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ORIGINAL ARTICLE

The Impact of Gestational Age on Resource Utilization After Open Heart Surgery for Congenital Cardiac Disease From Birth to 1 Year of Age

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Abstract The impact of gestational age on perioperative morbidity was examined using a novel construct, the resource utilization index (RUI). The medical records of subjects from birth to 1 year of age entered into a pediatric cardiothoracic surgery database from a major academic medical center between 2007 and 2011 were reviewed. The hypothesis tested was that infants born at 37–38 weeks (early-term infants) experience greater resource utilization after open heart surgery than those born at 39 completed weeks and that this association can be observed until 1 year of age. The results support the premise that resource utilization increases linearly with declining gestational age among infants at 0–12 months who undergo cardiac surgery. Five of the six variables comprising the RUI showed statistically significant linear associations with gestational age in the predicted direction. Multivariate linear regression analysis showed that gestational age was a significant predictor of an increased RUI composite. Further investigation is needed to test the concept and to expand on these findings.

Keywords Congenital cardiac surgery · Early-term birth · Gestational age · Postoperative outcomes

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Introduction

Factors that determine the outcome for infants with congenital heart disease (CHD) after open heart surgery can be broadly classified into three categories [8]. The first set of characteristics is preoperative and individual. Specifically, relevant variables include the anatomic lesion, the timing of diagnosis (pre- vs postnatal diagnosis, and if postnatal, the age at diagnosis), comorbidities such as chromosomal abnormalities and extracardiac anomalies, and noncardiac acute intercurrent illnesses such as necrotizing enterocolitis and sepsis. The second set of factors comprises operative events including timing of surgery, prolonged cardiopulmonary bypass and aortic cross-clamp times, the need for deep hypothermic circulatory arrest, and intraoperative complications such as hemodynamically significant dysrhythmias, pulmonary hypertensive crises, difficulty separating from bypass, or the need for return to bypass. The third group, postoperative events, includes complications related to cardiac intensive care such as respiratory failure with prolonged intubation or need for reintubation, other pulmonary complications such as pneumothorax or chylothorax, postoperative rhythm disturbances or low cardiac output, coagulopathy or surgical bleeding, and profound fluid shifts into the interstitial space. These three factors are interrelated, and postoperative events, in particular, are very much influenced by preoperative characteristics and the intraoperative course.

To date, research on prognosis after pediatric cardiac surgery has addressed primarily surgical variables, with the lesion and procedure carrying significant weight in validated, objective risk assessment scoring systems such as risk adjustment in congenital heart surgery—version 1 (RACHS-1) and Aristotle comprehensive complexity (ACC) [6, 7, 17, 19]. In-hospital and 28-day mortality have been the end points most often measured [5]. Outcomes research specifically has focused on the modification of operative risk factors including refinements in surgical and procedural technique, technologic advances in the bypass circuit, use of blood prime for the youngest infants, more rapid and effective cardioplegia, modified ultrafiltration, and more sophisticated intraoperative neurologic monitoring and neuroprotective strategies.

More recent investigations have begun to address the potential contribution of modifiable patient-related risk factors to surgical outcomes. This change reflects the fact that operative survival after repair of most congenital cardiac lesions (excluding stage 1 palliation for hypoplastic left heart syndrome [HLHS]) exceeds 90 % at high-volume specialized centers [9, 14]. In addition, oversight and regulatory agencies currently are targeting inpatient experience and quality of care as key performance benchmarks.

Admittedly, opportunities are by definition limited and to date have included changes in practice that permit earlier, more accurate prenatal diagnosis [4, 11, 18, 20, 21, 26, 28] (e.g., increasing referrals to specialized centers for fetal echocardiography and ongoing monitoring and implementation of pulse oximetry before discharge from the newborn nursery to screen healthy neonates for ductal-dependent congenital heart defects).

Gestational age at delivery represents an important, recently identified, potentially modifiable risk factor for adverse outcomes in neonates, including those with congenital heart defects. Although the association between prematurity, defined as <34 weeks gestation, and increased morbidity and mortality has long been appreciated [1–3], reports of adverse outcomes for infants delivered before 39 completed weeks can currently be found in the literature [3, 15, 25], challenging established theories about what constitutes term gestation and which infants are truly at risk.

