABSI (n)</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Total central line days (d)</td>
<td>3230</td>
<td>10528</td>
</tr>
<tr>
<td>CLABSI rate per 1000 line days</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Length of Stay (LOS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharged home directly from the NICU (n, %)</td>
<td>104 (73.8%)</td>
<td>225 (74.8%)</td>
</tr>
<tr>
<td>Discharged home from a non-NICU location in the hospital (n, %)</td>
<td>32 (22%)</td>
<td>69 (22.9%)</td>
</tr>
<tr>
<td>Median hospital LOS (d)</td>
<td>27 (22, 40)</td>
<td>34 (26, 52)</td>
</tr>
<tr>
<td>All infants discharged home (n, %)</td>
<td>136 (96.5%)</td>
<td>294 (97.7%)</td>
</tr>
<tr>
<td>Median hospital LOS (d)</td>
<td>31 (24, 45)</td>
<td>56 (38, 83)</td>
</tr>
<tr>
<td>Median hospital LOS (d)</td>
<td>28 (23, 40)</td>
<td>37 (27, 61)</td>
</tr>
</tbody>
</table>

Late preterm birth defined from 34\textsuperscript{6/7} to 36\textsuperscript{6/7} weeks' gestation; SGA: small for gestational age, reference values adopted from Olsen 2010; IQR: inter-quartile range; NEC: necrotizing enterocolitis; SBS/IF: short bowel syndrome/intestinal failure; CLABSI: central-line associated bloodstream infection; NICU: neonatal intensive care unit; LOS: length of stay.

### Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staged closure</td>
<td>1.35</td>
<td>1.21, 1.52</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>NEC</td>
<td>1.99</td>
<td>1.71, 2.32</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SBS/IF after closure</td>
<td>2.62</td>
<td>1.92, 3.59</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CLABSI</td>
<td>1.39</td>
<td>1.01, 1.91</td>
<td>0.042</td>
</tr>
</tbody>
</table>

CI = confidence interval; NEC = necrotizing enterocolitis; SBS/IF = short bowel syndrome/intestinal failure; CLABSI = central line associated blood stream infection.

* The referent mean LOS was 32.2 days for infants who received primary closure and who did not experience NEC, SBS or CLABSI.
reached full enteral feedings later relative to infants receiving primary closure (Table 3). At discharge, 341 (77.1%) infants were receiving at least 100 kcal/kg/day; 47 were discharged on feeds without having reached the specified caloric intake although some may have been breast-feeding. Of the 101 infants that were transferred from the NICU to another location in the CHND hospital, fifty-nine (58.4%) infants were receiving full enteral feedings (100 kcal/kg/day) at the time of intra-facility transfer.

3. Discussion

Gastrochisis is one of the most common congenital anomalies requiring surgery [1,28]. With a rising incidence, understanding the implications of the current management strategies is critical to optimize these infants’ outcomes while minimizing unnecessary resource utilization. In this large, multi-center cohort of infants with uncomplicated GS born ≥ 34 weeks’ gestation, our study demonstrates that staged closure was associated with a greater LOS independent of patient characteristics [29]. Also, infants who received staged closure had the anticipated delay in initiating enteral feedings, in weaning from mechanical ventilatory support, and in discontinuing both empiric anti-microbial treatment and PN [30]. These results should allow clinicians to refine how they counsel families by providing a representative set of outcomes at large, as well as outcomes specific to the type of closure. Finally, these data suggest that some infants with GS may benefit from primary closure in order to reduce their LOS. The optimal selection of the infants and their type of closure, however, remains uncertain.

Staged closure offers many potential advantages: silo placement permits assessment of the intestine through the transparent silastic bag, allows upward traction of the abdominal wall concurrent with gradual intestinal reduction, the possible decrease in the duration of mechanical ventilation related to silo placement [11,31], and provides a potentially autonomous experience for surgeons in-training. In addition, silo placement is usually a technically straightforward procedure that is less likely than primary closure to require urgent mobilization of operating room resources. Thus, the urgent closure of the abdominal wall can become a semi-elective operation. Correspondingly, we speculate that the conveniences of the surgical and non-surgical staff may have influenced the decision to perform staged closure. Previous studies have suggested that, given the variability of surgical technique among institutions with similar patient populations, the choice is often the result of an institutional bias [32] rather than clinical characteristics. The results presented here demonstrating the marked inter-center variability further support this claim. We believe this topic of conveniences and their potential appropriateness warrants future qualitative explorations.

This study demonstrates that staged closure typically confers a 4–7 day longer LOS as evidenced by both the main findings and a secondary analysis. Because the duration from final closure to discharge is similar by the type of closure, these results support, but do not prove, that there were few intrinsic patient differences that accounted for the eventual LOS.

We observed significant inter-center variation in closure approach as well as LOS, suggesting that institutional practices or physician preferences rather than intrinsic patient differences influenced the decision to perform staged closure. In some centers, only staged closures were performed. Staged closure may have been utilized more frequently in infants with matted, thickened and/or dilated bowel to circumvent abdominal compartment ischemia previously described with primary closure [33]. However, compartment syndrome was not observed in our cohort. Both the variability by center and the absence of compartment syndrome suggest that primary closure may be appropriate for a larger subset of infants with GS. Currently, we were underpowered to study the inter-center effects of staged closure on LOS, however, further investigation is warranted and planned to define the patient, treatment, and center characteristics that will confer benefit to these affected infants. To answer this definitively, prospective trials would be needed [32,34–40].

