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Pediatric Intensive Care Unit (PICU) Length of Stay: Factors Associated with Bed Utilization and Development of a Benchmarking Model

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Abstract

Objective—ICU LOS is an important measure of resource use and economic performance. Our primary aims were to characterize the utilization of PICU beds and to develop a new model for PICU LOS.

Design—Prospective cohort. The main outcomes were factors associated with PICU LOS and the performance of a regression model for LOS.

Setting—Eight pediatric ICUs.

Patients—Randomly selected patients (newborn to 18 years) from 8 PICUs were enrolled from December 4, 2011 to April 7, 2013. Data consisted of descriptive, diagnostic, physiologic, and therapeutic information.

Interventions—none

Measurements and Main Results—The mean LOS for was 5.0 days (SD 11.1), with a median of 2.0 days. The 50.6% of patients with LOS < 2 days consumed only 11.1% of the days of care, while the 19.6% of patients with LOS 4.9 to 19 days and the 4.6% with LOS ≥ 19 days consumed 35.7% and 37.6% of the days of care respectively. Longer LOS was observed in younger children, those with cardiorespiratory disease, post-intervention cardiac patients, and those who were sicker assessed by PRISM scores receiving more intensive therapies. Patients in the cardiac ICU stayed longer than those in the medical ICU. The LOS model using descriptive, diagnostic, severity, and therapeutic factors performed well (R-squared of 0.42). Standardized (observed divided by expected) LOS ratios at the individual sites ranged from 0.87 to 1.09.

Conclusions—PICU bed utilization was dominated by a minority of patients. The 5% of patients staying the longest utilized almost 40% of the bed days. The multivariate LOS model used descriptive, diagnostic, therapeutic and severity factors and has potential applicability for benchmarking.

Keywords

length of stay; outcomes research; critical care; pediatric critical care; quality assessment; health care economics

Introduction

Critical care efficiency and quality are associated with length of stay (LOS).^{1,2} Intensive care units (ICUs) are a major driver of hospital costs. In 2011, almost 27% of hospital stays involved ICU charges, and the hospital stays that involved the ICU were 2.5 times more costly than other hospital stays.³ The national trend in managing health care costs places a priority on efficient bed utilization. Operational efforts to control LOS include critical pathways, case management, and new management systems.^{4,5} Managing critical care resources is often difficult because there are complex associations between personnel and facility needs when the provision of timely and sophisticated but unanticipated care by skilled personnel results in important outcome differences.^{6,7}

ICU LOS is an important measure of resource use and economic performance.^{8,9} Yet, ICU LOS varies with respect to many factors including severity of illness, diagnostic diversity, and other patient factors.^{8,10-12} In addition, institutional practices substantially contribute to variability as evidenced by the wide disparity in LOS for both pediatric and adult ICUs despite controlling for patient factors.^{2,8,11,13,14}

Models predicting ICU LOS have been disappointing.^{8,15-17} Patient descriptive factors along with physiological profiles are statistically important but insufficient to explain the majority of LOS variability. Most models have included therapies and even then, model performances have been modest. For example, the proportion of variance (R^2) accounted for by an adult model using physiological profiles, patient admission characteristics, and therapies implemented in the first 24 hours in over 200,000 patients was less than 25%.⁸

There has not been a recent characterization of pediatric intensive care unit (PICU) utilization described by LOS distributions, and the patient characteristics associated with resource use. Our primary aims for this analysis were to characterize the utilization of PICU beds using the focus of LOS and to develop a multivariate model for PICU LOS to better understand the importance of patient and therapeutic factors in a sample of over 10,000 patients from eight institutions. Since model performance has been disappointing using variables only from the early ICU time period, we included therapies used during the entire PICU stay and PICU outcome. Inclusion of these post-admission factors is appropriate for our goal of investigating the relationship of patient and therapeutic factors in a multivariate model with potential applicability to internal and external benchmarking.

