The association between transport duration and distance on pediatric intensive care outcomes in British Columbia from 2015 to 2017: a retrospective data analysis.

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	386 direct admissions and 484 transferred patients. Transported patients were younger, more critically ill on presentation, and required longer length of stay in the PICU. The odds of requiring mechanical ventilation and of hospital mortality in the transport group compared to children directly admitted from the ED were 2.27 (95% confidence interval, 1.70-3.03, p<0.001) and 2.23 (95% confidence interval, 1.21-4.10, p=0.008), respectively. There was no significant relationship between transport distance and risk-adjusted mortality. Interpretation: Transfer status of pediatric critical care patients is associated with PICU length of stay, the need for invasive ventilatory support and crude hospital mortality.

The association between transport status, duration and distance on pediatric intensive care unit outcomes in British Columbia from 2015 to 2017: a retrospective cohort study

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Abstract

Background:

Approximately 3 million children in Canada reside in regions without direct access to specialized care. In British Columbia (BC), BC Children's Hospital houses the only level-1 pediatric intensive care unit (PICU) in the province, providing pediatric critical care coverage for BC and the Yukon Territories. This study aimed to explore the impact of transfer status on the use of mechanical ventilation, length of PICU stay, and hospital mortality.

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Results:

During the study period, there were 870 unique admissions comprising 386 direct admissions and 484 transferred patients. Transported patients were younger, more critically ill on presentation, and required longer length of stay in the PICU. The odds of requiring mechanical ventilation and of hospital mortality in the transport group compared to children directly admitted from the ED were 2.27 (95% confidence interval, 1.70-3.03, $p<0.001$) and 2.23 (95% confidence interval, 1.21-4.10, $p=0.008$), respectively. There was no significant relationship between transport distance and risk-adjusted mortality.

Interpretation:

Transfer status of pediatric critical care patients is associated with PICU length of stay, the need for invasive ventilatory support and crude hospital mortality.

Introduction

Pediatric intensive care across the world is typically delivered through a centralized model where specialized resources, including personnel and equipment, are concentrated in a specific region, often at tertiary centres. This model relies on having experienced and effective transport systems to transfer critically ill children to the appropriate centre for care. Existing literature have suggested that the centralization of pediatric intensive care services to high-volume centres is associated with decreased mortality in pediatric populations. (1–7)

With this centralization, it has also been shown that, compared to direct in-hospital admissions, children who were transported from other hospitals were more critically ill at pediatric intensive care unit (PICU) admission, had longer hospital length of stay (LOS) and higher use of intensive care-specific therapies such as mechanical ventilation and inotropic infusions. (8–12) Risk-adjusted mortality rates did not differ significantly between the groups. (8–10, 13)

Canada has the second largest geographic area in the world and has nearly 3 million children living in areas without direct access to these specialized pediatric critical care services, with approximately 20% of the population living outside of urban centres. (12) The objective of this study was to explore the association between transfer status and patient outcomes (mechanical ventilation use, PICU LOS, and hospital mortality) among critically ill children residing in British Columbia and the Yukon.

Methods

Setting

The PICU at BC Children's Hospital is a 28-bed level-1 medical, surgical, and cardiac intensive care unit with approximately 1100 admissions annually, providing intensive care to critically ill children across British Columbia as well as the Yukon Territories. Children are admitted directly from the emergency department, inpatient wards, or from other hospitals. The process of transfer begins with the physician presented with a critically ill child from another hospital consulting the on-call intensivist. Once a decision to transfer and admission to PICU is made, a provincially run transport team is dispatched, with a number of fixed-wing, helicopter, and ambulance-based transport teams available.

Participants

All patients residing in British Columbia or the Yukon admitted to the PICU from January 2015 to December 2017 were considered for inclusion. Patients were excluded if they were admitted on an elective basis, for recovery post-operatively, had more than one residential address or had an out-of-province (other than Yukon) residential address. Out-of-province residents were excluded to minimize potential bias as primary residential address was used to estimate transport distance and duration.