Congruent with the results from recent national cohort studies, the strengths of this study are the standardized data collection, rapid accrual of cases, and a multi-center representation of practices and outcomes in the CHND. The current results are consistent with findings from the Canadian Pediatric Surgical Network demonstrating that primary closure was associated with a shorter LOS relative to staged closure [9]. Additionally, work from the British Association of Paediatric Surgeons Congenital Anomalies Surveillance System determined that reaching full enteral feeds was delayed and intestinal failure was more likely in infants receiving staged closure. Also, the British Association study showed that in 219 infants with simple GS, primary closure was associated with decreased proportion of patients needing prolonged PN (>28 days) and hospitalization (≥ 30 days) [36]. Indeed, the primary and secondary analyses corroborate the results from prior studies using these international patient populations.

The majority of infants were born during the late preterm gestational period [37], and these results demonstrate that the intrauterine weight gain of infants with uncomplicated GS is lower

### Table 3

Secondary outcomes stratified by the type of surgical closure.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Primary</th>
<th>Staged</th>
<th>P</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>414</td>
<td>301</td>
<td>442</td>
<td></td>
</tr>
<tr>
<td>Median duration to abdominal wall closure (d)</td>
<td>3 (0, 4)</td>
<td>6 (2, 10)</td>
<td>&lt; 0.001</td>
<td>4 (0, 9)</td>
</tr>
<tr>
<td>Median duration of mechanical ventilation: (d)</td>
<td>0.9 (0.8, 1.0)</td>
<td>0.9 (0.8, 1.0)</td>
<td>0.181</td>
<td>0.9 (0.8, 1.0)</td>
</tr>
<tr>
<td>Median duration of empiric antibiotics (d)</td>
<td>3 (2, 7)</td>
<td>8 (5, 11)</td>
<td>&lt; 0.001</td>
<td>7 (3, 10)</td>
</tr>
<tr>
<td>Median duration of parental nutrition (d)</td>
<td>20 (16, 31)</td>
<td>27 (22, 43)</td>
<td>&lt; 0.001</td>
<td>25 (19, 37)</td>
</tr>
<tr>
<td>Infants who had feeds initiated in NICU (n, %)</td>
<td>133 (94.3%)</td>
<td>284 (94.4%)</td>
<td>0.991</td>
<td>417 (94.3%)</td>
</tr>
<tr>
<td>Median age at initiation of feeds (d)</td>
<td>13 (10, 19)</td>
<td>18 (14, 27)</td>
<td>&lt; 0.001</td>
<td>17 (12, 24)</td>
</tr>
<tr>
<td>Number of babies achieving full feeds at discharge from NICU (n, %)</td>
<td>110 (78.0%)</td>
<td>231 (76.7%)</td>
<td>0.767</td>
<td>341 (77.1%)</td>
</tr>
<tr>
<td>Median age to achieve full feedings (d)</td>
<td>23 (19, 32)</td>
<td>29 (23, 45)</td>
<td>&lt; 0.001</td>
<td>27 (21, 40)</td>
</tr>
<tr>
<td>Discharged to home from NICU without full feed date: (n, %)</td>
<td>18 (12.8%)</td>
<td>29 (9.6%)</td>
<td>0.32</td>
<td>47 (10.6%)</td>
</tr>
<tr>
<td>Number of babies discharged home from the NICU (n, %)</td>
<td>104 (73.8%)</td>
<td>225 (74.8%)</td>
<td>0.824</td>
<td>329 (74.4%)</td>
</tr>
<tr>
<td>Median duration from final closure and discharge home from NICU (d)</td>
<td>27 (22, 38)</td>
<td>28 (21, 45)</td>
<td>0.042</td>
<td>27 (21, 42)</td>
</tr>
</tbody>
</table>

Medians presented with (inter-quartile range).

* Defined as the ratio = number of days with a central venous catheter in place/the number of hospital days.

b 5.7% of infants did not have feeding initiated in the NICU.

c 101 infants were discharged home after transfer from the NICU to another site in the CHND hospital.
relative to published normative birth weights [26]. Although the birth lengths and head circumferences were not systematically measured, these disease-specific fetal growth curves suggest that the biology of GS interferes with fetal growth. Further studies are needed to hypothesize and understand the potential mechanisms behind this cohort's decreased fetal growth velocity. Until then, these data can be used by obstetric and neonatal clinicians to inform expectant mothers of the anticipated duration of pregnancy and fetal growth relative to a representative national birth cohort [26].