Patients and Methods

The data for this analysis originated in the Trichotomous Outcome Prediction in Critical Care (TOPICC) study conducted by the Collaborative Pediatric Critical Care Research Network (CPCCRN) of the *Eunice Kennedy Shriver* National Institute of Child Health and

Human Development. Data collection methods and institutional characteristics have been previously described.¹⁸ There were seven funded sites, one being composed of two institutions. In brief, patients aged from newborn to less than 18 years were randomly selected and stratified by hospital from December 4, 2011 to April 7, 2013. Patients from both general/medical and cardiac/cardiovascular PICUs were included. Moribund patients (vital signs incompatible with life for the first two hours after PICU admission) were excluded. Only the first PICU admission during a hospitalization was included. The protocol was approved by all participating Institutional Review Boards. Other analyses utilizing this database have been published.^{18–22}

Data included descriptive and demographic information (Supplemental Table 1). LOS was recorded in hours and converted to days of care starting with the first vital sign and ending with the last vital sign, with LOS less than one hour rounded up to one hour. The primary analyses treat days of care as a continuous outcome (for example, a patient in the PICU for exactly 27 hours is analyzed as having 1.125 days of care). For display in histogram form, LOS is presented as the number of 24-hour periods in the PICU (<1 days = 24 hours, 1 day = 24 to < 48 hours, etc.) For model building (below), LOS was truncated at 30 days to eliminate the effects of outliers and to be consistent with other publications;^{8,16,17,23} overall, 97.7% of patients had an actual LOS of 30 days or less. In some institutions, infants were admitted prior to cardiovascular interventions to “optimize” their pre-operative status. For these infants, we used their time of admission following the operation as the initiation of intensive care stay. This *a priori*, objective classification scheme has been published.¹⁸

Interventions included both surgery and interventional catheterization. Diagnosis was classified by system of primary dysfunction based on the reason for PICU admission; cardiovascular conditions were classified as congenital or acquired. Cardiac arrest included closed chest massage within 24 hours prior to hospitalization or after hospital admission, but prior to PICU admission. Severity of illness was characterized by physiological profiles using the PRISM score based on the first 4 hours of PICU care.²⁴ Outcomes utilized in this analysis were hospital survival and death. The Functional Status Scale (FSS) was used to describe baseline (pre-illness) and hospital discharge functional status as good/mild dysfunction (FSS 6 – 9) and moderate to very severe dysfunction (FSS >9).²⁵ New functional status morbidity was defined as a change of FSS from baseline to hospital discharge of ≥ 3 .²² Therapies included mechanical ventilation, vasoactive agents, neuromuscular blockage, antibiotics, steroids, renal replacement therapies, and extracorporeal membrane oxygenation (ECMO).

Model

Statistical analyses utilized SAS 9.4[®] for descriptive statistics, model development, and fit assessment. The statistical analysis was conducted under the direction of R.H. Patient characteristics were evaluated for univariate association with LOS using nonparametric approaches (Kruskal-Wallis test for binary or unordered categorical variables, and Jonckheere-Terpstra test for ordered categorical variables; continuous factors were categorized into a modest number of clinically relevant levels for these assessments.)

The final model was constructed using a nonautomated (examined by biostatistician and clinician at each step) forward stepwise selection approach from the factors significantly associated with truncated, untransformed LOS in the univariate analyses. Survival or death at PICU discharge was included as a predictor. Several categorizations of age and baseline FSS were considered in the model, as was an alternative diagnostic categorization predictive of mortality in a previous report.²⁴ The reported model includes variables, as described above, entered sequentially with an F-statistic of significance <0.05 at each step; this model also achieved optimal cross-validated performance in the sequence of candidate models as assessed by the predicted residual sum of squares criterion.²⁶

Modifications of the above specific selection criteria, which were examined to assess robustness of the analyses, sometimes generated slightly different “final” models with very similar performances. We considered modeling log-transformed LOS as outcome, as well as using generalized linear models, and found that the predictive ability of these models for the original LOS outcome ranged from somewhat worse to only slightly better than standard regression on truncated LOS. Others have reported similar results.¹⁶ We therefore report results of the standard regression model, in part because unlike for other approaches, untransformed linear regression coefficients are directly interpretable as magnitude of change in LOS attributable to differences in a factor. Use of this untransformed model, whose residuals are not normally distributed, is acceptable for our aim of gauging whether mean PICU LOS appears to be higher or lower than expected at an aggregate, institution-wide level in this large dataset.²⁷ Standard errors and significance tests reported for our model use heteroscedasticity-consistent covariance estimates robust to residual nonnormality.²⁸

