Developing an Evidence - Informed Pediatric Retrieval System for Alberta

by

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ABSTRACT

As medical care in developed countries has become increasingly specialized, health care resources by necessity have become more regionalized. The assessment and management of critical illness and injury in infants and children requires specialized training and experience. To improve patient care and outcomes, specialized pediatric transport teams are commonly used to transfer critically ill or injured children from community hospitals to tertiary care hospitals. The goal of pediatric critical care (PCC) transport is to not only transport patients from community hospitals to tertiary care centers, but do so while providing patient care as close as possible to what would be provided in a Pediatric Intensive Care Unit (PICU).

Communities in Alberta are scattered over a large geographic area. Critically ill or injured children are transferred to one of Alberta's two children's hospitals (Stollery Children's Hospital (SCH) in Edmonton, or Alberta Children's Hospital in Calgary) to receive specialized care. Over the last two decades, a hospital-based PCC transport team in SCH has functioned as the principal provider of inter-hospital transport of critically ill or injured infants and children for Northern Alberta as well as for the Western Arctic.

This thesis project aimed: to better understand the unique aspects of PCC transport programs across Canada by characterizing the current workforce of each transport program; to characterize PCC transport activity in Northern Alberta and in the Western Arctic to explore the effect of adult intensive care services/specialties provided at referral hospitals and their association with patient outcomes; to examine the effect of physician non-accompanying PCC transport on patient

outcomes; to identify factors that are currently being considered with regards to transport team composition when deploying the PICU transport team; and to explore the impact of patient transport itself on the outcomes of critically ill or injured children.

First, in our national survey of PCC transport services, we revealed complexity and variability in transport team demographics, volumes, team compositions, decision-making processes, and quality assurance when comparing programs. Our study also found that many regions in Canada remain under-serviced by PCC transport teams. Second, we made several findings with respect to the currently operating PCC transport system in Northern Alberta and the Western Arctic, such as a low PICU admission rate following transports, an increasing trend in number and distance of transports, an increase in dispatch time over the period studied, significant monthly variations in transport activities, and an expansion in the areas/communities supported by the SCH PCC transport program. We also found that availability of adult intensive care services in referral hospitals might be associated with a higher probability of requiring PICU admission after inter-hospital transport; however, the difference was not consistent among the referral hospitals, suggesting that certain hospital-level factors might affect the likelihood of requiring PICU admission. Third, we found no difference in patient outcomes associated with the increasing use of a physician non-accompanying transport team in our current pediatric retrieval system. An appreciable variation was observed among triage physicians with respect to their team selection (i.e., either sending physician accompanying team or not). Although we did not examine how the triage decision by each physician affected outcomes, our findings suggest the need for a standardized approach to transport triage practice. Finally, we found that children admitted to a PICU who were transported from another hospital by a PCC transport team had higher mortality in the acute phase when compared to children presenting directly to a pediatric emergency department in a tertiary children's hospital that required PICU admission. It was unclear whether worse outcomes stemmed from the specific patient population presenting to the rural sites, the care provided prior to the arrival of the PCC transport team, and/or the care provided by the PCC transport teams themselves; the existing disparity and its cause need to be further examined by future study.

PREFACE

This thesis is an original work by Atsushi Kawaguchi. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Developing an evidence-informed pediatric retrieval system for Alberta." (Pro00053596).

All of the research conducted for this thesis stems from a research collaboration, led by Professor Allan de Caen at the Faculty of Medicine and Dentistry in the University of Alberta and Professor Yutaka Yasui at the School of Public health in the University of Alberta. The review in ***Chapter 1, 2 and 7*** are my original work.

The study in ***Chapter 3*** has been published as A. Kawaguchi, A. Gunz, and A. de Caen, "Cross-sectional Survey of Canadian Pediatric Critical Care Transport" in *Pediatric Emergency Medicine,* August 20, 2016, [Epub ahead of print]. I conceptualized, designed the survey, carried out analysis, drafted the initial manuscript, and revised the initial manuscript, and approved the final manuscript as submitted. A. Gunz conceptualized the study, revised the questionnaire, supervised, reviewed and revised the initial manuscript, and approved the final manuscript as submitted. A. de Caen supervised the construction of the questionnaire, reviewed and revised the initial manuscript, and approved the final manuscript as submitted.

The study in ***Chapter 4*** has been published as Atsushi Kawaguchi, Charlene C. Nielsen, Gonzalo G. Guerra, L. Duncan Saunders, Yutaka Yasui, and Allan de Caen, "Epidemiology of Pediatric Critical Care Transport in Northern Alberta and the Western Arctic." in *Pediatric Critical Care Medicine*, 2018 Jun; 19(6): e279-e285. I conceptualized and designed the study, conducted data collection and cleaned the data, carried out analysis, drafted the initial manuscript, revised the initial manuscript, and approved the final manuscript as submitted. C. Nielsen conducted spatial data analysis and other mapping procedures, reviewed and revised the original manuscript, and approved the final manuscript as submitted. G. Guerra helped to conceptualize the study, revised the initial manuscript, and approved the final manuscript as submitted. D. Saunders helped to conceptualize and design the study, helped with data analysis, reviewed and revised the initial manuscript, and approved the final manuscript as submitted. Y. Yasui helped with data analysis, reviewed and revised the initial manuscript, and approved the final manuscript as submitted. A. de Caen conceptualized and designed the study, revised the initial manuscript, and approved the final manuscript as submitted.

