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A risk calculator predicting postoperative adverse events in neonates undergoing major abdominal or thoracic surgery

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ABSTRACT

Purpose: This study sought to demonstrate the feasibility of a risk calculator for neonates undergoing major abdominal or thoracic surgery with good discriminative ability.
Methods: The American College of Surgeons' National Surgical Quality Improvement Program Pediatric (ACS-NSQIP-P) 2011–12 data were queried for neonates who underwent major abdominal or thoracic surgery. The outcome of interest was the occurrence of any adverse event, including mortality, within 30-days postoperatively. The preoperative clinical characteristics significantly associated with any adverse event were used to build a multivariate model. The model's discriminative ability was assessed with the area under the receiver operating characteristic curve (AUROC). The model was split-set validated with 2013 data.
Results: A total of 2967 neonates undergoing major abdominal or thoracic surgery were identified. The overall rate of adverse events was 23.3%. Sixteen variables were found to be associated with adverse events. Four variables increased the odds of adverse events at least two-fold: dirty or infected wound class [odds ratio (OR) = 2.1] dialysis (OR = 3.8), hepatobiliary disease (OR = 2.1), and inotropic agent use (OR = 2.6). The AUROC = 0.79 for development data and 0.77 on split-set validation.
Conclusion: Preoperatively estimating the probability of postoperative adverse events in neonates undergoing major abdominal or thoracic surgery with good discrimination is feasible.

Despite improvement in neonatal surgical care [1], surgical procedures in neonates are often associated with higher rates of postoperative adverse events compared to other children [2]. Neonates undergoing surgery have heterogeneous clinical and comorbidity profiles, resulting in different risks of postoperative adverse events [3,4]. Many families in the stressful weeks after their infant's birth wish for, and could benefit from, more quantitative information regarding postoperative prognosis [5,6].

This study sought to create a risk calculator model that could help preoperatively estimate patient-specific probability of postoperative adverse events in neonates undergoing major abdominal or thoracic surgery. The specific aim was to use the American College of Surgeons' National Surgical Quality Improvement Program Pediatric (ACS-NSQIP-P) preoperative clinical and procedural data to estimate probability of postoperative adverse events with good discriminative ability. The ACS-NSQIP has built a risk calculator model for adults that can be used by physicians and patients to better estimate patient-specific probability of postoperative adverse events preoperatively [7]. The purpose of this study was to determine the feasibility of developing a similar tool in neonatal surgery.

1. Materials and methods

1.1. Data source and patient sample

This observational study used 2011–2013 clinical registry data from the ACS-NSQIP-P. The setting consisted of 50 participating ACS-NSQIP-P hospitals across North America. The dataset included demographic, preoperative clinical, and procedural variables as well as postoperative adverse events in the 30 days following surgery, as described elsewhere

Abbreviations: ACS-NSQIP-P, American College of Surgeons National Surgical Quality Improvement Program Pediatric; CPT, Current Procedure Terminology; ASA, American Society of Anesthesiologists; AUROC, Area Under the Receiver Operating Characteristic.

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Table 1
Preoperative clinical characteristics of study sample of neonates undergoing major abdominal or thoracic surgery (total $N = 2967$).