Results

Overall, the 10,078 patients stayed in the PICU for a total of 50,621 days. Supplemental Table 1 shows the distribution of the patient characteristics. In the total sample, 27.7% of patients were less than 1 year of age. Most patients had good pre-illness functional status (78.6%), were emergency admissions (63.6%), were medical patients not receiving a surgical or catheterization intervention (62.3%), and the most common primary systems of dysfunction were cardiorespiratory (57.6%), and neurological (20.1%). ICU therapies ranged from common to very uncommon including mechanical ventilation (38.1%), vasoactive agent infusions (23.7%), neuromuscular blockade (13.6%) and ECMO (1.1%). Most patients were cared for in medical-surgical ICUs (80.8%) while 19.2% were cared for in cardiac ICUs. A total of 53.8% of patients had government insurance. Outcomes included death (2.7%), new significant functional status morbidity (4.6%), and intact survival (92.7%).

The mean LOS for all patients was 5.0 days (standard deviation 11.1), with a median length of 2.0 days. A total of 9842 patients (97.7%) had PICU stays of 30 days or less. Truncating LOS to a maximum of 30 days accounted for 43,918 PICU days (86.8% of the days of care); the truncated LOS variable had a mean of 4.4 days (standard deviation 6.1), and median of 2.0 days. Figure 1 illustrates the distributions of PICU LOS as well as LOS in the hospital. Of note, 50.6% of patients stayed in the PICU for less than 48 hours. Figure 2 illustrates that

a large number of PICU days of care are used by a relatively small proportion of the population. For example, the 50.6% of patient with LOS fewer than 2 days consumed only 11.1% of the days of care, while the 19.6% with LOS 4.9 to 19 days and the 4.6% with LOS of 19 days or longer consumed 35.7% and 37.6% of the days of care respectively.

Supplemental Table 1 reports the mean and median LOS data by descriptive category, primary system of dysfunction, functional status on admission, severity of illness categories, for selected critical care therapies and for hospital outcome. Overall, there were significant LOS differences in all patient categories except elective/emergency admission status. In general, longer LOS was observed in younger children, those with cardiorespiratory disease, post-intervention cardiac patients, patients who had a cardiac arrest prior to admission, those with the highest severity of illness, and those receiving the most intensive therapies. Patients in the cardiac ICU stayed longer than those in the medical ICU (median 3.2 vs. 1.8, $p<0.001$), and patients discharged from the hospital with a new significant functional morbidity stayed longer than deaths or those discharged without a new significant functional status morbidity. As the PRISM score increased, median LOS increased in parallel with mortality risk until a PRISM score of 20–25 when median LOS decreased due to earlier mortality (Figure 3).

Table 1 reports the final model for LOS truncated at 30 days from data obtained during the entire PICU stay (Methods). All significant variables from Supplemental Table 1 were included except race which was missing in >20% of patients, and cardiac versus non-cardiac ICU type whose association was largely subsumed by diagnosis. Age, admission source, system of primary dysfunction, baseline functional status (dichotomized as normal/mild dysfunction versus worse), PRISM score, survival/death at PICU discharge, and the critical care therapies were included as predictors of LOS in the final regression model. The R-squared for LOS truncated at 30 days is 0.42, indicating that this model predicts truncated LOS moderately well overall.¹⁶ Notably, the model relies on therapies received during the PICU stay for a large amount of its performance. During model construction, the first four variables entered were therapies (neuromuscular blockade, vasoactive infusions, mechanical ventilation, and ECMO), and a model with these four therapies alone achieves an R-squared of 0.365. Modeling using only patient factors at admission and the admission PRISM score lead to substantially lower R-squared values around 0.16. Overall, the model generally over-predicted for short stays and under-predicted for longer stays (Figure 4).

Figure 5 illustrates the LOS observed and predicted by the model when it is applied to all patients at each of the sites. The overall results are summarized as the standardized ratio of observed divided by predicted LOS (SLOS_R). Among the sites, the overall the SLOS_R ranged from 0.87 to 1.09. There are some centers (A, D) where mean truncated LOS is over predicted by 0.4–0.6 days, and others (C, E, G) where mean LOS is under predicted. These observed differences in model fit by center are statistically significant ($p<0.0001$ by F test) when center is added as a predictor to the model in Table 1.