In view of these findings, Costello et al. [12] in 2010 reviewed hospital records from 971 neonates with critical CHD, defined as cardiac defects requiring surgery or an interventional procedure for survival within the first 28 days of life. They observed that delivery at 37–38 weeks gestation was independently associated with a significant increase in mortality, morbidity, days of mechanical ventilation, and intensive care unit and hospital lengths of stay for neonates up to 28 days of age. They noted further that the majority of patients with complex CHD at their center were born before 39 weeks and that 26 % of those born at 37–38 weeks with prenatally diagnosed heart disease were elective deliveries, suggesting an opportunity for risk modification.

Investigators elsewhere have observed this same practice, attributing it to logistics, convenience, and maternal and provider preference [10, 15, 16]. Explanations for this "normalization of deviance" or unsound practice that continues because of an anecdotally derived favorable experience [10] are multifactorial and beyond the scope of this report.

In this study, we sought to investigate whether the impact of gestational age younger than 39 weeks on outcomes after congenital cardiac surgery extends beyond the neonatal period all the way up to 1 year of age, by which time most serious congenital heart lesions require intervention.

Methods

Study Design

For this retrospective, single-center, observational study, all available electronic medical records of patients registered in the pediatric cardiac surgery database of a large academic medical center from January 2007 through December 2011 were reviewed. All subjects who underwent surgery involving thoracotomy or cardiopulmonary bypass between birth and 1 year of age were included in the initial selection. Subjects who had procedures such as patent ductus arteriosus (PDA) ligation, extracorporeal membrane oxygenation (ECMO) cannulation, and pacemaker implantation were excluded from the study, as were follow-up operative interventions such as delayed sternal closure, diaphragm plication, and thoracic duct ligation.

Primary outcomes analyses were performed for 179 subjects. Subject selection is further summarized in Tables 1 and 2. Table 3 provides an overview of the demographics and relevant variables for the study subjects.

Table 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Age ≤ 1 year at time of surgery	PDA ligation, device placement (pacemaker), ECMO cannulation
Congenital heart surgery requiring thoracotomy or cardiopulmonary bypass	Procedures for addressing postoperative complications[a]
Admission to the PICU postoperatively	

PDA patent ductus arteriosus, *ECMO* extracorporeal membrane oxygenation, *PICU* pediatric intensive care unit

[a] Includes delayed sternal closure, thoracic duct ligation, and diaphragm plication

Table 2 Selection of study population

	n
Patients entered into surgical registry from 2007 to 2011	725
Subjects satisfying inclusion criteria	248
Subjects further excluded based on procedure (exclusion criteria)	69
Study population used for creation of RUI composite	179
Gestational age data unavailable	17
Sample used for multivariate regression	162

RUI resource utilization index

Table 3 Demographic and perioperative characteristics of the study population

Total subjects	179 (100)
Male sex	86 (48)
Gestational age	
≥39 completed weeks	95 (58)
37–38 6/7 completed weeks	34 (21)
34–36 6/7 completed weeks	21 (13)
<34 completed weeks	14 (8)
Mean gestational age (weeks)	38.0 ± 3.0
Age at surgery	
<1 month	51 (29)
>1–6 months	101 (56)
>6–12 months	27 (15)
Mean age at surgery (months)	3.25 ± 2.86
Prenatal diagnosis of cardiac anomaly	63 (35)
Chromosomal anomalies	
Trisomy 21	27 (15)
DiGeorge syndrome (22q11 deletion)	10 (6)
Other anomaly	16 (9)
RACHS-1 category	
1	6 (3)
2	90 (50)
3	42 (24)
4	41 (23)
Mean cardiopulmonary bypass time (min)	97.0 ± 48.4
Mean aortic cross-clamp time (min)	44.5 ± 29.2
Mean deep hypothermic circulatory arrest time (min)	9.8 ± 17.0

RACHS-1 risk adjustment in congenital heart surgery-version 1

Data are presented as *n* (%) unless otherwise noted as mean ± standard deviation

The primary exposure variable was gestational age at delivery as recorded in the medical record. Where discordant values were assigned by the obstetricians and the cardiologists (based on ultrasound dating), the obstetrician's assessment was chosen.

