RESEARCH ARTICLE

A Pragmatic Method for Identification of Long-Stay Patients in the PICU

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ABSTRACT

OBJECTIVES: To develop a pragmatic method of identifying long-stay patients (LSPs) in the PICU.

METHODS: We surveyed 40 expert stakeholders in 14 Canadian PICUs between February 2015 and March 2015 to identify key factors to use for defining LSPs in the PICU. We then describe a pragmatic method using these factors to analyze 523 admissions to an academic, tertiary-care PICU from February 1, 2015, to January 31, 2016.

RESULTS: The overall response rate was 70% (28 of 40). Of respondents, 75% (21of 28) stated that it was important to define LSPs and identified present and future resource consumption (18 of 21 [86%] and 16 of 21 [76%], respectively) as the key reasons for defining LSPs. Respondents valued a definition that was consistent and ranked a percentile cutoff as the preferred analytic method for defining LSPs. Of respondents, 86% (24 of 28) though the LSP definition should include factors other than length of stay. We developed a surrogate marker for LSPs using mechanical ventilation and presence of a central venous catheter in our sample population to compare to varying percentile cutoffs. We identified 108 patients at the 80th percentile as LSPs who used 67% of total bed days and had a median length of stay of 11.3 days.

CONCLUSIONS: We present a pragmatic method for the retrospective identification of LSPs in the PICU that incorporates unit- and/or patient-specific characteristics. The next steps would be to validate this method using other patient and/or unit characteristics in different PICUs and over time.

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In North America, >230 000 children are admitted to PICUs per year.[1] The median PICU length of stay is ~2 days,[2] with a small percentage of patients staying for significantly longer periods. These long-stay patients (LSPs) account for only 1% to 8% of all patients in the PICU but use 15% to 58% of total bed days and ~50% of PICU resources.[2–5] Optimal care of LSPs involves unique considerations, including assignment of appropriate nursing ratios, provision of long-term family and health care provider support,[6] and efficient use of available hospital resources (eg, determination of the ideal location for the long-term care of these patients). Hence, accurate and consistent identification of LSPs within the PICU environment is important.

However, there is no consensus method for the identification of LSPs. As such, LSPs have been variably defined by PICU length of stay (ranging from >12 to ≥30 days)[5,7–11] or percentile cutoffs (75th–95th percentile).[3,12] Specified methods used to derive these numerical cutoffs have included values from the literature,[5] adult critical care data,[10] and percentiles above the median length of stay.[3,12] In the majority of studies, authors did not provide a justification for their chosen definition nor did they incorporate clinical criteria, such as patient care requirements, into their methodology. LSPs are a complex patient group with varying care needs, and therefore, consideration of patient factors and unit-specific practices in the identification of such patients is paramount to making decisions for appropriate care and use of resources.

Because there is no laboratory test or established gold standard criteria for LSPs in the PICU, we sought to develop a pragmatic method of identifying LSPs on the basis of previous years' data that incorporates important clinical criteria and accounts for individual PICU specifications. We begin by conducting a survey of key PICU administrative stakeholders across Canada to determine the components to be included in the LSP definition. We then use these survey results and an existing PICU database to devise a pragmatic method of identifying LSPs that incorporates the key factors emphasized by stakeholders.

METHODS

We identified all 14 academic, level III PICU's in Canada as potential survey participants. We targeted administrative stakeholders in each center with the necessary expertise to answer questions on LSPs and therefore used purposive sampling to identify 1 PICU medical director, 1 PICU nurse manager, and 1 hospital executive from each PICU. A list of e-mail contacts was generated by using information from Web sites and personal contacts and through contact with administrative assistants. We obtained ethics approval from the relevant research ethics boards.

Questionnaire Development

We generated questionnaire items through a review of relevant publications[3–7,9,10] and through discussion with experts in the field (an ex-medical director, a nursing leader, a previous hospital administrator, and a researcher). The generated items were grouped into domains and included questions on (1) demographics, (2) relevant patient characteristics of LSPs, and (3) preferred methods for defining LSPs. We sent the questionnaire to 3 experts in the field (an ex-PICU medical director, a nurse manager, and a hospital administrator), who did not participate in the final version and revised questions on the basis of their feedback.