Discussion

The efficient utilization of critical care services has important practical implications. Inefficient use of critical care beds, if it limits bed or staff availability, may result in delays in care, patient care in suboptimal care areas, or patients diverted to other facilities with the associated risks of transport and delayed therapies. Reliable methods that assess institutional bed utilization could prevent or ameliorate these suboptimal care issues if they improve efficiency. In addition, better utilization of critical care beds could improve the economics of critical care units if it reduces labor needs, prevents the allocation of capital to new bed construction, and/or improves the utilization of beds by those waiting for critical care services.²⁹

We assessed PICU bed utilization in over 10,000 patients utilizing over 50,000 days of PICU care. The mean patient LOS was 5.0 days (standard deviation 11.1), with a median LOS of 2.0 days. In this large dataset, LOS was significantly associated with essentially all patient characteristics. It displayed an association with physiological status previously found in both pediatric and adult patients where LOS increases with physiological instability until patient deaths decreases the LOS.^{9,23} Notably, while most patients stayed a relatively short time in the PICU, PICU bed utilization was dominated by a minority of patients. The 5% of patients staying the longest utilized almost 40% of the bed days. The patients with the highest 25% LOS utilized approximately 75% of the PICU bed days.

Our regression model for LOS utilized age, admission source, primary system of dysfunction, baseline (pre-illness) FSS, the PRISM score based on the first 4 hours of PICU care, outcome (survival or death) and seven therapies as predictors. For the outcome LOS truncated at 30 days, the model R-squared of 0.42, indicates reasonable model performance, and compares favorably to other LOS models. Our model's performance is comparable to that reported in a Finnish study in adult ICUs that also used ICU survival and treatment intensity throughout the ICU stay as independent variables.¹⁴ The three factors with the largest influence in long ICU stay were all therapies associated with prolonged stay including ECMO, neuromuscular blockade, and vasoactive infusions. These therapies are associated with severe but often treatable cardiopulmonary disease and the need for sophisticated life support methods. Notably, when therapies were included in the modeling, they became the dominant factors with only 4 therapies (neuromuscular blockade, vasoactive infusions, mechanical ventilation, and ECMO) achieving an R-squared of 0.365. The factor with the greatest influence on reducing LOS was death. Physiological status (PRISM) was a significant but relatively weak factor in this model, probably because other measures of severity of illness such as therapies and outcome were included in the model. Overall, the model worked well with SLOSR ranging from 0.89 to 1.09. The model performance indicates its potential widespread applicability for internal and external benchmarking.

Comparison of critical care outcomes has been unsatisfactory when the outcomes have not been adjusted for patient characteristics unless these characteristics remain constant, an uncommon event even in single units. Therefore, statistical models generating benchmarks that are case-mix or risk-adjusted are important in assessing comparative performance. In pediatrics, this has been successful for one critical care outcome – mortality,²⁴ and has been

suggested for another outcome – morbidity.¹⁸ However, these approaches have had limited success in assessing LOS.⁹ To improve model performance to a level that has applicability to individual units, we made several important decisions. First, we truncated the LOS data to 30 days or less to eliminate outliers. This included 97.7% of the patients but only 86.8% of the days of care. Exclusion of outliers has been a common decision in benchmarking and is consistent with federal programs that have special reimbursement structures for outliers.³⁰ Second, we elected to include information from the entire ICU stay including outcomes, selected therapies, physiological profiles, and patient characteristics to improve model performance. While this decision did result in improved model performance, it also limits the model to internal and external benchmarking as it eliminates real-time management of ICU resources. Use in real-time ICU management may require a new analytic method or a different conceptual approach.³¹

Our reported model was primarily designed for assessing LOS for at least modestly large institution-wide cohorts. While the model's overall performance is equivalent or better than previous efforts, its performance will not be as good in subgroups, especially those with longer LOS and we do not recommend it for evaluation of individual patients. Since the model is dependent on data accumulated during the entire PICU stay, interpreting clinical factors must be done in the context of the therapeutic variables. Importantly, deviations from predicted may be controlled by factors beyond the ICU control such as bed availability or institutional practice patterns. Despite these issues, we believe our model has potential utility in assessing LOS utilization for pediatric ICUs and their institutions.