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The study in ***Chapter 6*** has been submitted to *Journal of Intensive Care Medicine* as of June 2018, as Atsushi Kawaguchi, L. Duncan Saunders, Yutaka Yasui, and Allan de Caen, "Effects of Medical Transport On Outcomes in Children Requiring Intensive Care". I conceptualized and designed the study, conducted data collection and cleaned the data, carried out analysis, drafted the initial manuscript, revised the initial manuscript, and approved the final manuscript as submitted. D. Saunders helped to conceptualize and design the study, helped with data analysis, reviewed and revised the initial manuscript, and approved the final manuscript as submitted. Y. Yasui conceptualized and designed the study, helped with data analysis, reviewed and revised the initial manuscript, and approved the final manuscript as submitted. A. de Caen conceptualized and designed the study, revised the initial manuscript, and approved the final manuscript as submitted.

DEDICATION

To my parents Hiroko and Takeshi Kawaguchi,

my two wonderful kids Wataru and Sakura, and wife Ayako Kawaguchi.

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First of all, I would like to thank the people who, directly or indirectly, made this thesis and project possible. I would like to express my endless gratitude and respect to my two exceptional supervisors, Prof. Yutaka Yasui and Prof. Allan de Caen, and Prof. Duncan Saunders as my supervisory committee members. I have learned from them over the years, which is invaluable beyond what words can describe. I would also like to thank all the dedicated transport team members.

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LIST OF ABBREVIATIONS

(Alphabetical order)

AAP: American Academy of Pediatrics

ACH: Alberta Children's Hospital

AHS: Alberta Health Services

ALS: Advanced Life Support

CI: Confidence Intervals

ED: Emergency Department

EIA: Edmonton International Airport

ENT: Ear Nose Throat

HLC: High-Level Care

HR: Heart Rate

IQR: Inter-Quartile Range:

LOS: Length of Stay:

NHLC: Non-High-Level Care

PCC: Pediatric Critical Care

PICU: Pediatric Intensive Care Unit

PLT: Physician-less Transport

PRISM: Pediatric Risk of Mortality:

PT: Physician accompanying Transport

RAAPID: Referral, Access, Advice, Placement, Information, and Destination

RN: Registered Nurse

RR: Respiratory Rate

RT: Respiratory Therapist

SBP: Systolic Blood Pressure

SCH: Stollery Children's Hospital

SD: Standard Deviation:

SOTM: Section on Transport Medicine

SpO_2: Oxygen Saturation

UK: United Kingdom

US: United States

CHAPTER 1

Introduction

1.1 History and Recognition of Pediatric Critical Care Transport

1.1.1 General Aspect

As medical care in developed countries has become increasingly specialized, health care resources by necessity have become more regionalized. Recent studies of specialized medical services have shown that the centralization of patients to high-volume centers is associated with improved cost-effectiveness and patient outcome [1-5].

Specialized medical transport systems for critically ill or injured patients evolved initially from military experience [6]. In the United States (US), medical transport systems were developed in the early 1960s to provide care for critically ill neonates [7, 8]. Transport programs for older children began to emerge in the 1980's [9]. The American Academy of Pediatrics (AAP) established a Section on Transport Medicine (SOTM) in 1990, which has been led by neonatologists, pediatric intensivists, and pediatric emergency medicine physicians that oversee the inter-facility transport of critically ill neonates, children, and adolescents [10]. The first guidelines from the AAP for pediatric inter-facility transport were developed in the late 1980's. In the United Kingdom (UK), several regional free-standing pediatric dedicated critical care transport teams (as opposed to hospital-based pediatric critical care (PCC) transport team) have evolved since the late 1990s [11]. The European Society of Paediatric and Neonatal Intensive Care (ESPNIC) developed a section of transport medicine [12].

1.1.2 The Canadian Perspective

In Canada, intensive care services for severely ill and injured children have undergone substantial centralization since the 1980's, with these services currently being coordinated through Pediatric Intensive Care Units (PICU) in tertiary hospitals in major Canadian cities [13]. Starting in the 1980's, some of the Canadian PICUs established ICU-based PCC transport teams. Due to the differences in geography, referral patterns, and locally available transport system resources, programs for the transport of critically ill or injured children have evolved very differently across the country [13]. In 2009, the Canadian Association of Pediatric Health Centers (CAPHC) established a National Transport Systems Steering Committee and initiated working groups to develop specific national standards [14].