Table 4 Component measures of the resource utilization index

Postoperative hospital length of stay (LOS)[a]
PICU length of stay (PLOS)
Time to first extubation (TE)[a]
Time to negative fluid balance (TNB)
Need for vasopressors > 24 h (P24)[a]
Mortality before hospital discharge (total mortality)[a,b]

PICU pediatric intensive care unit

[a] Included in the final resource utilization index (RUI) composite

[b] Total mortality of 6 % includes perioperative mortality of 2 %

Table 5 Individual and perioperative variables

Gender
Mode of delivery
Prenatal diagnosis of cardiac anomaly
Chromosomal anomaly
Age at surgery
RACHS-1 category
CPB time
Aortic cross-clamp time
DHCA time

RACHS-1 risk adjustment in congenital heart surgery-version 1, *CPB* cardiopulmonary bypass, *DHCA* deep hypothermic circulatory arrest

Subject gestational age was stratified into four groups: 39 weeks or older, 37–38, 34–36 weeks, and younger than 34 weeks. For purposes of statistical analysis, subjects whose gestational age was designated as full-term in the medical record were assigned to the 39 or more completed weeks group.

The primary outcome variable was the resource utilization index (RUI), a derived composite of the six outcome measures listed in Table 4. These outcome measures were analyzed first at the univariate level, then composited after transformation of the individual variables to standard scores and testing of internal consistency reliability.

To establish gestational age as an independent risk factor for increased perioperative morbidity and to adjust for potential confounders, it was tested with the nine perioperative and individual characteristics specified in Table 5. The following five individual characteristics, all of which could be relevant in the association between gestational age and cardiac surgery outcomes, were recorded: gender, mode of delivery (vaginal vs cesarean), chronological age at surgery, prenatal diagnosis of cardiac anomaly, and presence of chromosomal abnormalities.

Three perioperative variables were recorded: cardiopulmonary bypass time, duration of deep hypothermic circulatory arrest, and aortic cross-clamp time. Finally, each subject was assigned a RACHS-1 category score to allow adjustment for severity of cardiac lesion in subsequent analyses. This validated classification system groups cardiac surgical procedures with similar expected outcomes into one of six categories.

This study was approved by the medical college Institutional Review Board, and the requirement for informed consent was waived.

Statistical Analysis

Data were analyzed using SPSS for Windows (SPSS, Chicago, IL, USA). First, the six component variables of the RUI (Table 5) were compared in bivariate nonparametric analyses (chi-square) to gestational age. Descriptive data then were analyzed to define the means, ranges, and distributions of the six outcome (RUI) measures and the nine individual and perioperative variables in the sample of 179 subjects who underwent cardiac surgery.

With this information in hand, the four continuous variables were converted to standard scores, and missing variables were imputed using group means. The standardized scores then were analyzed for internal consistency and aggregated appropriately to create a composite of outcome, labeled RUI. Gestational age also was compared with the nine individual and perioperative characteristics that may have mediated the association between gestational age and outcomes.

Finally, multivariate linear regression analysis was performed on the 162 subjects for whom gestational age data were available. For this analysis, the RUI composite was the dependent variable and gestational age plus selected preoperative and individual characteristics comprised the independent variables in the equation. Significance was set at an alpha of 0.05. For all analyses, the sample size was adequate to achieve a power of 0.80 to detect moderate effect sizes.

Results

RUI Univariate Analysis

To address the study hypothesis, bivariate analyses were used to compare gestational age with data on the six components of the RUI: postoperative hospital length of stay (LOS), pediatric intensive care unit (PICU) length of stay (PLOS), time to first extubation (TE), time to negative fluid balance (TNB), need for vasopressors beyond 24 h (P24), and total mortality (also shown in Table 5).

First, the continuous variables (gestational age, LOS, PLOS, TE, TNB) were transformed into categorical variables based on variable distributions. Gestational age then was cross-tabulated with each of the six RUI components, and the associations were assessed using chi-square. The following results, summarized in Fig. 1, were obtained.