Questionnaire Administration and Analysis

The survey was administered in English by using the Web-based software REDcap[13] E-mail reminders were sent to nonrespondents at 2- and 3-week intervals, respectively. The survey consisted of open- and close-ended questions. Responses to multiple-choice and ranking-based questions were analyzed by using frequencies and descriptive statistics. Because of the small sample size, responses were not stratified by center. Open-ended questions were analyzed by using the framework method,[14,15] which is used to assess both the central research question and the specific nature of the responses and has been previously used to analyze qualitative data on LSPs in the PICU.[6]

Data Used for Development of LSP Definition

On the basis of the findings of the survey, we sought to develop a pragmatic method of identifying LSPs. This method involved the secondary analysis of a prospectively collected administrative data set of admissions to an academic, tertiary-care children's hospital PICU from February 1, 2015, to January 31, 2016. Patient-level variables that were collected included hospital admission time, PICU length of stay, age, diagnosis, previous hospital admissions, admission type, where the patient was admitted from, illness severity scores (including the Pediatric Risk of Mortality III score[16]), and treatments received (eg, mechanical ventilation).

There were 523 distinct admissions for 407 unique patients, with 47 patients having >1 admission during the study period. The median age was 3 years (interquartile range [IQR]: 12.1–0.6; range: 0–20), the median PICU length of stay was 1.9 days (IQR: 0.9–5.7; range: 0.1–85.5), and the total number of patient bed days was 2413. The mortality rate was 2.3% (12 of 523).

Development of the LSP Definition

We created a surrogate marker to incorporate patient characteristics into an LSP definition (as suggested by survey respondents) as follows: We first identified the variables in the PICU database that had been shown in the literature to be associated with PICU length of stay (a central venous catheter, mechanical ventilation, the Pediatric Risk of Mortality III score, an age of <1 year, previous ICU admission, and postoperative status),[2,3] and using the described data set, we then conducted a survival analysis using Cox regression on PICU length of stay with the above variables as covariates. PICU length of stay was strongly associated with the presence of a central venous catheter (hazard ratio [HR]: 2.94; $P < .001$; 95% confidence interval [CI]: 2.30–3.74), mechanical ventilation (HR: 2.05; $P < .001$; 95% CI: 1.66–2.53), and an age of <1 year (HR: 1.59; $P < .001$; 95% CI: 1.31–1.93) but not with the use of extracorporeal life support (ECLS) (HR: 1.03; $P = .43$; 95% CI:

0.96–1.10). Given that the presence of a central venous catheter and mechanical ventilation were the patient characteristics most strongly associated with PICU length of stay in our unit, we chose these 2 variables to create our surrogate marker.

Discriminatory Power and Precision

The accuracy of diagnostic criteria is commonly tested by comparing their sensitivity and specificity to an established gold standard.[17] However, there is no gold standard for the identification of LSPs. Therefore, we present a novel analysis that alternates the use of 2 variables (our surrogate marker and the percentile cutoffs of PICU length of stay) as the gold standard using 2 measures: (1) sensitivity and specificity (discriminatory power) and (2) positive predictive value (precision). Discriminatory power is the ability of our variable to identify correctly, relative to a gold standard, those who are and are not classified as LSPs. An area under the receiver operating characteristic (ROC) curve of 0.75 to 0.92 was considered good, an area under the ROC curve of 0.93 to 0.96 was considered very good, and an area under the ROC curve of 0.97 to 1.0 was considered excellent.[18,19] The ROC curve is routinely used in the evaluation of binary variables, but in the case of imbalanced data, such as for LSPs, using positive predictive power provides a more robust method of evaluation.[20] Furthermore, discriminatory power and precision taken together provide a theoretically grounded method for identifying and justifying the percentile LSP definition that is most associated with the surrogate marker.

RESULTS

In this study, 42 potential experts in 14 centers were identified. Contact information for 2 hospital administrators was unavailable, resulting in 40 surveys being sent. The overall response rate was 70% (28 of 40), with at least 1 respondent from 13 of 14 centers.

Participant and Unit Demographics From Survey

Of the respondents, 43% (12 of 28) were medical directors, 36% (10 of 28) were nurse managers, and 21% (6 of 28) were hospital executives. All respondents had at least 1 university degree, and 71% (20 of 28) of respondents were >45 years of age. The median time the respondents had been in their current job was 4.5 years (IQR: 2–8), and 86% (24 of 28) of respondents had been in their current job for ≤10 years. The number of PICU beds reported per unit was between 5 and 10 for 46% (6 of 13) of hospitals, between 11 and 20 for 23% (3 of 13) of hospitals, and >20 in 31% (4 of 13) of hospitals. Yearly PICU admissions varied between 200 and 2000, with the mode being between 600 and 1000 (6 of 13 [46%]).

