Duration of Postoperative Mechanical Ventilation as a Quality Metric for Pediatric Cardiac Surgical Programs

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Background. **Few metrics exist to assess quality of care at pediatric cardiac surgical programs, limiting opportunities for benchmarking and quality improvement. Postoperative duration of mechanical ventilation (POMV) may be an important quality metric because of its association with complications and resource utilization. In this study we modelled case-mix–adjusted POMV duration and explored hospital performance across POMV metrics.**

Methods. **This study used the Pediatric Cardiac Critical Care Consortium clinical registry to analyze 4,739 hospitalizations from 15 hospitals (October 2013 to August 2015). All patients admitted to pediatric cardiac intensive care units after an index cardiac operation were included. We fitted a model to predict duration of POMV accounting for patient characteristics. Robust estimates of SEs were obtained using bootstrap resampling. We created performance metrics based on observed-to-expected (O/E) POMV to compare hospitals.**

Results. **Overall, 3,108 patients (65.6%) received POMV; the remainder were extubated intraoperatively. Our model was well calibrated across groups; neonatal age had the largest effect on predicted POMV. These comparisons suggested clinically and statistically important variation in POMV duration across centers with a threefold difference observed in O/E ratios (0.6 to 1.7). We identified 1 hospital with better-than-expected and 3 hospitals with worse-than-expected performance ($p < 0.05$) based on the O/E ratio.**

Conclusions. **We developed a novel case-mix–adjusted model to predict POMV duration after congenital heart operations. We report variation across hospitals on metrics of O/E duration of POMV that may be suitable for benchmarking quality of care. Identifying high-performing centers and practices that safely limit the duration of POMV could stimulate quality improvement efforts.**

(Ann Thorac Surg 2017;■:■–■)
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Quality assessment in pediatric cardiac operations suffers from a paucity of valuable metrics suitable for benchmarking. Death remains the predominant metric by which hospitals are compared, but many stakeholders have called for development of new quality

Dr Dimick discloses a financial relationship with ArborMetrix, Inc.

The Appendix and Supplemental Table can be viewed in the online version of this article [http://dx.doi.org/10.1016/j.athoracsur.2017.06.027] on http://www.annalsthoracicsurgery.org.

Accepted for publication June 6, 2017.

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Published by Elsevier Inc.

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2017.06.027

measures that assess morbidity and resource utilization [1, 2]. Duration of postoperative mechanical ventilation (POMV) may be one such important measure of quality care after pediatric cardiac operations. Although many children and adults undergoing operations for congenital or acquired heart disease wean from mechanical ventilation early in the postoperative period, prolonged ventilation may be necessary for complex patients [3, 4]. Data suggest that mechanical ventilation poses increased risk for infection, airway and lung injury, and failed extubation [3, 5, 6]. Increased duration of POMV prolongs the critical care period and further exposes patients to potential risks [4, 7, 8], so it is reasonable to conclude that shortening POMV duration may represent higher-quality, more cost-effective care. The National Quality Forum endorsed an adjusted prolonged mechanical ventilation hospital quality metric for coronary artery bypass operations [9].

However, the heterogeneity of pediatric cardiovascular surgical procedures and case-mix differences across hospitals [10] create challenges in assessing duration of POMV as a measure of hospital performance. An ideal quality metric of POMV would account for the patient factors and operative complexity that differ across hospitals. Previous investigators used this approach to measure ventilation time for critically ill adults [11–13], but these models do not apply to children with congenital heart disease. Some factors associated with POMV duration in children with cardiac disease are known, but no validated tool exists to predict the duration of POMV in this population [3, 4, 14–18]. Metrics of adjusted POMV duration would allow hospitals to measure performance and benchmark against peer institutions. These data could motivate improvement initiatives by collaborative learning with high-performing centers.

In this context, we aimed to develop hospital performance metrics for duration of POMV after pediatric cardiac operations using data from the Pediatric Cardiac Critical Care Consortium (PC^4) clinical registry. We developed and validated a model to predict duration of POMV and then created several metrics based on the observed-to-expected (O/E) duration of POMV. We describe differences in performance across hospitals for each metric and in aggregate.

Patients and Methods

Data Source

PC^4 is a voluntary quality improvement collaborative among hospitals across North America, and 15 hospitals were submitting data at the time of the analysis. All cardiac intensive care unit (CICU) encounters at participant hospitals are submitted to the PC^4 clinical registry. Each case record includes demographics, patient comorbidities, data on cardiac surgical procedures and other interventions, critical care therapies, and complications, all with standardized definitions.

The registry shares common terminology and definitions with the International Pediatric and Congenital Cardiac Code [19] and The Society of Thoracic Surgeons Congenital Heart Surgery Database, as previously described [20]; each site ensures that these data match across databases. Trained data managers, who pass a certification examination, abstract cases. We previously published results of the rigorous audit process demonstrating excellent data integrity within the registry [21]. Submission of data to PC^4 is considered quality improvement activity and is not subject to ongoing Institutional Review Board oversight. The University of Michigan Institutional Review Board oversees the PC^4 Data Coordinating Center; this study was approved with waiver of informed consent.

Inclusion and Exclusion Criteria

We considered all surgical hospitalizations for patients admitted to PC^4 hospitals that included at least one CICU encounter between October 1, 2013, and August 31, 2015. Each hospitalization included an "index" surgical procedure as defined by The Society of Thoracic Surgeons [22]. Although the unit of analysis is the surgical hospitalization, we refer to these episodes as "patients" throughout this report. We excluded patients with a tracheostomy in situ at the index operation, who weighed less than 2.5 kg undergoing isolated patent ductus arteriosus repair, who underwent index operations not classifiable into one of The Society of Thoracic Surgeons–European Association for Cardiothoracic Surgery (STAT) mortality categories [23], or who died before postoperative day 7.

Model Development: Outcomes and Predictor Variables

We developed a case-mix–adjustment model to predict duration of POMV after a congenital cardiac operation. Total duration of POMV was the dependent variable in the model. We calculated duration of POMV by adding the length of each episode of mechanical ventilation after the index operation. The registry includes the exact start and stop time of each mechanical ventilation episode in the CICU, including episodes in other critical care areas. Patients extubated in the operating room after an index procedure who never require mechanical ventilation were included with a POMV duration of 0 hours. Duration of POMV was capped at 60 days to eliminate the effect of extreme outliers on the model.

Our aim was to create a population-level case-mix–adjustment model. We did not attempt to predict duration of ventilation at the patient level. Thus, we explored candidate variables for our model present preoperatively or intraoperatively. We excluded postoperative variables that may be important for predicting the duration of mechanical ventilation for an individual patient such as vasoactive-inotropic score, complications, and critical care therapies. These variables could also reflect surgical or critical care quality and would therefore not be appropriate for a case-mix–adjustment model used in hospital quality assessment.

Preoperative patient factors, comorbidities, and operative complexity variables that affect outcomes after congenital cardiac operations were selected a priori.

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