1.1.3 Principle of PCC Transport

As medical care in developed countries has become increasingly specialized, health care resources by necessity have become more regionalized. The assessment and management of critical illness and injury in infants and children requires specialized training and experience. To improve patient care and outcomes, specialized pediatric transport teams are commonly used to transfer critically ill or injured children from community hospitals to tertiary care hospitals. The goal of pediatric critical care (PCC) transport is to not only transport patients from community hospitals to tertiary care centers, but do so while providing patient care as close as possible to what would be provided in a Pediatric Intensive Care Unit (PICU) [15-22].

1.1.4 Controversies in PCC Transport

Benefits and Drawbacks of PCC Transport Teams

Studies suggested that patient transport by specialist retrieval teams is associated with better patient outcomes [15, 17, 21]. Nonetheless, transport times may delay access to specialist services, the limited resources available, the transport specific environment such as excessive noise, movements, pressure changes in air transport, during transport may ultimately compromise patient outcomes [23].

Adult studies have suggested adverse-effects resulting from the transfer process, and that patients transferred from secondary-level hospitals to tertiary ICUs are at an increased risk of in hospital mortality compared to patients admitted to the ICUs from the non-ICU setting of the same hospitals, even after adjustment for severity of illness [24-26]. A recent systematic review reported that data was insufficient from which to draw firm conclusions regarding any associations between adult inter-facility transport and patient mortality and morbidity, or the risk factors associated with poor outcomes from the inter-facility transport of critically ill adult patients [27].

Only a few published reports have examined the impact of patient transport on the outcomes of critically ill or injured children[15, 28-30]. A study from the UK examined the effect of regionalization of critical care on the outcomes of critically ill children transferred from referral hospitals, using a nation-wide PICU audit database. It reported that children retrieved from other hospitals had an equivalent PICU mortality to children admitted to the PICU from within a tertiary hospital [15]. However, recent data suggested a significant variation in short-term patient outcomes across PCC transport teams/programs in the UK [31].

Team Composition and Selection

In recent years, specialized PCC transport teams without an accompanying physician have become commonplace in many North American transport programs [32, 33]. On the other hand, PCC transport teams in the European countries such as in the United Kingdom (UK) are mostly staffed by physicians trained in PCC who can undertake invasive interventions [15 34]. The most recent nation-wide data from the UK and Ireland reported that 78% of their transport were led by physicians [31]. Choice of specific team compositions may reflect unique aspects of each healthcare system, especially as it pertains to local thresholds for the referral and transport of critically ill children. The availability/ presence of medical professionals such as respiratory therapists or nurse practitioners in North American practice could also explain some differences. Little evidence exists to support an ideal transport team composition or required competencies, and in particular whether there is a need for a physician-presence on a PCC transport team [18-20, 22, 35].

Timing and Triage in Transport

Many factors can influence the timing of the transport and its relationship to outcomes, including transport distance and time (i.e., nighttime vs. daytime), weather, the patient's medical condition, medical services available at referring centers, and availability of specific transport carriers (fixed-wing propeller, ground ambulance, jet, or helicopter). Few pediatric studies have examined the usefulness of triage scoring systems in predicting the need for transport, let alone the need for ICU level of care [36-38] No universally accepted triage scoring model exists as of now.

1.2 PCC Transport in Alberta

1.2.1 PCC Transport System in Alberta

Communities in Alberta and the Western Artic are scattered over a large geographic area. The majority of pediatric acute care is not provided by specially trained healthcare providers or performed in dedicated pediatric facilities in Alberta and the Western Arctic. Critically ill or injured children are usually transferred to one of Alberta's two children's hospitals to receive specialized care, at either the Stollery Children's Hospital (SCH) in Edmonton, or Alberta Children's Hospital (ACH) in Calgary.

Referral physicians call and consult PICU physicians in either Edmonton or Calgary concerning the stabilization of critically ill or injured pediatric patients and to ask for their assistance in arranging the transfer of these children to one of the two children's hospitals. For the regionalized PCC system to function, critically ill or injured children have to be safely and efficiently moved to the tertiary care centers (SCH or ACH) from referring hospitals. The patient transport is coordinated by Referral, Access, Advice, Placement, Information, and Destination (RAAPID) in Alberta Health Services (AHS). AHS is the provincial agency responsible for all health care in Alberta. RAAPID connects healthcare practitioners from remote centers (i.e., clinics, regional hospitals) with specialists in the tertiary centers in Edmonton (SCH) and Calgary (ACH) by tele-consult [39, 40]. An overview of the system is illustrated in the Figure 1.

