

# Impact of Deferring Critically Ill Children Away from Their Designated Pediatric Critical Care Unit: A Population-Based Retrospective Cohort Study

## L'impact d'une réorientation des enfants gravement malades hors de leur unité de soins intensifs pédiatriques désignée : une étude de cohorte rétrospective



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## Abstract

*Background:* The impact of deferring critically ill children in referral hospitals away from their designated pediatric critical care unit (PCCU) on patients and the healthcare system is unknown. We aimed to identify factors associated with deferrals and patient outcomes and to study the impact of a referral policy implemented to balance PCCU bed capacity with regional needs.

*Methods:* We conducted a population-based retrospective cohort study of admissions to a PCCU following inter-facility transport from 2004 to 2016 in Ontario, Canada.

*Results:* Of 10,639 inter-facility transfers, 24.8% (95% confidence interval [CI]: 23.5–26.1%) were deferred during pre-implementation and 16.0% (95% CI: 15.1–16.9%) during post-implementation of a referral policy. Several factors, including previous intensive care unit admissions, residence location, presenting hospital factors, patient co-morbidities, specific designated PCCUs and winter (versus summer) season, were associated with deferral status. Deferrals were not associated with increased mortality.

*Conclusions:* Deferral from a designated PCCU does not confer an increased risk of death. Implementation of a referral policy was associated with a consistent referral pattern in 84% of transfers.

## Résumé

*Contexte :* On ne connaît pas l'impact, sur les patients et le système de santé, d'une réorientation des enfants gravement malades hors de leur unité de soins intensifs pédiatriques (USIP) désignée. Nous voulions dégager les liens entre les réorientations et les résultats pour les patients ainsi qu'étudier l'impact d'une politique d'aiguillage des patients mise en place pour assurer l'équilibre entre le nombre de lits en USIP et les besoins de la région.

*Méthode :* Nous avons mené une étude de cohorte rétrospective des admissions à l'USIP suite à un transfert inter-établissements entre 2004 et 2006 en Ontario, au Canada.

*Résultats :* Parmi les 10 639 transferts inter-établissements, 24,8 % des cas (95 % intervalle de confiance [IC]: 23,5–26,1 %) ont été redirigés avant la mise en œuvre de la politique d'aiguillage et 16,0 % (95 % IC: 15,1–16,9%) après sa mise en œuvre. Plusieurs facteurs sont liés à une situation de réorientation, notamment les admissions antérieures à l'unité de soins intensifs, le lieu de résidence, les facteurs d'hospitalisation, la comorbidité des patients, les USIP désignés et les saisons (hiver ou été). Les réorientations ne sont pas associées à un accroissement de la morbidité.

*Conclusions :* Le fait d'être redirigé hors de l'USIP désignée ne présente pas un risque accru de mortalité. Nous observons un lien entre la mise en œuvre de la politique d'aiguillage et un schéma d'aiguillage cohérent dans 84 % des cas de transfert.

## Background

Regionalized care networks with centralized expertise make inter-facility transfers a necessary element of modern healthcare. Critically ill pediatric patients have improved outcomes when treated in a tertiary care centre rather than a community hospital (Holmes and Reyes 1984; Newgard et al. 2007; Pearson et al. 1997; Pollack et al. 1991; Pracht et al. 2008), providing a compelling rationale for the centralization of care. Inter-facility transfers have increased in frequency in Ontario and elsewhere (Franca and McManus 2018; Tijssen et al. 2019). Ideally, children requiring critical care are transferred to their designated pediatric critical care unit (PCCU); however, when this is not possible, they are deferred to an alternate PCCU. The designated PCCU is usually the PCCU closest to the referring hospital; there is usually some familiarity by the receiving PCCU and transport teams with the referring hospital and its clinicians. Alternatively, the non-designated PCCU may have a required service that is not available at the designated PCCU, for example, cardiovascular surgery. The impact of PCCU deferrals on patients and the healthcare system has not previously been studied and is unknown.

In 2014, there were 85 beds in four PCCUs for critically ill children in Ontario, Canada. Of these, 65 were equipped to manage children who require mechanical ventilation (CritiCall Ontario b). To administer critical care services in Ontario, an official referral policy was implemented in 2010 to guide the inter-facility transfers of critically ill children based on regions, distance and predicted bed capacity. Prior to 2010, referral patterns were based on shortest distance and informal relationships between hospitals and/or clinicians. The new referral policy was based on the 14 local health integration networks (LHINs) in the province, which are regional networks of healthcare institutions through which funding flows with an aim to improve patient access and experience. It is not known whether this new referral policy made patient transfers more consistent and improved healthcare outcomes.