All respondents from 8 of 13 hospitals stated that their hospital did not have a separate area for LSPs, and all respondents from 1 hospital stated that they did. It was not possible to determine if the remaining 4 hospitals had a separate area for LSPs because of the intrahospital variation in responses. Respondents from 3 of 13 hospitals (23%) indicated that their center had plans for a separate unit for LSPs in the future.

Characteristics and Methods for Defining LSPs

Of all respondents, 75% (21 of 28) thought it was important to define LSPs (83% [10 of 12] of medical directors, 60% [6 of 10] of nurse managers, and 83% [5 of 6] of hospital administrators). Of these 21 respondents, 18 cited assessing future PICU resource needs as a reason, 18 cited determining alternate models of care as a reason, 16 cited current use of resources as a reason, and 14 cited nursing staff needs as a reason. Respondents were asked to rank the importance of 6 characteristics of an LSP definition and 5 methods for defining LSPs (Table 1). The most preferred characteristic was consistency, and the most preferred method for defining LSPs was a percentile cutoff.

TABLE 1 Ranking of Respondents' Preferred Methods and Characteristics for Defining LSPs

Preference	Ranking
Method	
Percentile	1
Predefined cutoff	2
Multiple of the average	3
Share of resources	4
Subjective	5
Characteristics	
Consistent	1
Useful	2
Easy to use	2
Flexible	4
Precise	5
Exhaustive	6

Qualitative Responses

Of the respondents, 86% (24 of 28) thought it was important to incorporate patient characteristics other than length of stay in an LSP definition (Table 2), but the majority of respondents did not specify which characteristics to include. In addition, 2 respondents thought it was important to consider each hospital's unique circumstances, and 2 respondents expressed that long-term mechanical ventilation and the use of ECLS were important determinants of a prolonged PICU stay.

Characteristics of the Surrogate Marker

The patient characteristics that were chosen from our database and used to define the surrogate marker were use of mechanical ventilation and/or presence of a central venous catheter at any time during the admission. In 523 admissions, 46% (242 of 523) of patients were mechanically ventilated. The median duration of mechanical ventilation was 0 days (IQR: 0–1.8; range: 0–118). In 523 admissions, 114 patients (21.8%) had a central venous catheter. The median time with a central venous catheter was 0 days (IQR: 0–2; range: 0–124). Outliers were defined as any duration >1.5 times the IQR plus the 75th percentile for each of the 2 variables, respectively.[21] There were 87 patients who were outliers for the duration of having a central venous catheter, and 75 patients were outliers for the duration of mechanical ventilation. In 523 admissions, 110 (21%) had the surrogate marker for patient characteristics of LSPs.

TABLE 2 Factors To Consider in a Definition of LSPs

Theme	Responses, *n* (%)
Patient condition (diagnosis, complexity, and stability)	14 (50)
Resource use	9 (32)
Technology requirement or dependence	8 (29)
Available alternatives to PICU	4 (14)
Family situation or support	4 (14)
Recurrent admissions	2 (7)

Respondents were allowed to choose >1 response.

Identification of the Percentile Cutoff

We started by examining the ability of different percentile cutoffs for LSPs to identify the surrogate marker as the gold standard using discriminatory power and positive predictive power. The percentile cutoff for LSPs was varied from the 70th to the 90th percentile of length of stay, and its discriminatory power and positive predictive power were recorded. The discriminatory power and positive predictive power of the chosen percentile cutoff increased at higher percentiles (Fig 1). We then repeated this entire procedure in reverse, using the percentile cutoff for LSP as the gold standard and treating the surrogate marker as the classifier (Fig 1), and found that the discriminatory power and positive predictive power decreased at higher percentiles.