Gestational age and LOS showed a significant linear association ($\chi^2[1] = 6.5$; $p < 0.05$). As gestational age decreased, length of hospitalization increased, with 21 % of the ≥39-week subjects having stays of 14 days or more compared with 26 % of the 37- to 39-week subjects, 29 % of the 34- to 37-week subjects, and 57 % of the <34-week subjects.

Gestational age and PLOS showed a significant linear association ($\chi^2[1] = 6.9$; $p < 0.01$). As gestational age decreased, the length of PICU stay increased, with 20 % of the ≥39-week subjects having stays of 10 days or more compared with 26 % of the 37- to 39-week subjects, 33 % of the 34- to 37-week subjects, and 43 % of the <34-week subjects.

Gestational age and TE also showed a significant linear association ($\chi^2[1] = 7.0$; $p < 0.01$). Among the subjects born at 39 weeks or later, 21 % were intubated 87 h or more compared with 26 % of those born at 37–39 weeks, 38 % of those born at 34–37 weeks, and 50 % of those born before 34 weeks.

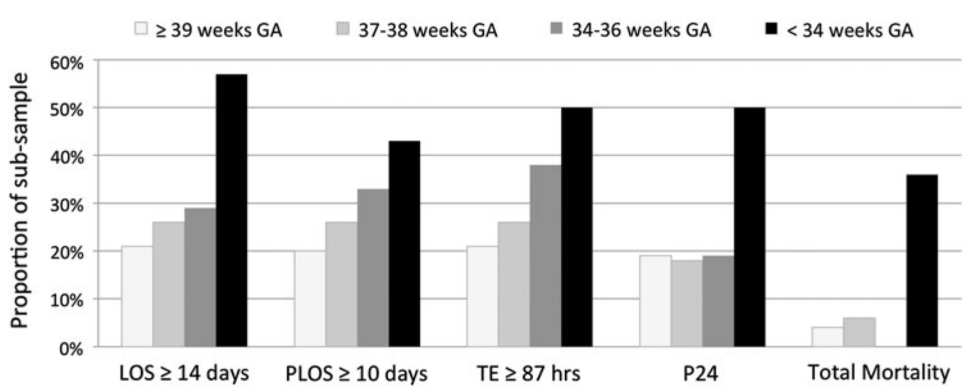

Fig. 1 Nonparametric associations between gestational age and the six components of the resource utilization index (RUI). Gestational age showed significant linear associations with hospital length of stay (LOS), pediatric intensive care unit length of stay (PLOS), time to first extubation (TE), need for vasopressors beyond 24 h (P24), and total mortality

Gestational age and TNB did not show any significant association ($\chi^2[6] = 11.2$, nonsignificant).

Gestational age and P24 showed a near-significant linear association ($\chi^2[1] = 3.6$; $p = 0.058$). Among subjects born at 39 weeks or later, 19 % required vasopressors for more than 24 h compared with 18 % of those born at 37–39 weeks, 19 % of those born at 34–37 weeks, and 50 % of those born before 34 weeks.

Gestational age showed a significant linear association with mortality ($\chi^2[1] = 8.2$; $p < 0.01$) because the rate of death was elevated for the subjects born before 34 weeks (36 %) compared with subjects born at 34 weeks or later (4 %). We note that this does not constitute a novel finding, but in composite is consistent with other findings presented in this report.

Individual and Perioperative Characteristics: Univariate Analysis

Gestational age also was compared with nine individual and perioperative characteristics (Table 5) that may have mediated the association between gestational age and RUI outcomes. In particular, we examined gender, mode of delivery, presence of chromosomal anomaly, prenatal diagnosis of cardiac anomaly, age at surgery, RACHS-1 score, cardiopulmonary bypass time, duration of aortic cross-clamp, and deep hypothermic circulatory arrest time.