Our study's objectives were to identify factors associated with deferrals of critically ill children away from their designated PCCU, evaluate patient outcomes as they related to deferrals away from a PCCU and study the impact of the 2010 referral policy implementation. We hypothesized that season, presenting diagnosis, presence of specific co-morbidities and specific designated PCCUs would be associated with deferrals. We also hypothesized that deferrals would not be associated with increased risk of mortality and that the policy would lead to more consistent referral patterns.

### *Study design and setting*

We conducted a population-based retrospective cohort study of all inter-facility transports of children to PCCUs using administrative healthcare data in Ontario, Canada. Ontario has four Level 3 and above PCCUs, and all residents of Ontario (population approximately 14 million) obtain healthcare services from a government-administered single-payer system. A PCCU is a ward within a hospital that specializes in caring for critically ill children from

newborn to 18 years of age, and Level 3 units are capable of providing the highest level of service to meet the needs of patients who require advanced or prolonged respiratory support or basic respiratory support together with the support of more than one organ system (Critical Care Services Ontario). A unique, encoded identifier permits linkage across several administrative databases, which were then analyzed at the Institute for Clinical Evaluative Sciences (ICES). This report follows the RECORD (REporting of studies Conducted using Observational Routinely-collected health Data) statement (Benchimol et al. 2015).

### *Data sources*

Data sets included the Canadian Institute for Health Information's (CIHI) Discharge Abstract Database, Same-Day Surgery Database and National Ambulatory Care Reporting System; the Registered Persons Database; census; and LHIN databases (Supplement Tables 1 and 2 available online at [longwoods.com/content/25939](http://longwoods.com/content/25939)). This study was approved by the institutional review board at Sunnybrook Health Sciences Centre, Toronto, Canada.

### *Study cohort*

Our study cohort included all eligible transports of patients who were of age <18 years and were transported directly from a referral centre to one of Ontario's four Level 3+ PCCUs between January 1, 2004 and December 31, 2016. Patients who did not reside in Ontario at the time of transport, patients who did not have a valid Ontario Health Insurance Plan number during the study period and patients with missing information on age or sex were excluded from the final cohort.

### *Patient factors and outcomes*

We identified the following patient characteristics: age, sex, rural dwelling, distance traveled from the referral hospital to the PCCU, originating location within the referral centre (ward, emergency department [ED] or operating room), time spent in the ED (for those who originated in the ED), most responsible diagnosis, time and season of PCCU admission, fiscal year of transport, total acute care days, prior intensive care unit (ICU, not specifically pediatric) admission in previous 12 months, prior hospitalization in the previous two years, co-morbidities and designated PCCU. Rurality was determined using the Statistics Canada (2011) definition of rurality with coding based on the Statistics Canada Postal Code Conversion Files (Wilkins 2009). Distance was calculated using straight-line distance from latitude and longitude values. The time to definitive critical care was calculated as the time between ED registration and PCCU admission for patients who presented to the ED. Most responsible diagnosis was based on the International Classification of Diseases 10th revision coding associated with the PCCU admission and collapsed into nine categories (congenital malformations [for newborns]/genetic abnormalities, respiratory, psychiatric/neurologic, perinatal complications [for newborns], accidents or ingestions, acquired cardiac/circulatory,

infection, hematology/oncology, infection and other) (Supplement Table 3). The time of admission to the PCCU was defined as daytime (08:00–16:00), evening (16:00–24:00) or night (24:00–08:00). The seasons of the PCCU admission were defined as winter (January, February, March), spring (April, May, June), summer (July, August, September) and fall (October, November, December). The “total acute care days” were calculated as the sum of days with ED visits, hospitalization and same-day surgeries in the six months prior to transfer. The following co-morbidities were identified for patients who required acute care in the one year prior to transfer: malignancy, cerebral palsy, tracheostomy, congenital cardiac malformation, heart failure, chronic liver failure, chronic renal failure or history of an organ transplant (Supplement Table 4). The four designated PCCUs were randomly assigned letters A, B, C and D.