Demographic	Count	%
Male	1725	58.1
Race		
Caucasian	2398	80.8
African American	489	16.5
Asian	54	1.8
Native American	21	0.7
Other	5	0.2
Hispanic ethnicity	347	11.7
Chronological age		
≤28 days	2270	76.5
29−365 days	697	23.5
Gestational age		
Less than 24 completed weeks gestation	50	1.7
24 completed weeks gestation	87	2.9
25–26 completed weeks gestation	198	6.7
27–28 completed weeks gestation	177	6.0
29–30 completed weeks gestation	168	5.7
31–32 completed weeks gestation	165	5.6
33–34 completed weeks gestation	278	9.4
35–36 completed weeks gestation	477	16.0
37 or greater completed weeks of gestation	1365	46.0
Procedural variables		
Major abdominal	2581	87.0
Major thoracic	386	13.0
Case		
Elective	1381	46.5
Emergent	933	31.5
Urgent	653	22.0
Inpatient	2929	98.7
Wound class		
Clean	612	20.6
Clean-contaminated	1811	61.1
Contaminated	258	8.7
Dirty/infected	286	9.6
American Society of Anesthesiologists		
ASA class I	58	2.0
ASA class II	502	16.9
ASA class III	1543	52.0
ASA class IV	804	27.1
ASA class V	60	2.0
Metabolic and nutritional conditions		
Preoperative nutritional support	1563	52.7
Renal conditions		
Preoperative dialysis	27	0.9
Cardiac conditions		
Cardiac risk factors		
No cardiac risk factors	1665	56.1
Minor risk factors	820	27.6
Major risk factors	350	11.8
Severe risk factors	132	4.5
Cardiac surgery	204	6.9
Alimentary tract conditions		
Esophageal gastrointestinal disease	2138	72.1
Hepatobiliary pancreatic disease	167	5.6
Pulmonary conditions		
Chronic lung disease	476	16.0
Neurologic conditions		
APGAR at 5 minutes		
APGAR score 1	42	1.4
APGAR score 2	74	2.5
APGAR score 3	81	2.7
APGAR score 4	143	4.8
APGAR score 5	230	7.8
APGAR score 6	326	11.0
APGAR score 7	553	18.6
APGAR score 8	1430	48.2
APGAR score 9	88	3.0
Hematologic and oncologic conditions		
Bleeding disease	97	3.3
Hematologic disorder	449	15.1
Preoperative transfusion	327	11.0
Acuity of illness		
Inotropic support	224	7.6
Sepsis preoperatively		
No sepsis	2779	93.7
Systemic inflammatory response syndrome	33	1.1
Sepsis	100	3.3
Septic shock	55	1.9

[8,9]. Inclusion criteria were the following: children accrued in ACS-NSQIP-P that were designated as neonates (0–28 days old corrected for gestational age) undergoing major abdominal or thoracic surgery as specified by the current procedural terminology (CPT) codes in the 'principal procedure' data field (Appendix A).

1.2. Measures

The primary outcome of interest was a composite 30-day adverse event variable. This composite variable was generated for two reasons. First, the rate of any single adverse event in this population was too low to model accurately in isolation. Second, the 30-day mortality rate was not common in this group of infants therefore mortality was added to the composite 30-day morbidity rate commonly used by ACS-NSQIP-P in performance benchmarking. The resulting variable was a composite dichotomous outcome variable of whether any one or more complications or mortality occurred within 30 days of the neonatal abdominal or thoracic surgery. The complications included in addition to mortality were: surgical site infection, pneumonia, reintubation, pulmonary embolism, renal insufficiency, urinary tract infection, coma, seizure, peripheral nerve injury, intraventricular hemorrhage, intracranial hemorrhage, cardiac arrest, intraoperative or postoperative transfusion, graft failure, venous thrombosis requiring therapy, sepsis, central line associated blood stream infection. The presence of complications was assessed at 30 days from the operation as defined within the ACS-NSQIP-P.

The predictors of interest were patient preoperative demographic and clinical variables as defined and collected by ACS-NSQIP-P. CPT codes were grouped into clinically similar categories and then converted into a linear risk variable. Case-mix was adjusted in the risk-calculator model using this previously described CPT linear risk approach (using CPT categories) [10].

1.3. Statistical analysis

Count and frequency of preoperative demographic and clinical variables in neonates who underwent abdominal or thoracic surgery were calculated. Next, the preoperative clinical characteristics significantly associated ($p < 0.05$) with the composite 30-day postoperative adverse event outcome on initial bivariate logistic regression were included in the multivariate hierarchical logistic model. Stepwise selection was used to select the variables most statistically associated with the composite outcome.

Parameter values from the final equation were used as the components of the risk calculator model to estimate the predicted probability of "any" postoperative adverse event for each individual infant. The predicted probability was output from the multivariate hierarchical model using only (patient-level) fixed effects. The model's discriminative ability was assessed by calculating the area under the receiver operating characteristic (AUROC) curve (the plot of sensitivity versus 1-specificity), also known as the c-statistic. Calibration was assessed with the Hosmer–Lemeshow chi-square and associated p-value. The Brier score was also calculated to assess discrimination and calibration. The Brier score is interpreted such that the lower the score the better the predictions' calibration. Finally, data from 2013 were used to split-set validate the model. The RAND CORPORATION institutional review board approved this study. All data management and analyses were performed in SAS 9.3 (SAS Institute, Cary NC).