Gestational age was significantly associated with three of the nine variables, showing significant linear associations with delivery mode, prenatal diagnosis, and chromosomal anomaly. As shown in Fig. 2, the prevalence of cesarean delivery increased as gestational age decreased (39, 50, 50, 100 %: $\chi^2[1] = 12.3$; $p < 0.001$); the prevalence of prenatally diagnosed cardiac anomaly decreased as gestational age decreased (42, 38, 11, 17 %: $\chi^2[1] = 6.5$; $p < 0.05$); and the prevalence of chromosomal anomaly increased as gestational age decreased (20, 35, 48, 43 %: $\chi^2[1] = 8.0$; $p < 0.01$). As detailed later, these potential modifiers were integrated into the regression model.

Calculating an RUI Composite

Correlations among the six components of the RUI were calculated using Spearman rank coefficients. The findings indicated that TNB was not correlated with any of the other five variables. Furthermore, LOS and PLOS were highly correlated ($r_s [179] = 0.71$) because PLOS is essentially a subset of LOS. Therefore, PLOS was not further analyzed because it was not likely to contribute novel information.

Before computing an aggregated index of resource utilization, variable transformations were necessary. First, the three continuous variables (LOS, TE, TNB) were standardized into *z*-scores. The two nominal variables (mortality and P24) were not transformed. These five variables then were submitted to an analysis of internal consistency, yielding an alpha coefficient. The analysis indicated that the TNB variable (which also did not show a bivariate association with gestational age) significantly suppressed internal consistency (alpha = 0.63 vs 0.75). This evidence, taken together with its absence of association with gestational age and its zero-order correlations with the other variables, indicated that TNB merited exclusion from calculation of the RUI composite.

Ultimately, four of the six RUI variables were used in the composite. The final RUI composite included LOS, TE, P24, and mortality. The standardized item alpha was 0.75, indicating adequate internal consistency. Correlations of each of the four RUI variables with the composite were statistically significant and positive as follows: LOS ($r_s[177] = 0.82$; $p < 0.001$), TE ($r_s[177] = 0.91$; $p < 0.001$), P24 ($r_s[177] = 0.57$; $p < 0.001$), and mortality ($r_s[177] = 0.34$; $p < 0.001$).

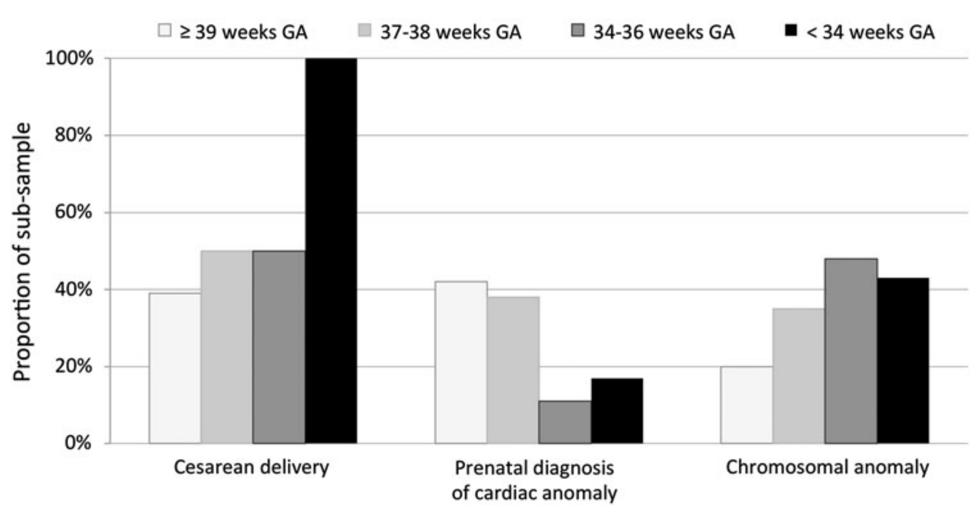

Fig. 2 Correlations between gestational age and prevalence of cesarean delivery, prenatal diagnosis of cardiac anomaly, and chromosomal anomalies

The raw RUI composite showed a high positive skew and highly non-normal kurtosis (clustering). Thus the composite was submitted to a natural log (ln) transformation, which yielded a symmetric distribution with normalized clustering.

RUI Composite and Gestational age

Pearson product-moment correlation showed that the correlation between gestational age and the ln-transformed RUI composite score was r (164) = –0.28 ($p < 0.001$).