Our primary outcome was deferral status. Secondary outcomes included mortality in the PCCU, mortality in the PCCU within 24 hours of transfer, mortality within six months of transfer and PCCU and hospital lengths of stay (at the receiving hospital, LOS), defined as long if the LOS was greater than the median LOS for all transferred patients. Our main predictor of interest was the patient’s transfer status (deferred or not) based on the 2010 referral policy. According to the policy, a deferred patient is one who requires a PCCU admission but is transferred to a PCCU other than their designated centre (Supplement Table 5). A deferral could occur if the designated centre is at full bed capacity or has other resource shortages (e.g., insufficient nurses or no available pediatric neurosurgeon), there are weather restrictions on travel or because of patient preference or specific individual needs (e.g., patient requires a cardiac surgical evaluation not offered at each PCCU centre).

### *Statistical analysis*

Transfers were the unit of analysis in this study. We compared patient characteristics between deferred and non-deferred transfers, using the chi-square test for categorical variables and Student’s *t*-test or Kruskal–Wallis for continuous variables where appropriate. We used multivariable logistic regression models to examine factors associated with deferrals in the pre-implementation and post-implementation periods. The generalized estimating equation (GEE) estimation method was used to account for the potential within-patient clustering among children who experienced more than one transfer during the study periods. Factors included age, sex, previous ICU stay, rurality, designated PCCU, distance from referral hospital to designated PCCU, presentation to local hospital, originating location in referral hospital, transfer time of day, transfer season, total acute care days in the previous six months, previous case of cancer, chronic respiratory failure, congenital cardiac malformation, heart failure and transplant and most responsible diagnosis of the PCCU admission.

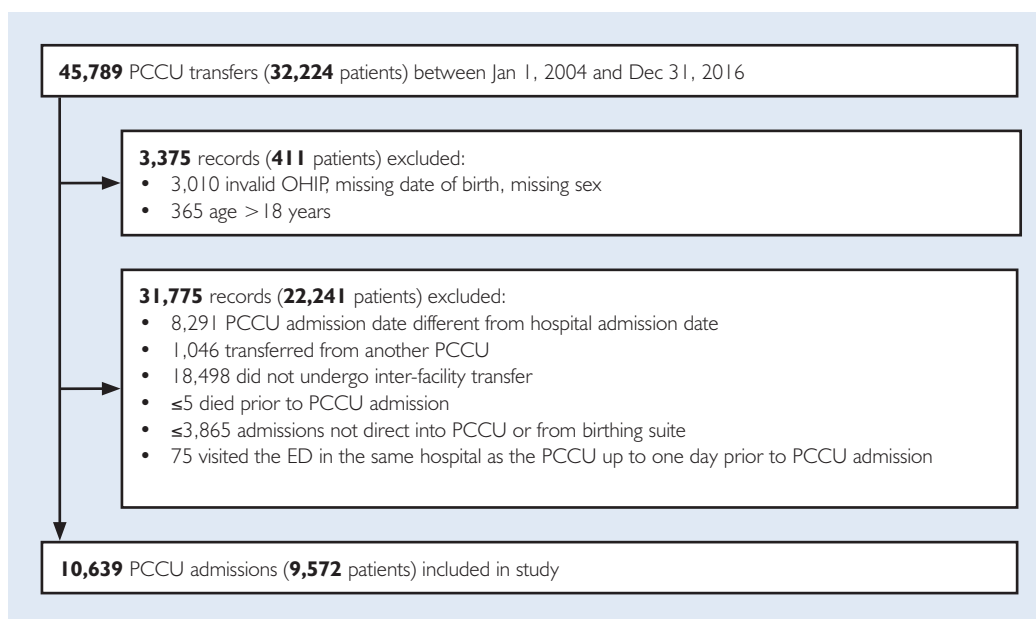
Similarly, we used the GEE to examine the risk of deferral on our primary and secondary outcomes of interest: mortality in the PCCU, mortality in the PCCU within 24 hours, mortality within six months and PCCU and hospital LOS. Model covariates included: age,

sex, rurality, previous PCCU stay, origin in referral hospital, transfer time of day, total acute care days in previous six months, most responsible diagnosis of the PCCU admission and the absence of co-morbidities identified in the previous year.

Sensitivity analyses were completed for all outcomes in the period following the introduction of the referral policy (January 1, 2010). This was done to assess whether observed effects were consistent after implementation of the referral policy.

All analyses were performed using SAS Enterprise Guide version 7.1 (SAS Institute Inc., Cary, NC). The 95% CIs reported for deferral rates in the pre- and post-implementation periods were calculated using Wilson's score method.  $p < 0.05$  was considered statistically significant.