Data Sources

Data was extracted from a database of patients requiring admission to the PICU (Virtual Pediatric Systems) as well as the electronic medical charts. The following data elements were collected: residential postal codes, age and weight at admission, admission diagnosis, admission source, transport mode, transport duration, initial vital signs on admission, severity-of-illness score (Pediatric Risk of Mortality 3 [PRISM3]), length of PICU stay, use of mechanical ventilation, and mortality. PRISM3 is a validated composite score calculated using 17 physiological variables collected on PICU admission to predict the risk of mortality. (13–15) Ethics approval was obtained from the Research Ethics Board at Children's and Women's Health Centre of British Columbia and the University of British Columbia.

Statistical Analysis

Descriptive analyses were used to summarize the demographics of the study population. Continuous data were expressed as means and standard deviations for normal distribution and medians and interquartile range (IQR) for non-normal distribution. Means were compared using Student's *t* test and medians were compared using Mann-Whitney *U* ranked sum test. Categorical data were summarized as counts and proportions and compared using Chi squared test. Transport distances were calculated using an online tool (16) by inputting residential postal codes of the patients and measuring distance by land or by crow (i.e., for air transport) to BCCH as the reference point. Distance was categorized as 0 – 100km, 100 – 200km and > 200km to account for changes in transport modality and associated differences in transport duration above a specific threshold distance. Admission diagnoses were categorized into one of the following: respiratory, cardiac, neurological, gastrointestinal/surgical, infection/sepsis, endocrine, trauma/burns/drowning, oncological, poison/overdose/other, and missing, using admission ICD10 codes. The primary outcome was hospital mortality. Secondary outcomes were the use of mechanical ventilation, and PICU LOS. Logistic regression was used to evaluate the relationship between transport status and crude and risk-adjusted mortality. Additional logistic regression analyses were done to compare transport distance and modality on hospital mortality. Linear regression was used to examine the association between transport distance and PICU LOS. Analysis was conducted using R version 3.6.1 (R Core Team, Vienna, Austria). Statistical significance was considered at a p-value < 0.05.

Missing Data

Patient encounters were excluded if there was unavailable or unusable data for any of the primary analyses. These included patients with addresses that were missing, incomplete, or inconsistent with the recorded transport modalities (i.e., using a fixed-wing aircraft for addresses within 50 kilometers).

Table 1 Baseline demographic and characteristics of patients

Variable	All children admitted to PICU (n=870)	Children admitted to PICU from ER (n=386)	Children transported to PICU from referring hospital (n=484)	p-value

Sex, n (%)				
Male	490 (56.3)	217 (56.2)	273 (56.4)	1
Female	380 (43.7)	169 (43.8)	211 (43.6)	1
Age (months), median (IQR)	41 (9-121)	52 (10-135)	32 (7-115)	0.01
Weight (kg), median (IQR)	15 (8-35)	16 (9-36)	14 (7-31)	0.04
PRISM+ 3 Risk, median (IQR)	0.63 (0.3-1.1)	0.49 (0.3-1)	0.63 (0.3-1.6)	<0.001
Admission Category, n (%)				
Respiratory	360	168 (43.5)	192 (39.7)	0.28
Cardiac	49	18 (4.7)	31 (6.4)	0.34
Neurological	156	59 (15.3)	97 (20)	0.08
General Surgical	13	5 (1.3)	8 (1.7)	0.88
Sepsis/Infection	60	32 (8.3)	28 (5.8)	0.19
Endocrine	40	19 (4.9)	21 (4.3)	0.81
Trauma/Burns/Drowning	89	39 (10.1)	50 (10.3)	1
Oncological	15	7 (1.8)	8 (1.7)	1
Poison/Overdose	40	11 (2.8)	29 (6)	0.04
Other	29	18 (4.7)	11 (2.3)	0.08
Missing	19	10 (2.6)	9 (1.9)	0.62
Transport Modality, n (%)				
Private Vehicle	249	248 (64.2)	1 (0.2)	-
Ambulance	402	138 (35.8)	264 (54.5)	-
Helicopter	41	0	41 (8.5)	-
Fixed Wing Aircraft	178	0	178 (36.8)	-
Distance (km), median (IQR)	-	-	67.1 (32.9-274.2)	-
Duration (min), median (IQR)	-	-	38.1 (29-54.9)	-