Institutional factors not assessed in our study are a likely cause of much of the inter-institutional variability in LOS and the limitations of statistical models predicting LOS. Institutional practice patterns and factors such as the ability of institutions to care for patients in less intense environments, nurse: patient ratios, practice patterns of physician groups, the availability of intermediate care, open vs. closed units, clinical protocols and pathways, end-of-life practices, as well as other factors will significantly influence when and for how long patients are cared for in ICUs.³² These are some of the important factors potentially impacting bed utilization that simultaneously support the need for LOS benchmarking while making generalizable models difficult. Models may need to be limited to internal benchmarking due to inter-institutional variability.

The length of hospital stay for pediatric patients has been relatively constant over the last three decades even though the average national hospital LOS has been reduced by almost 50%.³³ Reductions in LOS for adults have been most marked in patients over 65 years.³³ Our challenge in pediatrics will be to participate in these needed national efforts to improve efficiency and utilization while maintaining and improving quality of care.

Conclusion

PICU bed utilization was dominated by a minority of patients. The 5% of patients staying the longest utilized almost 40% of the bed days. Longer LOS was observed in younger children, those with cardiorespiratory disease, post-intervention cardiac patients, and those who were sicker receiving more intensive therapies. Patients in the cardiac ICU stayed

longer than those in the medical ICU. The multivariate LOS model used descriptive, diagnostic, therapeutic and severity factors and has potential applicability for benchmarking.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

ICU	Intensive Care Unit
PICU	Pediatric Intensive Care Unit
LOS	Length of Stay
SLOS	Standardized Length of Stay Ratio
TOPICC	Trichotomous Outcome Prediction in Critical Care
FSS	Functional Status Scale
PRISM	Pediatric Risk of Mortality
SD	Standard Deviation
CPCCRN	Collaborative Pediatric Critical Care Research Network
ECMO	Extra-Corporeal Membrane Oxygenation

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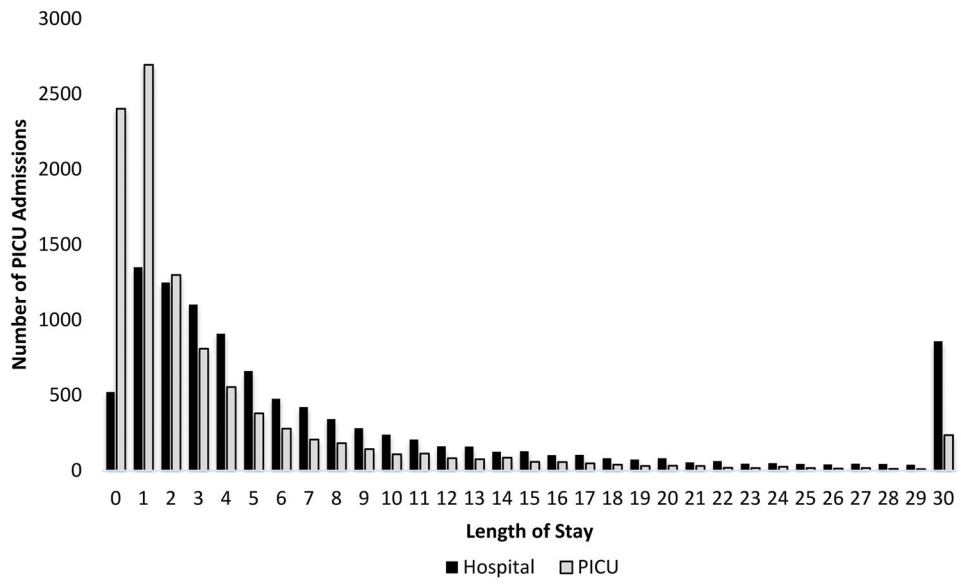


Figure 1. PICU and Hospital Length of Stay Distributions. PICU lengths of stay are skewed to short stays compared to hospital stays.