Multivariate Regression Analysis

The ln-transformed RUI composite was submitted as the dependent variable to a stepwise linear regression. Gestational age plus appropriate individual and perioperative characteristics were submitted as independent variables. In the first step, the three variables with significant bivariate associations (mode of delivery, presence of chromosomal anomalies, prenatal diagnosis of cardiac anomaly) and RACHS-1 score (included to index overall risk of cardiac surgery) were entered. In the second step, gestational age was entered. The resulting model included all entered variables. Specifically, the four individual and perioperative variables yielded an adjusted R^2 of 0.315. The addition of gestational age to the equation yielded a significantly increased variance in RUI outcomes (F [1,126] = 9.6; $p < 0.01$), with an R^2 of 0.36.

These analyses support the premise that resource utilization is increased in infants born at earlier gestation who undergo cardiac surgery at the age of 0–12 months.

Study Limitations

This study was subject to the known limitations of observational data obtained retrospectively in a single-institution/single-surgeon cohort. Because these are retrospective data, there is the additional challenge of missing values. To address this limitation, we assigned means to the ranges with missing values. Although the study population was underpowered for accurate prediction of specific ranges for prospective risk scoring, using this framework in larger multicenter studies will identify critical variables and ranges, thus increasing the predictive value.

The convention of designating gestational age in the medical record as full-term rather than the precise number of completed weeks was another limitation imposed by this retrospective data set. Because elimination of those subjects would have significantly reduced sample size, we elected to include them in the >39-week gestational age category. In a post hoc analysis, the subjects with specific information indicating a gestational age of 39 weeks or greater (GA39) were compared with those designated only as full-term on the six RUI variables. These results indicated that the full-term subjects showed lower levels of risk for LOS, P24, and TE ($p < 0.01$) than the GA39 subjects. The two groups did not differ in terms of mortality, PLOS, or TNB. These findings suggest that subjects designated only as full-term were not likely to have been younger than 39 weeks gestation.

Another major limitation was the absence of subjects with RACHS-1 scores of 5 and 6. Adequate representation of this subgroup in subsequent studies will allow a more robust head-to-head comparison of RACHS-1 score and early-term gestational age in relation to outcomes.

Variables that might have confounded the association between gestational age and RUI may have been present but not accounted for.

For subjects referred from outside institutions, we were reliant on transfer records. Established predictors of outcome may not have been communicated or may have been omitted from the chart at the time of data collection. Peripartum maternal variables, invasive procedures, and associated complications occurring before surgery would be important elements to include in larger, prospective studies. Likewise, variations in intensive care practice among different centers may factor into the results.

Discussion

Recent evidence suggests that the generally accepted and somewhat arbitrarily determined designation of full-term gestation as 37–41 weeks may deserve reappraisal [15]. Term births have traditionally been considered a homogeneous group in terms of morbidity and mortality risk, providing a safe window for the process to occur. Large epidemiologic surveys of newborns conducted within the last 5 years, however, demonstrate significant differences in outcome and mortality risk for neonates born at 37–38 weeks gestation, so-called early-term births, compared with those born at or after 39 completed weeks [13, 15, 22, 24, 29].

A review of the U.S. National Center for Health Statistics data from 1995 to 2006 demonstrated a nearly twofold increase in the risk for neonatal mortality in otherwise healthy neonates, without birth defects or other predisposing factors, born at 37 versus 39 weeks gestation [25]. Several investigations also have shown significant morbidity associated with delivery at 37–38 weeks compared with 39–40 weeks [10, 29].

One such study examined several indicators of neonatal morbidity, including respiratory complications, seizures, necrotizing enterocolitis, hypoxic-ischemic encephalopathy, admission to the neonatal intensive care unit, and hospitalization prolonged 5 days or more, and found a significantly lower likelihood of these events occurring as gestational age increased from 37 to 40 weeks [27]. Data on outcomes for infants with CHD stratified by gestational age are limited, and a literature search by these authors identified only the study by Costello cited earlier [12] and a recent one by Natarajan et al. [23], which found significantly higher rates of necrotizing enterocolitis, seizures, prolonged hospital stay, and mortality in late preterm infants with CHD, defined as 34–37 weeks gestation, than in similarly affected neonates born at term. Given the high incidence of CHD, which complicates approximately 1 % of U.S. births, and the significant contribution to neonatal mortality, accounting for approximately 25 % of all neonatal deaths attributable to birth defects, additional, more rigorous investigations into risk-related outcomes are warranted.