+PRISM: Pediatric Risk of Mortality score

Table 2: Transport mode and duration by distance from residential address to BC Children's Hospital

Distance Categories	Time (min)	Private (n)	Ambulance (n)	Helicopter (n)	Fixed Wing (n)
A. ≤100km (n=290)	40.5	1	251	27	1
B. 100km-≤200km (n=34)	51.9	0	13	11	10
C. ≥200km (n=160)	51.8	0	0	3	157

Table 3: Outcome comparisons according to source of admission

Outcome	Total (n=870)	Emergency Department (n=386)	Transport (n=484)	OR (95% CI)	p-value
Length of Stay (days), median (IQR)	1.88 (0.8-4.1)	1.60 (0.8-3.4)	2.43 (0.9-4.6)	-	<0.001

Use of Mechanical Ventilation, n (%)	591 (68)	224 (58)	367 (75.8)	2.27 (1.70, 3.03)	<0.001
Mortality, n (%)	55 (6.3)	15 (3.9)	40 (8.3)	2.23 (1.21, 4.10)	0.008

Table 4: Risk-adjusted and crude odds of mortality by transport distance

	Mean PRISM-3+ Risk (%)	PRISM-3+ Adjusted Odds of Mortality		Crude Odds of Mortality	
Distance (km)		OR (95% CI)	p-value	OR (95% CI)	p-value
≤100 (n=290)	5.31	-	-	-	-
100-≤200 (n=34)	4.30	0.75 (0.07-3.69)	0.77	0.69 (0.10-2.49)	0.63
≥200 (n=160)	5.76	0.86 (0.33-2.10)	0.75	1.06 (0.52-2.09)	0.86

+PRISM: Pediatric Risk of Mortality Score

Results

Over the two-year study period, there were a total of 870 unique eligible admissions with 386 direct admissions and 484 patients transported from another hospital. Baseline characteristics of the study population are shown in Table 1. Overall, patients who were transported from another hospital were younger (median age 32 months, IQR, 7-115 vs 52 months, IQR, 10-135; p=0.01) compared to those admitted directly from the emergency department. Transported patients also had higher median PRISM3 (0.63, IQR, 0.3-1.6 vs 0.49, IQR, 0.3-0.1; p=<0.001) scores at admission to PICU. Among the diagnostic categories, there were similar rates of admission for respiratory, cardiac, general surgical, infectious, endocrine, trauma, and oncological causes between the direct admission group and the transported group. However, a higher proportion of admissions in the transported group were for poison or overdose-related conditions, comprising 6% of admissions in the transported group compared to 2.8% in the direct admission group (X^2 = 4.14, p=0.04).

Transported Patients

Eight children (1.7%) had residential addresses in the Yukon Territories while the remainder resided in British Columbia. The median estimated distance travelled by transported patients was 67.1km (IQR 32.9-274.2km) with a median estimated duration of 38.1 minutes (IQR 29-54.9 minutes). Ambulance transport was used for 54.5% of the transports, fixed wing aircraft for 36.8% and helicopter for 8.5% of all transports. Table 2 shows the analysis of transport modality and mean transit duration by distance from residential address to BCCH. The proportion of patients for whom fixed wing aircraft was used increased with distance and was greatest for distances more than 100 kilometers.

Outcomes

Compared to the patients directly admitted to the PICU, transported patients had a longer length of PICU stay (2.43 days, IQR, 0.9-4.6 vs 1.60, IQR, 0.8-3.4; p<0.001), higher odds of receiving mechanical ventilation within the first 24 hours (OR 2.27, 95% CI, 1.70-3.03 p<0.001) and higher odds of hospital mortality (OR 2.23, 95% CI 1.21-4.10, p=0.008) (Table 3).