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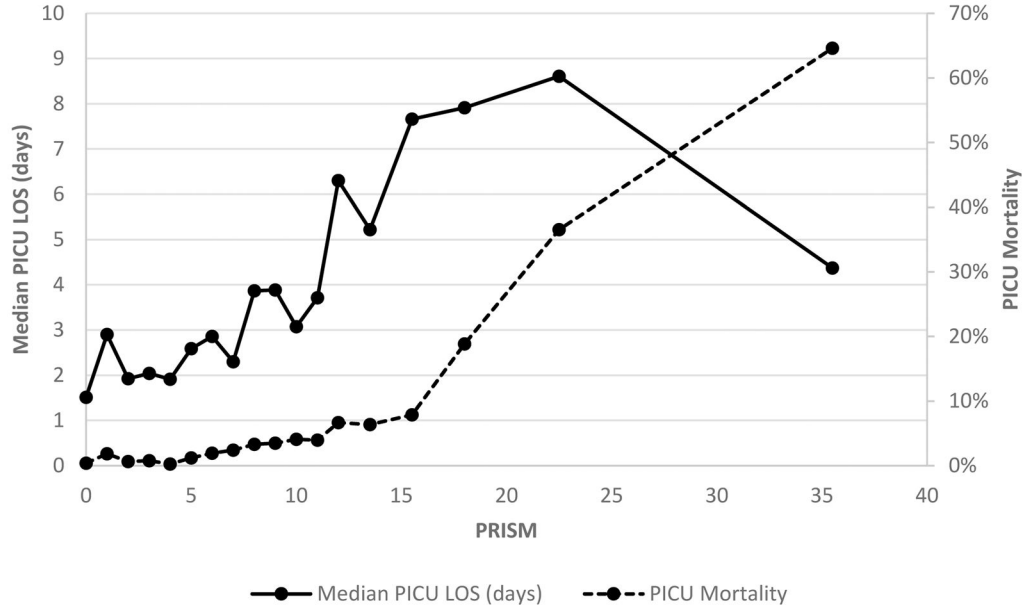


Figure 2. Utilization of PICUs by Percent of Admissions and Percent of Total PICU Days. Four ranges are displayed for approximately the shortest 50%, next 25%, next 20% and longest 5% LOS admissions. The corresponding percentage of days of PICU care used by these groups are indicated by identical fill patterns. Half of the study population (50.6%) with the shortest PICU LOS (less than 2 days) consumed only 11.1% of the days of care. In contrast, the 19.6% of patients with LOS 4.9 to 19 days and the 4.6% with LOS of 19 days or longer consumed 35.7% and 37.6% of the days of care respectively.