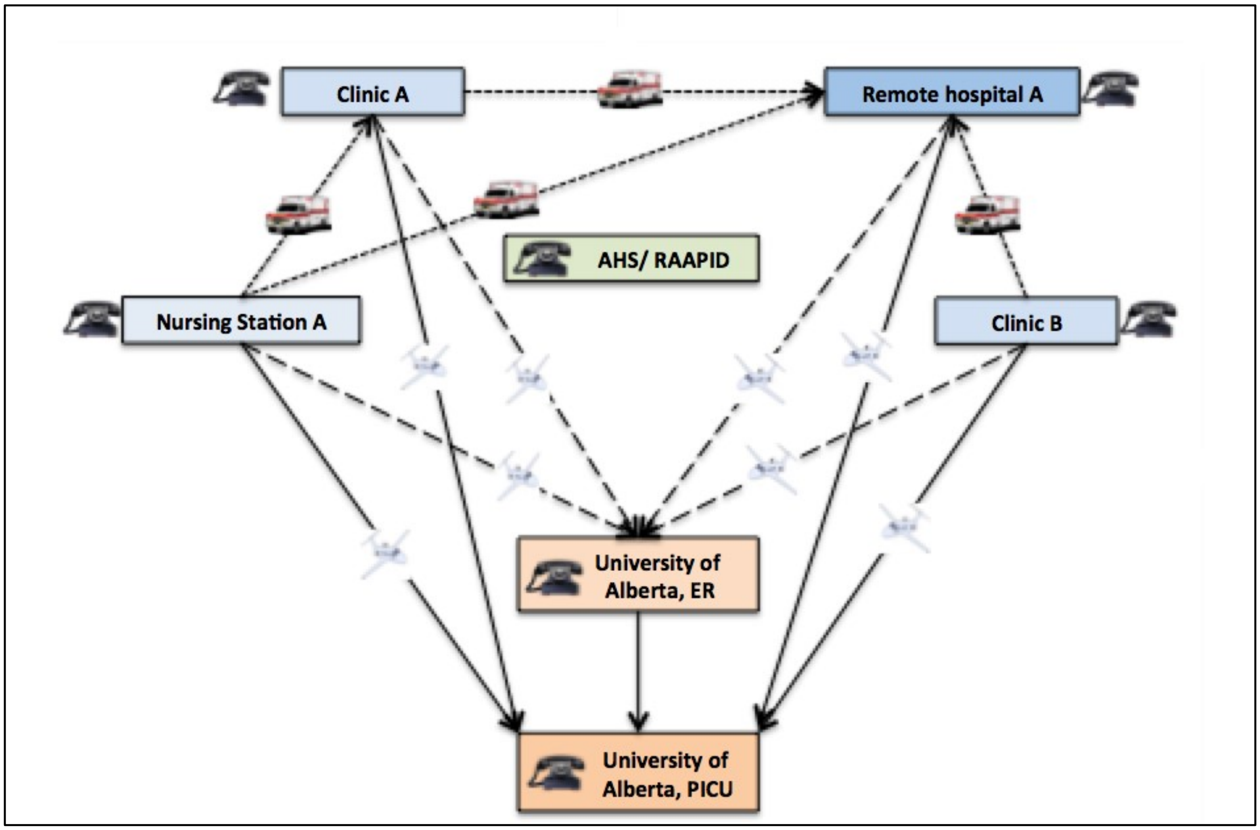


Figure 1: Overview of Inter-Hospital Transport in Northern Alberta and Territories.

1.2.2 PCC in Northern Alberta

PICU in SCH was established in the early 1990's stemming from the evolution of pediatric critical care medicine that started in the 1980s. Subsequently, SCH built a PICU-based, dedicated PCC transport team in 1996 based on the principles outlined in section 1.1.3.

SCH, a Western Canadian reference hospital, has a large catchment area. including central and northern Alberta, surrounding regions in Saskatchewan and British Columbia, as well as the North

West Territories and Nunavut. The catchment area has population of at least 850,000 children under 17 years of age [41]. SCH PICU has been a mixed medical and surgical unit, with 800 to 1,000 admissions per year during the study period, including 400-500 post-cardiac surgery patients annually (The unit was split into pediatric cardiac ICU and general medical and surgical PICU in 2017).

1.2.3 Staffing of the PCC Transport Team

The SCH PCC transport team is staffed by physicians (trained in pediatric critical care, anesthesiology, or emergency medicine), respiratory therapists and nurses, all with extensive experience and training in the assessment and management of critically ill or injured children. In recent years, SCH PICU has increasingly sent non-physician transport teams as opposed to teams including a physician. This approach was intended to maximize the efficiency of resource utilization and counterbalance the expanding intra-hospital workloads for PICU physicians (the number of admissions to the PICU in Edmonton has been steadily increasing over the last ten years, Figure 2).