After adjusting for severity of illness on PICU admission, there was no significant relationship between distance and duration on mortality (Figures 1 and 2). Individual transport modalities were not shown to be associated with mortality. The odds of mortality were lowest in distance category B (100-200km) where a higher proportion of children were transported by air relative to land transport; however, this did not reach statistical significance (Table 4). A general additive model was used to evaluate the relationship between distance and PICU LOS (Figure 3). No significant association between transport distance and PICU LOS was identified.

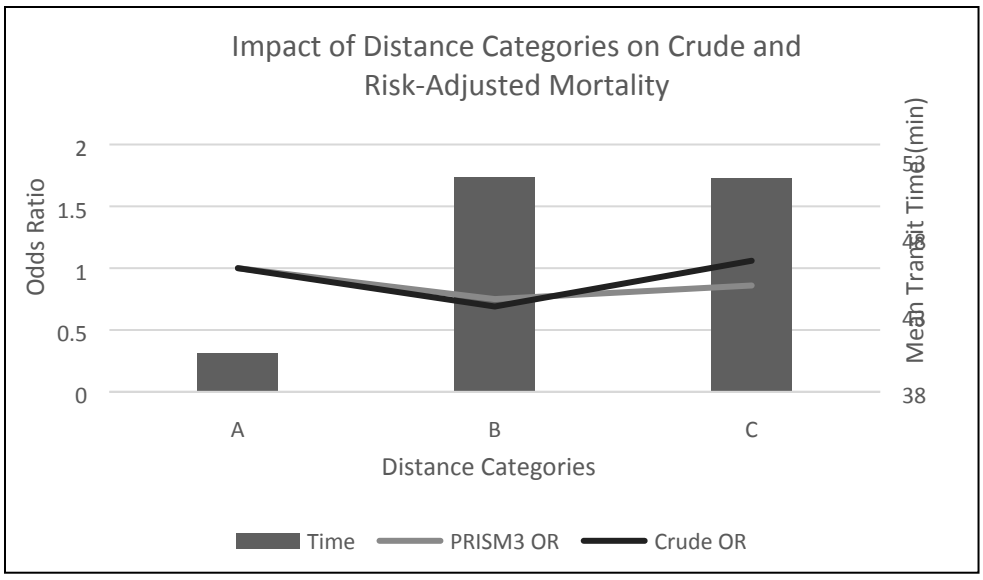

Figure 1. Impact of distance in categories on crude & PRISM3-adjusted mortality. Distance categories are as follows: A (0-100km), B (100-200km), C (≥200km). "Time" corresponds to the mean transit time in each distance category.

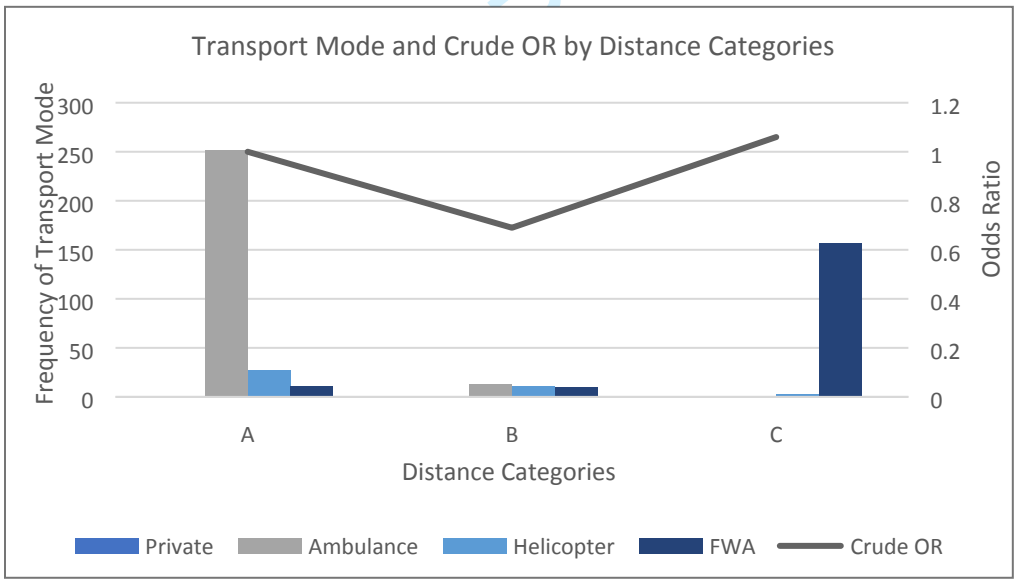

Figure 2. Impact of transport mode and distance categories on crude odds of mortality. Distance categories are as follows: A (0-100km), B (100-200km), C (≥200km).