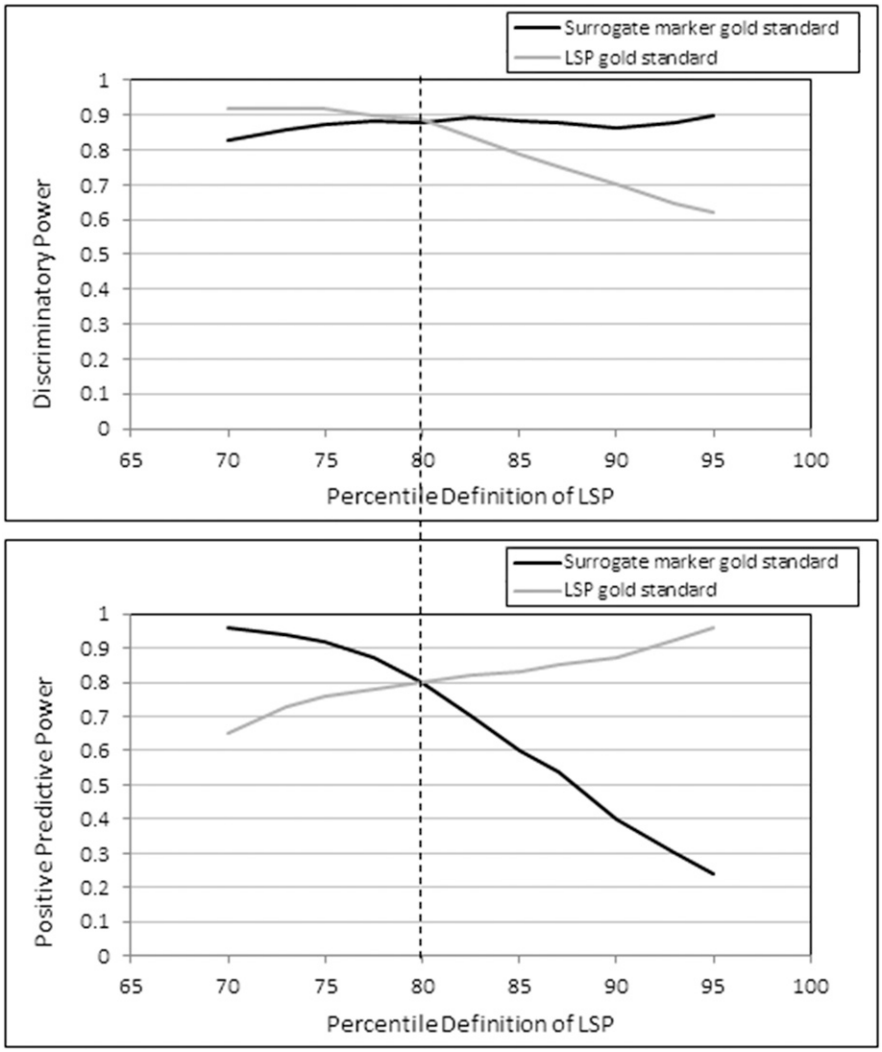

FIGURE 1 Determination of the LSP definition: trade-off between discriminatory power and positive predictive power (precision).

This created a clear trade-off in identifying the single percentile (80th) LSP definition that was most associated with our surrogate marker, as presented in Fig 1. The sensitivities and specificities in which the 80th percentile and the presence of the surrogate marker are used alternately as the gold standard are shown in Table 3. By using the 80th percentile, the PICU length of stay cutoff was corresponded to 7.0 days, and 108 patients were identified as LSPs in the year studied.

Effect of LSP Definition on Administrative PICU Variables

The effect of choosing different percentile cutoffs for PICU length of stay on various administrative variables in our sample population is shown in Table 4. A decrease in the percentile cutoff used for the LSP definition from the 90th to the 70th percentile resulted in a tripling of the number of patients labeled as LSPs (52 vs 157). In addition, the percentile variation more than doubled the PICU length of stay (4.3 vs 11.3 days) and greatly increased the percentage of bed days used (45% vs 77%). Using the 80th percentile cutoff obtained in our sample population, we found that LSPs (20% of patients) used 67% of the total bed days.

DISCUSSION

The survey of stakeholders across Canada supported the importance of developing a definition for LSPs in the PICU to determine future resource needs and alternate models of care for this patient population. In this study, we build on the survey results and develop a novel, pragmatic method of identifying LSPs by creating a trade-off between the discriminatory power and positive predictive power of a specifically

TABLE 3 Interaction of Selected LSP Definition (80th Percentile) With Surrogate Marker

Gold Standard	LSP	Not LSP
Contingency table		
Surrogate marker for patient characteristics	84	25
Not surrogate marker for patient characteristics	20	395
Length-of-stay percentile cutoff		
ROC	0.874	—
Sensitivity	0.81	—
Specificity	0.94	—
Positive predictive power	0.77	—
Negative predictive power	0.95	—
Surrogate marker		
ROC	0.86	—
Sensitivity	0.77	—
Specificity	0.95	—
Positive predictive power	0.81	—
Negative predictive power	0.94	—

—, not applicable.

created surrogate marker for LSPs using the previous years' unit-specific data.