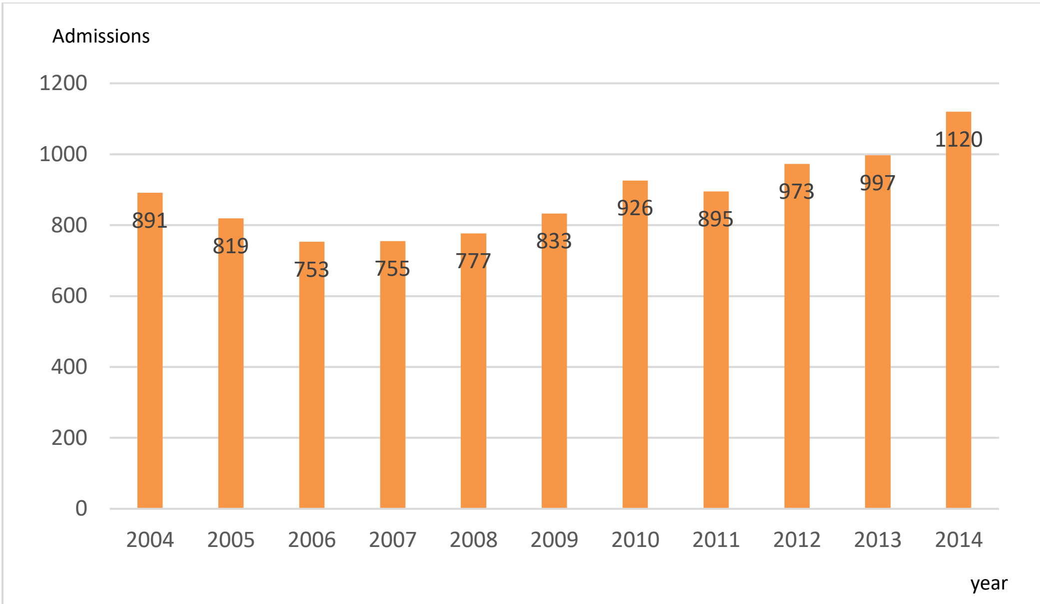


Figure 2: The Trend of Number of PICU Admissions in Edmonton in 2004-2014.

1.2.4 Decision Making Process of Transport Triage

PICU physicians assign the most appropriate transport team to transport the individual pediatric patient based upon information provided by referral physicians. They may send an ALS (paramedic) team; a PCC transport team (without a physician); or a PCC transport team with a physician. PICU physicians must also decide on the optimal disposition (destination) for the patient: to remain at the same hospital; to transfer to a secondary (regional) center; to transfer to a children's hospital general pediatric ward or the children's hospital PICU. This triage decision is based upon patient information provided over the telephone by the referral physician as well as by the PICU transport team once it arrives at the referral center. The triage decisions are currently made by PICU physicians without using a systematic process. Triage scoring systems/criteria have been used in other centers or clinical settings to help provide a consistent approach to matching transport resources to patient care needs ("sending the right team for each patient," as well as the "right destination for each patient"), but with limited success [36-38, 42, 43].

1.3 Controversies Surrounding Current PCC Transport in Northern Alberta

1.3.1 Transport Team Selection

There are two other transport programs that can be used for pediatric inter-facility transport in Alberta. STARS (Shock Trauma Air Rescue Service) is a transport team which is based out of an independent rotary transport organization [44]. The team consists of a dedicated transport nurse, a flight paramedic, and the option for an emergency medicine physician (either senior resident or fully trained emergency medicine physician). Advanced Life Support (ALS) fixed wing flight teams are made up of paramedics who are generally more comfortable caring for critically ill or injured adults. These two programs generally have shorter dispatch times (they are each based out of regional airports), when compared to the PCC transport team.

1.3.2 Increasing Demand and Cost Efficiency

Alberta has a population of about 4.1 million people (2014 Census), including ~850,000 children under 17 years of age [41]. The under 17 years of age population has been growing by roughly 10% every 5 years (Figure 3). These demographic changes have led to an increasing need for medical transport of critically ill or injured pediatric patients into Edmonton and Calgary. Figure 2 shows the trend of the number of the PICU transports in Edmonton from 1998 to 2015.