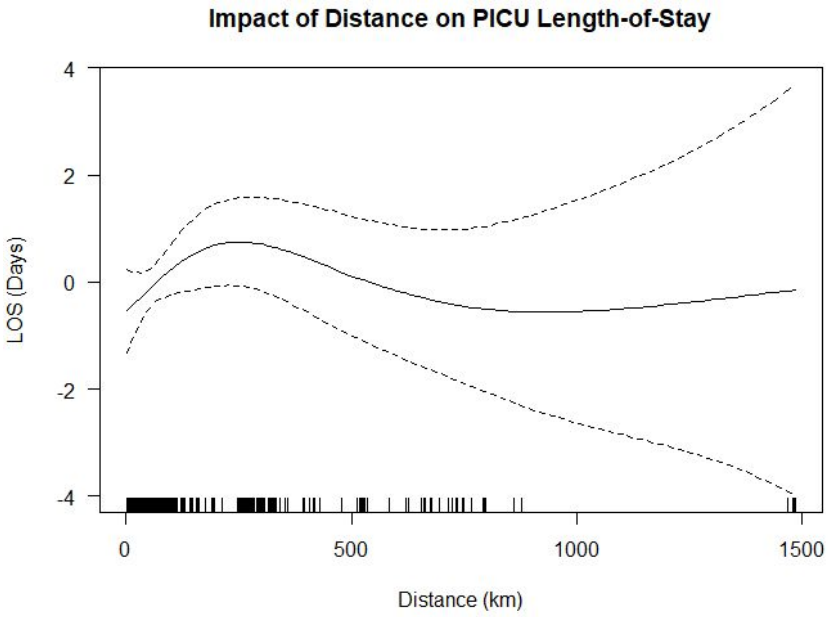

Figure 3. Length of stay as a continuous but non-linear function of distance. Dotted lines represent standard error bands.

Interpretation

Our study demonstrated that children transported to the BCCH PICU were younger and more acutely ill at admission by measures of PRISM3 risk of mortality. Transport status was associated with a longer length of PICU stay, greater odds of mechanical ventilation in the first 24 hours, and higher crude odds of hospital mortality as compared to patients admitted directly. Distance from primary residence or estimated transport duration were not found to be associated with PICU LOS or hospital mortality. Though there appeared to be a protective effect on hospital mortality of use of air transport with increasing distances (>100km), there was no significant association between transport modality, distance, and hospital mortality.

This is the first analysis of pediatric outcomes following inter-hospital transport in British Columbia. While existing studies are consistent in observing that transported critically ill pediatric patients were younger, more acutely ill, and used more intensive care resources, there remains conflicting findings in terms of crude mortality rate differences between direct and transport groups. Our study showed a significantly higher crude mortality rate in the transport group, consistent with the findings from similar analyses conducted in other provinces in Canada and a study evaluating the national PICU in New Zealand. (10,12,17) Conversely, a retrospective study of 20 PICUs in the United States demonstrated no difference in the crude or risk-adjusted mortality rates among transported children versus direct admissions. (8) Finally, a nationwide study in English and Wales found that the risk-adjusted mortality rate for transported patients was lower than for direct admissions. (9) These conflicting results highlight underlying differences among the pediatric critical care transport systems worldwide and limitations of currently available data. First, there exists a broad spectrum in the composition and skillset of the transport teams which may influence clinical outcomes. (11,18) Second, the median distance

travelled varied greatly among the studies with ranges from 35km in the United Kingdom study to 383km in an epidemiological study of pediatric critical care transport in Northern Canada. (19) The needs of a Canadian transport system are likely to be very different from countries with a smaller geographic footprint.