The current study adds to the emerging literature on the relationship between gestational age and outcomes of infants with CHD by proposing a novel paradigm for future research, the RUI, a composite of variables that should be readily available or at least easily obtainable for all infants with CHD. This simple tool uses previously validated contributors to risk, thus lending validity to the design of the construct.

In addition, testing for internal consistency ensured that the components selected for inclusion in the regression model were justified. From a statistical standpoint, using an aggregated outcome variable improved the reliability of the dependent measure, thus maximizing the likelihood that true significance would be detected, compared with analysis that rests on a single outcome variable. We anticipate that application of this index to a larger, more diverse patient population will add support to our hypothesis that gestational age is an important, potentially modifiable risk factor influencing perioperative outcomes.

The practical utility of the RUI in the clinical arena awaits further testing in future trials. The low rate of perioperative mortality (2 %) in our sample precluded death as a key outcome measure, but total mortality must be considered for inclusion in any study of outcomes. More detailed analysis will help to determine whether gestational age remains a significant determinant in the perioperative course of infants who undergo surgery at an age older than 1 month.

Additional studies are needed to confirm our findings regarding the associations between gestational age and delivery mode, prenatal diagnosis, and chromosomal anomalies. The increased prevalence of cesarean delivery with decreasing gestational age observed in subjects with chromosomal abnormalities was not seen in those with prenatally diagnosed cardiac disease, suggesting that in our tertiary academic referral center, earlier elective delivery of infants with known cardiac disease does not frequently occur. Including subjects from multiple sites in future studies would better define true associations and might yield more definitive explanations for our observations.

The TNB as a potentially important contributor to outcome has not been systematically studied. This surrogate marker for the robustness of the inflammatory response to cardiac surgery or more specifically to cardiopulmonary bypass is likely to be age dependent and most certainly genetically programmed, thus adding to the individual risk profile. Prospective studies with larger numbers of patients are needed to confirm this observation and to determine the degree of influence.

The use of P24 as a component of the RUI allowed us to identify those subjects who truly required vasopressor support because it is standard practice at our institution for all patients who have had surgery on cardiopulmonary bypass to be started on low doses of milrinone and epinephrine in the operating room. Patients with stable hemodynamics are rapidly weaned off the epinephrine, whereas the milrinone, which was not included in the P24 calculation, is continued until the patient is safely extubated.

Conclusions

This study provides additional support for recent observations regarding the impact of gestation shorter than 39 completed weeks (early-term birth) on outcomes after surgery for CHD disease in infants up to the age of 1 month. However, our hypothesis that increases in morbidity and resource use extend beyond the neonatal period, up to and including infants 1 year of age, potentially encompassing a significant number of infants with serious CHD, could not be confirmed in the cohort we examined. Still, given the high incidence of congenital heart defects, interventions that may improve outcomes in even a small subset of patients would be significant. Thus, this study provides the framework and justification for a larger, multicenter study in which we may test our hypothesis and refine and further validate the RUI.

We anticipate that a study cohort including subjects with classes 5 and 6 RACHS-1 scores and a greater number with documented gestational ages that fall in the early-term birth group will yield more definitive findings and provide more convincing support for our assertion that gestational age has an impact on perioperative outcomes beyond the neonatal period. In addition, we suggest that moving forward, providers should maintain detailed and precise documentation of gestational age, indications for elective delivery before 39 weeks, and the patient variables identified in this report, assembled as a concise "smart set" to be included in the electronic medical record of each newborn with

CHD. This will allow ongoing surveillance as practice patterns are modified, aid in much needed future study on long-term cognitive and developmental outcomes, and quite likely help to direct changes in the care of this at-risk population of infants with CHD.

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