FIGURE 1. Study flow diagram



OHIP: Ontario Health Insurance Plan

## Results

Over the study period, there were 10,639 inter-facility transfers for 9,572 patients, with 713 patients (7.4%) experiencing more than one transfer during the study period (Figure 1). The median age of transported patients was 17 months, and the interquartile range (IQR) was 1–103 months, with 5,720 (53.8%) transports for children of age less than two years (Table 1). 40.3%, ( $n = 4,284$ ) were transferred from an ED, and 1,533 (14.4%) lived in a rural setting. The median (IQR) distance from the referral hospital to the admitting PCCU hospital was 50 (21–105) km. The most common diagnosis was respiratory ( $n = 2,298$ , 21.6%), followed by congenital malformations/genetic abnormalities ( $n = 2,006$ , 18.9%) and other ( $n = 1,749$ , 16.4%). More transfers occurred in the evening and winter. Patients had a

median (IQR) of 1 (0–3) previous acute care days in the six months prior to transport, and 5,296 (49.8%) had no previous hospitalizations in the previous two years and 9,653 (90.7%) had no co-morbidities.

### Factors Associated with Deferrals

Comparing all deferred and non-deferred patients (Table 1 available online at [longwoods.com/content/25939](http://longwoods.com/content/25939)), it was noted that deferred patients were younger (median = 10 months; IQR = 1–78 months) than non-deferred patients (median = 20 months; IQR = 1–107 months). On average, deferred patients had more previous acute care days, more co-morbidities and presented more often in winter and from a non-ED area of the hospital (compared to an ED). However, among those presenting from the ED, median time to definitive critical care was 109 minutes longer for patient who were deferred. Patients presenting with congenital malformations/genetic abnormalities or acquired cardiac diagnoses were more often deferred, whereas those with psychiatric/neurologic, accidents or ingestions and other diagnoses were less frequently deferred. Those with the following co-morbidities were more likely to be deferred: congenital cardiac malformation, heart failure, chronic respiratory failure, transplant history, cancer and liver failure. Sex, time of day and rural status were not significantly associated with deferral status. Deferred patients were transported a median difference of 104 km more than those who were not deferred.

Regression models identified that previous ICU admissions, non-rural dwelling, patients not presenting to their local hospital, non-ED origin in the referral hospital, winter (versus summer) and a history of congenital cardiac malformation or a transplant and designated PCCU “B” and “C” (compared to “A”) were associated with a higher risk of deferral in both the complete study period and the post-implementation period. Designated PCCU “D” (compared to “A”), a history of chronic respiratory failure and a most responsible diagnosis of congenital malformation/genetic abnormalities were significant for the post-implementation period only. A history of heart failure was not significant for the post-implementation period only (Table 2 available online at [longwoods.com/content/25939](http://longwoods.com/content/25939)).

### Patient outcomes

#### MORTALITY OUTCOMES

Of all transported patients, 526 (4.9%) died in the PCCU (Table 3). Of these, 167 (1.6%) died within 24 hours of PCCU admission. Six-month mortality was 8.5% (903 transports). In the fitted regression models for the mortality outcomes, deferral status was not associated with increased mortality and was associated with decreased 24-hour mortality ( $p = 0.02$ ) (Table 4).

The median (IQR) PCCU LOS was 52 (25–127) hours or 2.2 days and receiving hospital LOS was 7 (3–15) days. In the fitted regression models for LOS outcomes, deferral status was significantly associated with a longer PCCU LOS (greater than 2.2 days) ( $p < 0.0001$ ) (Table 4).



**TABLE 3.** Primary and secondary outcomes by deferral status

Outcome	Transfer status		Total (n = 10,639)	p-value
	Deferred (n = 2,077)	Non-deferred (n = 8,562)		
Mortality within PCCU, n (%)	91 (4.4)	435 (5.1)	526 (4.9)	0.187
Mortality within 24 hours of transfer, n (%)	20 (1.0)	147 (1.7)	167 (1.6)	0.013
Mortality within six months of transfer, n (%)	188 (9.1)	715 (8.4)	903 (8.5)	0.304
PCCU LOS, days, median (IQR)	3 (1–7)	2 (1–5)	2 (1–5)	<0.001
Hospital LOS, days, median (IQR)	8 (4–17)	6 (3–15)	7 (3–15)	<0.001

PCCU = pediatric critical care unit; IQR = interquartile range; LOS = length of stay.