A crucial factor to consider is the transport modality used in relation to the distance travelled. There is a paucity of data available within existing literature examining the role of specific transport mechanisms on outcomes. This is especially important in trying to elucidate a relationship between distance, duration, and outcomes. Distance has been shown to be an adverse predictor of mortality in the adult ICU research with an increased risk of mortality at distances over 100 km. (20) Our study findings are consistent with current pediatric critical care evidence in that distance was not significantly associated with hospital mortality. Estimated transport duration was not shown to be associated with hospital mortality in our study, however this finding is limited by the inability to measure actual transport duration, thereby under-estimating the effects of transport team availability, urgency, and weather-related factors on duration. Sample et al. showed that among patients transported by air, duration was significantly associated with risk-adjusted PICU mortality while Moynihan et al. did not find a significant association. (10) Figure 2 demonstrates a trend of decreasing risk of mortality along with decreasing use of ambulance and corresponding increasing use of helicopter and fixed wing aircrafts with increasing distance. Further research is needed to understand the complex interplay between available transport modalities, distance, and duration.

Limitations

There are several limitations to this study. First, specific data pertaining to the initial presentation and care received at the referring hospital was limited due to the retrospective nature of this study. Specifically, pre-transfer severity of illness scores were not available; therefore, it is unknown whether differences in observed mortality among transported patients are related to differences in severity of illness at presentation or transport-specific factors and delay to definitive management. The vast geographical area of British Columbia and Yukon Territories allow for diverse enclaves of populations with different socioeconomic, cultural, and racial composition to be settled in specific regions. A future study is being planned to examine factors associated with regional burden of pediatric critical illness. Finally, transport distance and duration were estimated based on distance from listed residential address to the final destination. These estimates may not reflect total transport time, delays in transfer, or alternate departure locations than the primary residence.

Conclusions

In summary, patients transferred from another facility to the PICU were more critically ill on presentation, more likely to require invasive mechanical ventilation, and had a significantly higher odds of mortality. There was no significant relationship between estimated transport distance and risk-adjusted mortality. The association between transport status and outcome was not adjusted for severity of illness at first hospital presentation.

Contributors Statement

Srinivas Murthy designed the study with substantial input from Fiona Muttalib. Jollee Fung and Sean Wong extracted the data and performed the data analyses with input from all authors on interpretation and conclusions. Jollee Fung drafted the manuscript. All the authors revised the manuscript critically for content, approved the final version to be published, and agreed to be accountable for the work.

Data-Sharing Statement

Data may be available from the corresponding author upon request.

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+PRISM: Pediatric Risk of Mortality score

Table 2: Transport mode and duration by distance from residential address to BC Children's Hospital

Distance Categories	Time (min)	Private (n)	Ambulance (n)	Helicopter (n)	Fixed Wing (n)
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C. ≥200km (n=160)	51.8	0	0	3	157

Table 3: Outcome comparisons according to source of admission

Outcome	Total (n=870)	Emergency Department (n=386)	Transport (n=484)	OR (95% CI)	p-value
Length of Stay (days), median (IQR)	1.88 (0.8-4.1)	1.60 (0.8-3.4)	2.43 (0.9-4.6)	-	<0.001
Use of Mechanical Ventilation, n (%)	591 (68)	224 (58)	367 (75.8)	2.27 (1.70, 3.03)	<0.001
Mortality, n (%)	55 (6.3)	15 (3.9)	40 (8.3)	2.23 (1.21, 4.10)	0.008