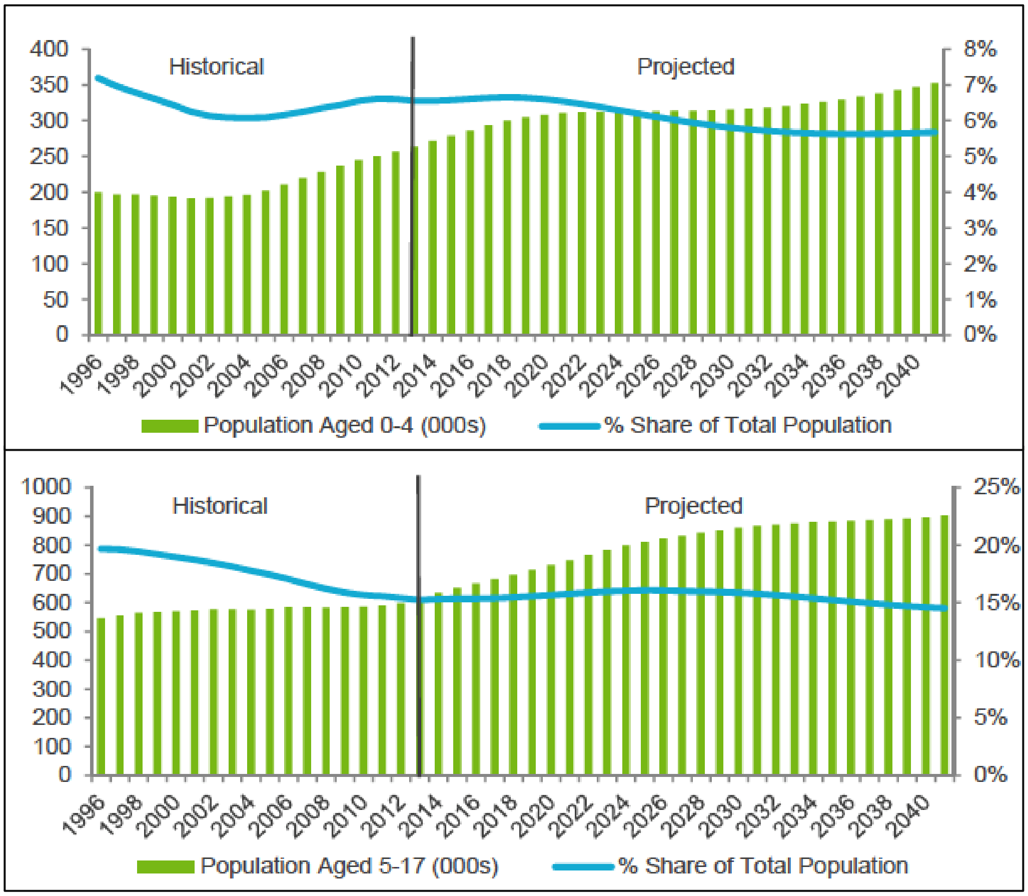


Figure 3: Pediatric Population Projection in Alberta; 2013-2040. Statistics Canada and Alberta Treasury Board and Finance 2014.

Alberta's two PCC Transport teams transport 500-600 severely ill or injured children to Alberta's PICUs each year, at a cost of approximately CD$1million annually. The average cost of dispatching a medical evacuation team (including fuel, pilot, and charter time) is approximately CD$7,000 (without the expenses of accompanying paramedics). Although the total costs for utilizing the PICU transport team are difficult to accurately predict due to the complexity of the PICU system (i.e., the team is unit-based, so some of the cost is attributable to team roles within the PICU or the hospital), it is estimated that it costs more than CD$2,500 per transport to dispatch a PICU team, in addition to the fixed costs for medical evacuation flights. Therefore, when it comes with other cost such as equipment and treatments provided during transports, at least CD$10,000 has been commonly accepted as a cost per trip in the current provincial transport system.

The expenses of the carrier are no different whether the paramedic or the PICU teams transport the patient. However, as the paramedic teams exclusively contract their services in medical attendance, a frequency of their call-out should not influence costs to AHS. Conversely, given the expanding intra-hospital workloads, if a reduction in the use of PICU teams can be achieved, playing another role increasingly as an intra-hospital resource (i.e., as a member of rapid response team or intravenous therapy team), it might reduce or at least contain transport-related costs by PCC Transport Teams (Personal correspondence with Dr. Mark MacKenzie, Medical Director of Provincial Air Ambulance, AHS EMS/STARS).

1.3.3 Non-Standardized Decision Making in Patient Triage

Decisions surrounding transport (i.e., whether to transport and admit children to a PICU, what clinical expertise is required in the transport team, and what level of inpatient care is appropriate for a given pediatric patient) have been made locally in an ad-hoc and subjective manner. Many factors can influence the choice of the transport team and transport modality, including transport distance and time, weather, patient's medical condition, medical services available at referring centers, and availability of specific transport carriers (fixed-wing propeller, ground ambulance, jet, or helicopter) [18, 33, 42]. Long transport distances and often limited rural (referral) health care resources in Alberta have made it challenging to use triage decision models developed in other parts of the world. The current Alberta system relies on individual dependent decision-making (by individual intensivists) as opposed to a consistent, systematic approach. This decision-making system should be an evidence-based process so as to provide optimal transport as well as avoid costs unnecessarily incurred by some of these decisions. As noted above, the avoidance of unnecessary care and subsequent allocation of health care resources would lead to improved patient care in the transport setting, as well as cost savings to the healthcare system.

CHAPTER 2

Study Objectives, Significance, and Methods

2.1 Objectives

This thesis has **five** specific objectives, each of which has specific research questions.

The population of interests for each objective and research question is described in each chapter.

Objective 1

To better understand the unique aspects of pediatric critical care transport programs across Canada by characterizing the current workforce of each transport program.

Research questions to be answered

1.1 What are the differences, if any, across Canadian PCC transport teams in their activities and programs?

Objective 2

To assess SCH PCC transport characteristics and activities and their outcomes by calendar time, transport distance, and the modality of transport.

Research questions to be answered

2.1 Who (i.e., age, weight, sex, severity of illness) have been transported to SCH by the SCH PCC transport team and what are their outcomes (i.e., PICU admission rate, PICU and hospital length of stay, mortality before/during transport or at PICU or hospital)?

2.2 How (i.e., fixed-wing propeller, ground ambulance, jet, or helicopter), from where (i.e., clinics, regional secondary hospitals), and when (year, month, day/night) have critically ill or injured children been transported by the PICU transport team?

Objective 3

To explore differences in transport characteristics, treatments at referral hospitals, risk of PICU admission, and PICU treatments and outcomes, between referral hospitals with and without adult ICUs.