The survey results revealed the importance of incorporating factors other than length of stay into the LSP definition. Although respondents highlighted patient characteristics (diagnosis, complexity, and stability) as the most important factors to consider, they did not provide a consensus on the specific characteristics to use. This may reflect the diversity of patient factors, intensivist opinions, and unit-specific practices that currently exist with regard to LSPs.[3,9] The novelty of our proposed method is that it allows each unit to select specific patient characteristics or unit practices to incorporate into their LSP definition. In our example, we used prolonged mechanical ventilation and the presence of a central venous catheter for the development of our surrogate marker. Other units have reported a strong association of the use of ECLS and prolonged mechanical ventilation with PICU length of stay[5,8] and may therefore chose to incorporate these measures into their surrogate marker instead. This would allow these units to determine future PICU resource needs and consider alternate models of care that are relevant to their hospitals' needs and data. Alternative models of care may include step-down units,[22] chronic care facilities, home care,[23] and others.

The importance of using factors other than length of stay to identify LSPs is further illustrated by examining the implications of using different length of stay cutoffs in our sample population. By using a length of stay cutoff of 7 days (the 80th percentile), 108 patients who used 67% of bed days were identified in our sample population. However, if we used a 20.4-day cutoff, as suggested by Shapiro et al,[9] this would include <27 patients and <31% of bed days (Table 4) and would have significantly different resource implications. The different resource implications reveal the importance of providing a justification for the chosen LSP definition rather than an arbitrary length-of-stay cutoff.

TABLE 4 Implications of Different Percentile Definitions for LSPs

Percentile	70th	75th	80th	85th	90th	95th
No. patients, *n* (%)	157 (30)	131 (25)	108 (20)	81 (15)	52 (10)	27 (5)
Bed days used by LSPs, d (%)	1868 (77)	1729 (72)	1620 (67)	1393 (58)	1097 (45)	758 (31)
Length-of-stay cutoff, d	4.3	5.7	7.0	8.4	11.3	15.4
Mean length of stay, d	11.9	13.2	15.0	17.2	21.1	28.1
Median length of stay, d	8.4	9.3	11.3	13.5	15.4	21.6

The difficulty of applying a single length-of-stay cutoff to all PICUs instead of a unit-specific approach is further highlighted by assessing the work of Marcin et al.[3] The authors studied 32 PICUs in the United States to determine the clinical profiles and relative resource consumption of LSPs using a fixed length-of-stay cutoff of >12 days. However, the mean (1.8–6.0 days) and median (1.0–2.0 days) length of stay for all PICU admissions in the participating units varied significantly, suggesting that the in-unit frequency distributions of length of stay were also different. Furthermore, the patient mix and available therapies in participating units also varied.[16] Thus, application of the same length-of-stay cutoff to all units has neither statistical nor physiologic support.

Finally, it is clear that there are numerous reasons why patients remain in the PICU for significantly longer than the median length of stay.[3,7,8] Some patients require prolonged PICU stays because of their high acuity and complexity,[3,24] whereas others remain in the PICU because of their technology dependence and lack of placement alternatives.[25,26] Although specific needs and potential care models may differ for individual LSPs, PICU managers and hospital administrators must still plan for overall unit resource consumption. As such, it is important that any method used to identify LSPs be broad enough to include all categories of such patients. In our method, the number and type of LSPs from the previous year is identified, which can then be used to guide resource allocation and development of alternative models of care for the upcoming year(s). For example, if by using our method, 80% of LSPs in the previous year(s) were identified as chronic, stable patients, it may be worthwhile for the hospital to develop and staff a separate, more efficient unit for these patients. Alternatively, if by using this tool, most LSPs were in fact retrospectively identified as patients who required the use of ECLS, a hospital could use this information to decide whether it should continue to provide ECLS or whether it might be a more

efficient use of hospital resources to put patients on ECLS and transport them to another center.[27]

There are several limitations to this study. First, we did not ask health care providers or families for their perspectives on the LSP definition. We believe that the opinions of these groups are extremely important and should be addressed in separate surveys. In addition to obtaining rich qualitative data, these groups could identify other factors with which to determine the percentile cutoff using our outlined method. Secondly, the survey was conducted within the context of the Canadian health care system, and therefore, the results cannot be automatically extrapolated to other countries. However, we believe the methodology may be applicable to other health care jurisdictions. Finally, the data analysis was conducted in 1 center over a single year.

CONCLUSIONS

We present a novel method for identifying LSPs in the PICU. This method incorporates potential patient characteristics and unit-specific data and can be customized to accommodate unit-specific characteristics. The next steps would be to validate this method over different periods and in different PICUs. This method could become a common tool for clinicians, administrators, and policy makers to use in identifying LSPs and optimizing care and resource use.

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