Table 4: Risk-adjusted and crude odds of mortality by transport distance

	Mean PRISM-3+ Risk (%)	PRISM-3+ Adjusted Odds of Mortality		Crude Odds of Mortality	
Distance (km)		OR (95% CI)	p-value	OR (95% CI)	p-value
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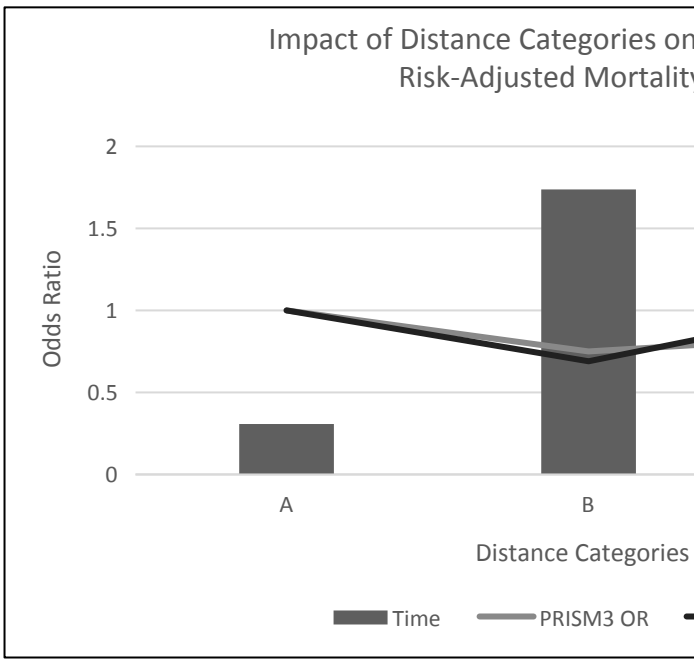
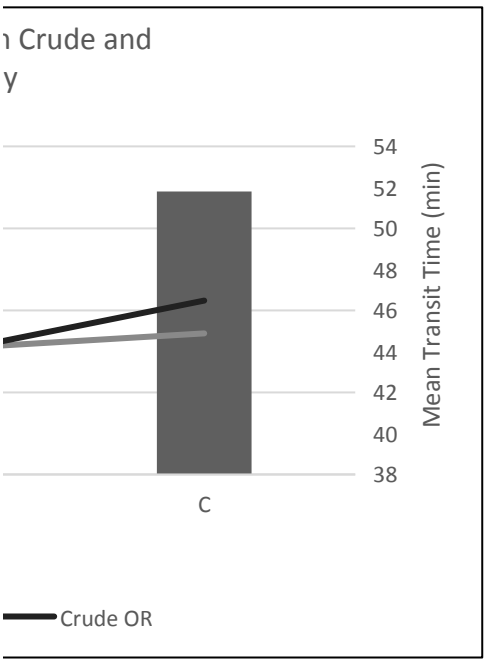
100-≤200 (n=34)	4.30	0.75 (0.07-3.69)	0.77	0.69 (0.10-2.49)	0.63
≥200 (n=160)	5.76	0.86 (0.33-2.10)	0.75	1.06 (0.52-2.09)	0.86

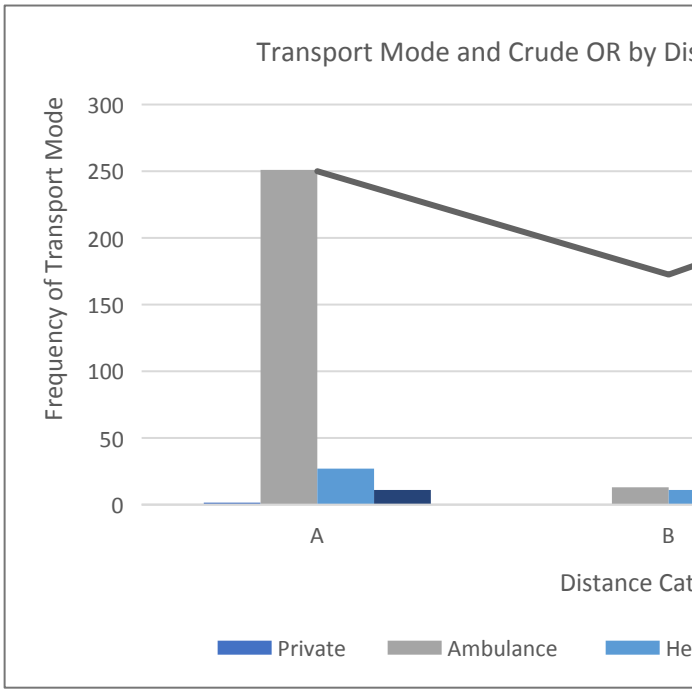
+PRISM: Pediatric Risk of Mortality Score