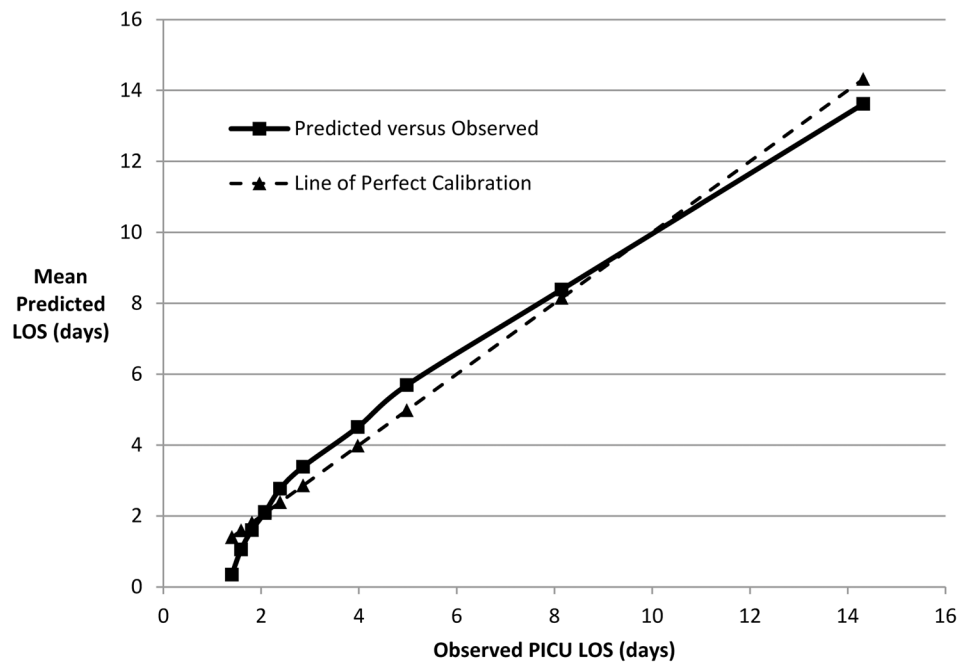


Figure 3. Length of Stay and Mortality Risk Versus Severity of Illness (PRISM). The median pediatric intensive care unit (PICU) LOS (solid line) and PICU mortality (hashed line) are plotted relative to the Pediatric Risk of Mortality (PRISM) score. As the PRISM score increases, the median LOS increases in parallel with mortality risk until a PRISM score of 20–25 when median LOS decreases due to increasing deaths.

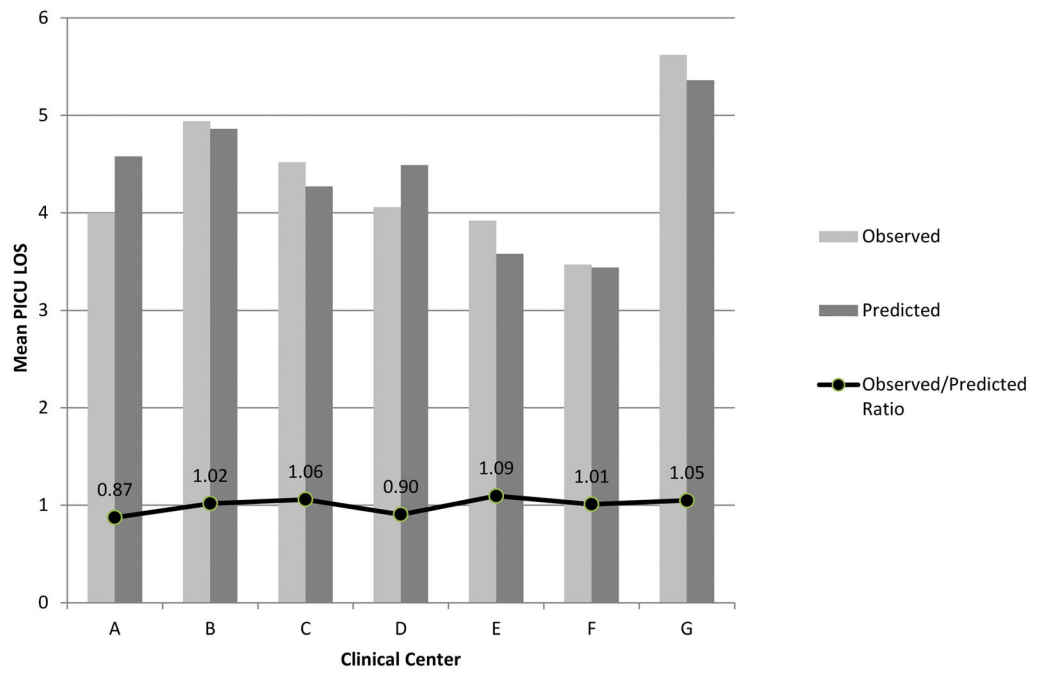


Figure 4. Mean Observed Versus Predicted Length of Stay. Data are displayed by deciles of predicted LOS.