Research questions to be answered

3. Are medical services/specialties provided at referral hospitals associated with outcomes of patients transported by the PICU transport team (i.e., PICU admission rate, PICU and hospital length of stay, mortality before/during transport or at PICU or hospital)?

Objective 4

To identify factors that are currently being considered by the SCH PICU intensivists in the decision-making of the PICU transport team composition (i.e., physician accompanying vs. physician non-accompanying) and identify differences between physician accompanying vs. physician non-accompanying transports in the following outcomes: time to transport; rate of unsuccessful procedures; treatments given during transports, and patients' clinical outcomes.

Research questions to be answered

4.1 What are the factors currently considered by the SCH PICU intensivists in making a decision regarding the PICU transport team composition (i.e., with vs. without a physician), in transports of critically ill or injured children?

4.2 Are there any differences in response time (i.e., time duration from consult call to team dispatch from SCH), stabilization time at referral hospital, total transport time, treatments/procedures provided during transport, presence of any successful/unsuccessful procedures at the referral hospital or during transports, PICU admission rate, and other patients outcomes (i.e., severity of condition at arrival to an accepting hospital, mortality at PICU or hospital, PICU and hospital length of stay after admission when admitted to the PICU), when comparing PICU transports with and without a physician?

Objective 5

To explore the impact of patient transport on the outcomes of critically ill or injured children at SCH.

Research questions to be answered

5. Do PICU patients who were transported by the SCH PICU transport team have different outcomes (i.e., mortality in 24 hours from PICU admission and PICU and hospital length of stay) compared to PICU patients with similar conditions who were admitted directly from an Emergency Department in the same tertiary hospital (SCH) without having been transported from a referral hospital?

2.2 General Methods

2.2.1 Data Used and Data Cleaning

I had access to two databases. They were (I) hospital-based transport database of SCH PICU (Jan 1998- Dec 2015) and (II) hospital-based administrative database of SCH PICU (August 2002-Dec 2015). I also accessed records in paper charts of individual patients and (III) created a list of medical care facilities in Alberta Health Services. Each dataset is described below in detail. This research project received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Developing an evidence-informed pediatric retrieval system for Alberta." (Pro00053596).

(I) A hospital-based transport database of the SCH PICU

PICU in SCH developed an electronic/ computer-based database for patients transported by the SCH's PICU transport team in 1998. Data is entered by the transport team members through electronic charting software (Microsoft Office Access® WA USA) and downloaded into a relational database. Standardized training for this electronic charting software provided when a new member joins the team. This database contained individual transport records. Variables include: patients' identifiers (including personal health care numbers), transport date and time (i.e., time of referral call, departure of a transport team from the PICU, arrival to a referring centre, departure from a referring centre, arrival to a receiving centre, and admission to a unit (i.e., PICU, ED, or general ward)), transport modality (i.e., fixed-wing propeller, ground ambulance, jet, or helicopter), name of referring and receiving centres, receiving units (i.e., PICU, ED, or general ward), patients demographics (age, gender, weight, residential address with postal codes), types of health care providers involved in a given transport (i.e., intensivist, transport nurse, and respiratory therapist), details of treatments provided and whether there was any unsuccessful procedure (Y/N) during the transport or at referring hospitals, and vital signs on physical examinations during the transport. The vital signs on physical examinations such as heart rate, blood pressure, respiratory rate, and oxygen saturation were recorded every 15 minutes from the initial assessment of the patients at the referral center to the end of the transport (i.e., arriving at a receiving center). Extensive data cleaning was performed by assessing the individual paper-based charts and the electronic database as needed. The proportions of missing values for any of these variables were less than 1%, except those for the vital signs on physical examinations, for which approximately 5% of the recorded patients had missing values.

(II) A hospital-based administrative database of the SCH PICU

This database houses prospectively collected data from the SCH's PICU since August 2002. PICU-dedicated research assistants record these data. The database includes individual patients' identifiers, demographics (i.e., age, gender, weight, unplanned admission (Y/N), primary/secondary diagnoses, severity of illness (i.e., PRISMIII)), unit prior to the PICU admission (i.e., general ward, ED, or operating room), and outcomes for all PICU admissions (i.e., PICU and hospital length of stay, invasive ventilation days, PICU and hospital outcome (i.e., alive or death), treatments given and procedures performed during the PICU stay). This dataset was successfully merged with the transport database above by using the individual identifiers and the transport dates and times.

(III) List of medical care facilities in Alberta Health Services

The list of healthcare facilities in Alberta as well as referring centers to SCH outside of Alberta was created by referring to the AHS website and personal correspondence with Dr. Sam Wong (Chair of the First Nations, Inuit and Metis Health Committee of the Canadian Pediatric Society) (Appendix1) [45].

2.2.2 Research Team

The directors of PICU transport team and Pediatric Emergency Medicine at SCH and ACH and RAAPID were stakeholders for this thesis project and were represented in the research team. The primary knowledge users were senior-level administrators in each department (Pediatric Critical Care Medicine and Pediatric Emergency Medicine at SCH and ACH) and clinicians and health care providers in their referral hospitals. The details of the members and roles can be found in the discussion section and acknowledgment in this thesis.