For nearly one-quarter (n = 101) of the cohort that was discharged home from a site other than the NICU, the hospital LOS was greater, and this difference is striking among those who receive staged closure. When infants may not need intensive care, we observed that centers may provide convalescent care outside the NICU. In this cohort, the majority (58.4%) of these transferred infants were receiving full enteral feedings at the time of transfer out of the NICU; this finding suggests that feeding advancement was not the primary issue for the prolonged hospitalization after transfer out of the NICU. Although the etiology of the increased hospital stay is unknown, we speculate that NICU clinicians are more familiar and experienced with the care and discharge of medically complex infants, and thus, were able to expedite discharge more efficiently. In addition, the increased LOS even if it occurred outside the NICU, by definition, may limit the parent–infant interactions, which in our experience, can be a barrier to discharging infants home successfully to a prepared, outpatient environment. Whatever the cause, the reasons are likely to be multifactorial, involving individual system processes, specific patients, treatment strategies, and family interactions.

There were several limitations of this study. Infants with more severe disease may have been preferentially selected for staged closure of GS, resulting in a longer LOS. Data captured in the CHND do not measure the full extent of the cardio-pulmonary or intestinal health of infants prior to closure or at the time of referral. Bowel appearance at the time of presentation was ascertained but missing during chart abstraction in 1/3rd of the eligible infants. Also, surgical preferences were likely to play a critical role in the decision to perform primary or even the varied approaches to staged closure (e.g., sutured, spring-loaded, sutureless). In this study, the factors that contributed to these preferences and/or the extent by which they may influence patient outcomes are uncertain. Nevertheless, this cohort is a large, contemporary, multi-center and even homogeneous sample of infants, and we believe this cohort is representative of the population with GS in the United States in general. Moreover, by analyzing a clinical data set, this study mitigates limitations that were inherent in analyzing historical administrative data in this population [38].

As in any analysis of secondary data, unknown and unmeasured factors could have modified the observed associations and trends. Pertinent to this cohort, factors such as bowel dilation, matting, defect size, and other factors related to abdominal–visceral disproportion could have contributed to the selection of the type of closure. Moreover, coding errors leading to misclassifications are a concern in retrospective analyses of administrative databases. However, proactive steps in this clinical dataset were taken to reduce the chance of misclassifications in the CHND, as described.

In summary, staged closure for GS is associated with a longer LOS, mechanical ventilation, and empiric antibiotics relative to infants who received primary closure of their abdominal wall. We found no evidence that primary closure led to complications necessitating re-operation, NEC, or SBS/IF. Thus, we speculate that primary closure may have been a preferable option for some infants who received staged closure in order to provide an opportunity for reductions in LOS. Exploration of this hypothesis requires randomizing infants to surgical closure or identifying the factors that contributed to selecting either closure type. Abdominal closure type is ultimately a process measure, and how closure ultimately impacts these infants’ growth and neuro-development remains unresolved [39]. Future research using CHND will focus on the factors underlying the observed inter-center variability [40] in association with the resultant outcomes.

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3. Children’s Hospital of Alabama, Birmingham, AL (Carl Coghill)
4. Le Bonheur Children’s Hospital, Memphis, TN (Ramasubbareddy Dhanireddy)
5. Children’s Hospital Boston, Boston, MA (Anne Hansen)
6. Ann & Robert H. Lurie Children’s Hospital of Chicago, Chicago, IL (Karna Murthy)
7. Nationwide Children’s Hospital, Columbus, OH (Kristina Reber)
8. Children’s Medical Center, Dallas, TX (Rashmi Savani, Luc Brion)
9. Children’s Hospital Colorado, Aurora, CO (Theresa Grover)
10. Children’s Hospital of Michigan, Detroit, MI (Gitija Natarajan)
11. Cook Children’s Health Care System, Fort Worth, TX (Jonathan Nedrelow, Annie Chi)
12. Texas Children’s Hospital, Houston, TX (Yvette Johnson)
13. Children’s Mercy Hospitals & Clinics, Kansas City, MO (Eugenia Pallotto)
14. Arkansas Children’s Hospital, Little Rock, AR (Becky Rodgers)
15. Children’s Hospital Los Angeles, Los Angeles, CA (Lisa Kelly*, Steven Chin)
16. Children’s Hospital & Research Center Oakland, Oakland, CA (David Durand, Jeanette Asselin)
17. The Children’s Hospital of Philadelphia, Philadelphia, PA (Jacque-lyn Evans, Michael Padula)
18. Children’s Hospital of Pittsburgh of UPMC, Pittsburgh, PA (Beverly Brozanski)
19. St. Louis Children’s Hospital, St Louis, MO (Joan Rosenbaum, Tasmin Najaf, Amith Mathur, Rakesh Rao)
20. All Children’s Hospital, St. Petersburg, FL (Victor McKay)
21. Rady Children’s Hospital, San Diego, CA (Mark Speziale)
22. Children’s National Medical Center, Washington, DC (Billie Short)
23. Al duPont Hospital for Children, Wilmington, DE (Kevin Sullivan)
24. Primary Children’s Medical Center, Salt Lake City, UT (Donald Null)
25. Children’s Hospital of Wisconsin, Milwaukee, WI (Michael Uhing)^
26. Children’s Hospital of Omaha (Lynne Willett, John Grebe)^
27. Florida Hospital for Children (Rajan Wadhawan)^

^deceased
^institution and site sponsor began participation during 2011–2012 academic year.

References