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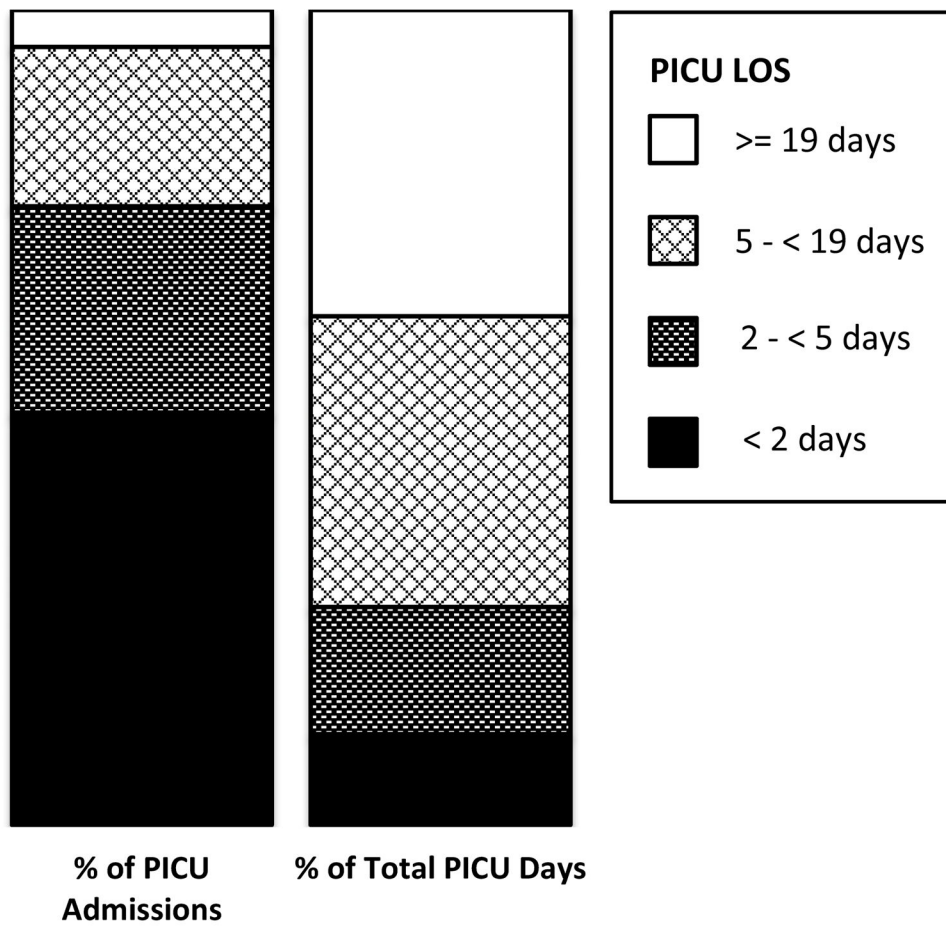


Figure 5. Observed and Predicted Length of Stay at the Participating Centers. The standardized length of stay ratio is the observed divided by the expected length of stay.

Table 1

Final Linear Regression Model for PICU Length of Stay.¹ The model R-squared was 0.42.

Predictor	Coefficient (SE ³)	p-value for predictor (F test ³)
Intercept	1.28 (0.25)	<0.001
Age at PICU Admission		<0.001
0 day to < 14 days	3.03 (0.35)	
14 days to < 1 month	2.39 (0.57)	
1 month to < 12 months	0.91 (0.13)	
>12 months	Reference	
Admission Source		<0.001
OR/PACU for post-intervention care after cardiac surgery	-3.08 (0.24)	
OR/PACU for post-intervention care after non-cardiac surgery	-0.57 (0.10)	
Non-post-intervention admission	Reference	
Primary System of Dysfunction		0.001
Cancer	Reference	
Cardiovascular/respiratory	-0.59 (0.24)	
Low risk (endocrine, hematologic, musculoskeletal, renal)	-0.95 (0.26)	
Neurologic	-0.74 (0.25)	
Other	-0.48 (0.28)	
Baseline FSS Score Categorized as Moderate or Severe (2)	1.28 (0.15)	<0.001
PRISM III Total Score	0.06 (0.02)	<0.001
Died in PICU (vs. Discharged Alive)	-3.66 (0.71)	<0.001
ECMO during PICU Stay (vs. No)	7.15 (0.93)	<0.001
Renal Replacement Therapy during PICU Stay (vs. No)	2.53 (0.67)	<0.001
Mechanical Ventilation during PICU Stay (vs. no)	2.09 (0.13)	<0.001
Vasoactive Infusions during PICU Stay (vs. No)	3.27 (0.21)	<0.001
Antibiotics during PICU Stay (vs. No)	1.27 (0.09)	<0.001
Neuromuscular Blockade during PICU Stay (vs. No)	4.79 (0.27)	<0.001
Steroids during PICU Stay (vs. No)	0.97 (0.12)	<0.001

¹ Length of stay in the model was truncated to a minimum of one hour and a maximum of 30 days.

² Baseline (pre-illness) FSS score > 9.

³ Coefficient standard error estimates and F-tests were calculated using the heteroscedasticity-consistent approach of White as noted in text.