**TABLE 4.** Multivariable regression models for deferral status and outcomes\*

Outcome	Complete study period (2004–2016)		Post-implementation period (2010–2016)	
	OR (95th CI)	p-value	OR (95th CI)	p-value
Mortality within the PCCU	0.81 (0.63–1.04)	0.1	0.74 (0.51–1.07)	0.1
Mortality within 24 hours of transfer	0.56 (0.34–0.92)	0.02	0.41 (0.18–0.91)	0.03
Mortality within six months of transfer	0.89 (0.74–1.07)	0.22	0.91 (0.7–1.19)	0.49
Longer than average hospital stay	0.95 (0.85–1.06)	0.38	0.99 (0.84–1.16)	0.86
Longer than average PCCU stay	1.26 (1.13–1.4)	<0.0001	1.28 (1.09–1.49)	0.002

\*OR compares outcomes for deferred to non-deferred transfers.

All models adjusted for age, sex, ICU admission in previous year, rurality, origin in the referral hospital, transfer time of day, total number of previous acute care days, most responsible diagnosis and absence of co-morbidities.

### Impact of referral policy implementation

In total, 2,077 (19.5%) transports were deferred based on the 2010 referral guide definition: 24.8% (95% CI: 23.5–26.1%) pre-implementation and 16.0% (95% CI: 15.1–16.9%) post-implementation of the 2010 referral policy (Supplement Figure 1). Since the introduction of the formal referral guide in 2010, the inter-facility transfers have followed the health region-based guide more frequently in all four PCCU designated regions (Supplement Figure 2). Despite the policy implementation, a significant number of transfers associated with two PCCUs were still being deferred after 2010 (>25% for one PCCU and 10–25% for the other).

### Discussion

The 2010 referral policy was introduced in an effort to improve efficiency and clarity when transferring a critically ill child from a community healthcare centre to a PCCU in Ontario, Canada. If the care pathway of a critically ill child is pre-emptively organized, then the time spent seeking an accepting physician and a PCCU bed can be minimized. In turn, this allows the physician more time to focus on the patient’s medical management. Furthermore,



ensuring that the patient gets transferred to their closest PCCU can be helpful for the provision of psychosocial support to the patient and their family. However, despite the policy's best intentions, it may not always be possible (e.g., bed capacity issues) or in the best interest of the patient (e.g., required specialized services not offered at the designated PCCU) to avoid a deferral.

The four main findings of this study were as follows: (1) previous ICU admissions, non-rural dwelling, patients not presenting to their local hospital, non-ED origin in the referral hospital, winter (versus summer) and a history of congenital cardiac malformation or a transplant and certain designated PCCUs were associated with a higher risk of deferral; (2) there was no increased risk of mortality for deferred patients compared to non-deferred patients; (3) deferred patients (from the ED) had to wait almost two hours longer for definitive critical care (i.e., PCCU admission) and had a longer PCCU LOS; and (4) implementation of the referral policy led to a more consistent inter-facility transfer process.

We found a number of associations for deferrals, both patient- and system-related. History of a congenital cardiac malformation or transplantation was associated with a higher risk of deferral. This is not surprising, as one centre serves as the provincial transplant and cardiac centre; thus, children with a history of one of these conditions were likely bypassing the designated PCCU and being sent directly to this centre if a complication related to their medical history arose. While controlling for this, we were surprised to find that children with a history of a PCCU admission in the previous year were more likely to be deferred. In addition, patients originating in a non-ED setting (e.g., hospital ward) were more likely to bypass their designated PCCU. Perhaps, because these patients were already admitted, they had more time to present a clearer indication for specialized care only offered at a non-designated centre. Another explanation may be that some ward patients were deemed stable enough to transfer to a farther PCCU. Perhaps these patients were being treated by a pediatrician (because the hospital had pediatric admitting capabilities), and thus also deemed to have "more time." This fact indirectly contrasts the findings of the study by Gregory et al. (2008), who demonstrated that patients transferred from an in-patient ward were sicker than those transferred from an ED. A future area of study would be to better understand the decision framework for these patients.