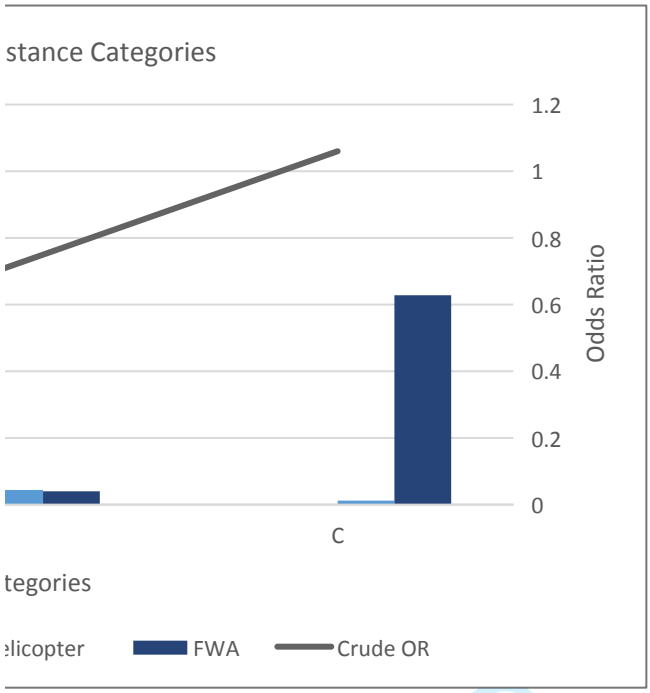
	A	B	C
Time	40.46	51.9	51.8
PRISM3 OR	1	0.75	0.86
Crude OR	1	0.69	1.06





	A	B	C
Private	1	0	0
Ambulance	251	13	0
Helicopter	27	11	3
FWA	11	10	157
Crude OR	1	0.69	1.06





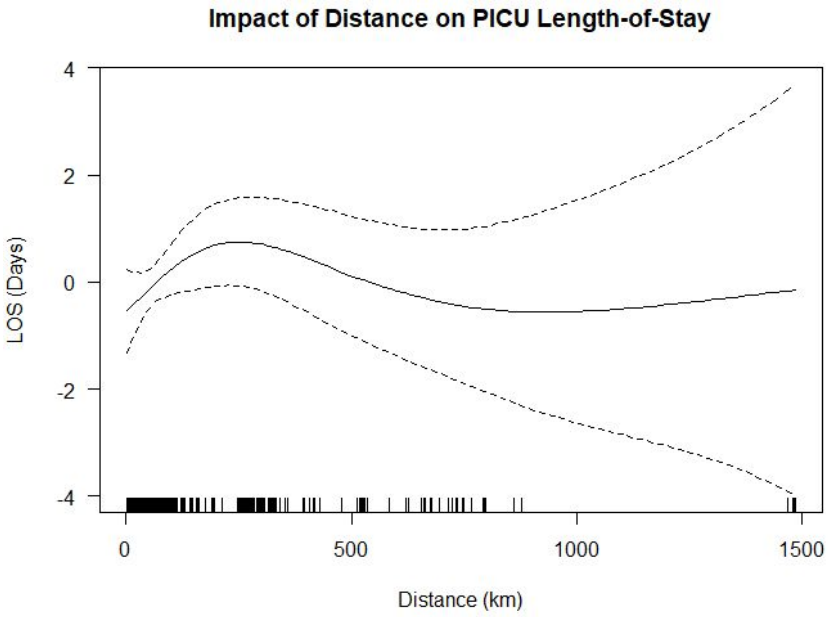


Figure 3

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (*b*) For matched studies, give matching criteria and number of exposed and unexposed	3
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	3
Study size	10	Explain how the study size was arrived at	3
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, explain how loss to follow-up was addressed (*e*) Describe any sensitivity analyses	4
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	5
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	5
Outcome data	15*	Report numbers of outcome events or summary measures over time	5-6

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	5-7
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	5-7
Discussion			
Key results	18	Summarise key results with reference to study objectives	8-9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.