As for system-related factors, patients were more likely to be deferred in the winter. Unit capacity is more strained in the winter when there are more respiratory illnesses. We also found that patients who presented to a hospital other than their local hospital were more likely to be deferred. This finding likely accounts for one aspect of the decision of where to transfer a patient that cannot be guided by a referral policy. A patient and family may be outside of their usual health region at the time of critical illness onset and thus may advocate for transfer to a PCCU that is closer to their home because of familiarity with that hospital, for social supports and the practical benefits of being closer to home. Interestingly, patients who lived in a rural setting were less likely to be deferred, independent of the distance to the designated PCCU. The increase in transport distance for deferred patients may be important.

There was a 2% increase in critical events for every 10-minute increase in transport duration for critically ill adults transported by air in Ontario, which may also be relevant for children (Singh et al. 2009).

When clinicians are faced with determining the best pathway for a patient, they assess the patient's characteristics and medical requirements with transport and hospital resources. The patient's best interest is always the guiding principle. We did not find deferrals to be associated with increased mortality. Results support clinicians and the current referral process, suggesting that patients were appropriately selected for deferral. The finding that deferred patients had a lower 24-hour mortality following transfer maybe speaks to a lower severity of illness that they had at the time of transfer decision and the appropriateness of the decision to defer when faced with capacity issues. Alternatively, we did not have data on patients who died prior to transfer, thus introducing an immortal time bias that may have preferentially affected the deferred group.

The finding that deferred patients from the ED spent an average of almost two hours longer waiting for definitive critical care may be important. This may mean more time without proper equipment, pediatric expertise and definitive PCCU care. Patients awaiting transfer, particularly if delayed, may benefit from ongoing remote support via telemedicine (Labarbera et al. 2013). Though deferral status did not result in increased mortality, it was associated with prolonged PCCU LOS while controlling for past ICU admissions and acute care contact, origin in the ED, diagnosis and presence of co-morbidities. It is difficult to reconcile this with reduced early mortality, as PCCU LOS reflects the patients' need for PCCU resources and is thus often a surrogate for severity of illness. A better understanding of the course of disease in the transported population is indicated.

The 2010 referral policy was successful in ensuring that most (84%) inter-facility transfers followed the designated referral patterns and the proportion of deferred patients decreased. The most significant decline in deferrals appeared to occur after 2007 (Supplement Figure 1), which might be explained by the introduction of a formal PCCU consultation service ("Criticall") in 2006. This service was designed to help connect referring physicians to accepting physicians in PCCUs in Ontario. This suggests that the 2010 referral policy did little else than to reinforce pre-existing relationships that had been established from about 2007. The fact that the rate of deferrals appears fairly constant since 2010 suggests that there are reasons beyond policy adoption that dictate whether a patient will be deferred. Although hospital referral capabilities dictate the need for transfers with metrics designed to track patient trajectories (Franca and McManus 2017), it is largely the ICU capacity that dictates where the patient is transferred to. ICU capacity has been studied at great length to predict and manage patient flow. Several mathematical models exist to do so for adult critical care, as capacity prediction is more complex than simply a function of the number of annual admissions, illness severity and LOS (Konnyu et al. 2011). For example, seasonality appeared to be the most influential factor in bed shortage risk for a hypothetical hospital in England following modelling of emergency admissions (Bagust et al. 1999).

There are a number of limitations. As discussed, though we managed to control for a number of patients, disease, transport and hospital factors associated with deferrals, we did not have data on severity of illness, PCCU bed capacity, the weather and availability of a given transport team. Measures of severity of illness were not available and surrogates of severity of illness (such as use of vasoactives or mechanical ventilation) either do not exist in the database or have not been validated. Although there is conflicting evidence on whether available scores can be accurately applied to this population (Freishtat et al. 2004; Orr et al. 1994), we used other variables in lieu of scores. Further, we did not have data on deferrals to out-of-province PCCUs from centres close to Manitoba, Quebec or the US.

## **Conclusion**

We conducted a 13-year study using health administrative data of critically ill children who underwent inter-facility transfer to a PCCU in Ontario to describe patients who were deferred away from their designated PCCU. Patients with a previous PCCU admission, non-rural dwelling, patients presenting to their local hospital, non-ED origin in the referral hospital, winter (versus summer) and a history of congenital cardiac malformation or a transplant and designated PCCU were associated with higher risk of deferral. Deferrals were not associated with an increased risk of death but were associated with a prolonged PCCU LOS and a delay in definitive critical care for the ED patients. We found that implementation of a referral policy was associated with a consistent referral pattern in 84% of transfers. Further study is indicated to better understand additional factors associated with deferrals as well as their impact on resource utilization and quality of life.

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