2.2.3 Study Design and Approach

The studies utilized quantitative methodologies to address each research question; these were described below in detail.

Approach to the Research Question 1.1 (Details in **Chapter 3**)

For the ***Research Question 1.1***, a cross-sectional survey was conducted to the medical directors of Canada's PCC transport teams, and to two transport services that are not affiliated with any hospital. The survey consisted of 41 multiple-choice or multiple-answer items (Appendix 2). Potential survey respondents were identified through known Canadian PCC transport content experts. This list included all of the medical directors of children's hospital-based pediatric transport programs, as well as two non-hospital affiliated transport services, STARS in Alberta, Saskatchewan, Manitoba, and Ornge in Ontario [46, 47]. If a children's hospital did not have a dedicated team for pediatric transport, the regional transport team providing this service was identified, and the annual activity of pediatric transports obtained. Further details and the results are reported in a peer reviewed paper [33] and the ***Chapter 3*** of this thesis.

Approach to the Research Questions 2.1, 2.2, and 3 (Details in **Chapter 4**)

Descriptive and cohort designs were adopted to answer the ***Research Questions 2.1, 2.2, and 3***. We accessed the two datasets (i.e., (I) and (II)) and described characteristics of the transports and transported patients' demographics, treatments, and outcomes. In addition, we compared High-Level-Care (HLC) hospitals (hospitals offering pediatric services where adult ICUs existed) and Non-HLC (NHLC) hospitals (all other hospitals) with respect to patient demographics, treatments and outcomes and transport characteristics. Logistic regression models with the referral hospitals as random effects were employed to estimate hospital effects on the likelihood of PICU admission, death before/during transport or in the PICU, death before/during transport or in the hospital, endotracheal intubations at the referral hospital and endotracheal intubations after PICU admissions, adjusted for propensity scores. Linear regression with random effects was also utilized for the outcome of PICU and hospital length of stay (LOS) and invasive ventilation days, for which logarithmic transformations were employed to remove skewness for the analyses. The adjusted odds for each hospital for PICU admission and endotracheal intubation at referral hospitals were compared to the referral hospitals' average and were plotted to examine hospital-specific effects. We performed analyses with adjustment by applying propensity scores. To examine year effects on the transport time, linear regression analyses were performed adjusting for triage intensivists, categorized working diagnoses during the transports, transport modalities, and initial vital signs measured when the PCC transport team arrived at the referral hospital. Further details and the results are reported in a peer reviewed paper [48] and the ***Chapter 4*** of this thesis.

Approach to the Research Questions 4.1 and 4.2 (Details in **Chapter 5**)

We adopted a retrospective cohort design to answer the ***Research Question 4.1 and 4.2***. First, we compared characteristics of the transports and the transported patients' demographics, including times of the transport, day, distances, modalities of the transports, procedures/treatments provided at the referral hospitals between the two time periods: (i) Physician Transport (PT)-era (2000-2007, when physicians regularly accompanied the transport team); and (ii) Physician-Less Transport (PLT)-era (2010-2015, when PLT team was increasingly used). Logistic regression was employed to compare the two eras, so as to estimate odds ratios, with 95% confidence intervals (CIs), of having the following transport-related outcomes in the PT-era relative to the PLT-era: admission to the PICU within 24 hours of referral call; having unsuccessful procedures performed during the transports; the need for endotracheal intubation at the referral hospital; and vital sign changes during transports. The median regression was employed to evaluate the differences in the continuous outcome variables (i.e., transport-related times) by the two eras. We performed the regression analyses above, adjusting for propensity scores. For the transports (patients) admitted to the PICU within 24 hours of referral call, PICU and hospital outcomes were compared with respect to the two eras. Logistic regression was employed to estimate odds of death during transport or after PICU admission, endotracheal intubation at the referral hospital or after PICU admission, pediatric risk of mortality (PRISMIII), and treatments/procedures provided in the PICU. The median regression was employed to evaluate differences in the PICU length of stay (LOS), hospital LOS, and the number of invasive ventilation days, between the two eras [49, 50].

For the second part of the study, transport and patient characteristics and treatments/ procedures performed at the referral hospitals before the transport team arrival were examined to identify factors associated with selection of transport team compositions. Multivariable logistic regressions with the triage physicians as random effects were also employed to estimate odds of sending a PT team in each triage physician. All those variables were kept in the final model. The adjusted odds of each triage physician sending a PT team was calculated: these estimated odds were plotted to examine the triage physician-specific effects adjusting for the case-mix variables. Further details and the results are reported in a peer reviewed paper [51] and the ***Chapter 5*** of this thesis.

Approach to the Research Question 5 (Details in **Chapter 6**)

For the ***Research Question 5***, we compared two cohorts using a matched procedure with regards to 72-hour mortality from initial contact with the "PCC team" as a primary outcome: children under 17 years of age who were admitted to the SCH PICU either by being transported by the PCC transport team, or those children directly admitted to PICU from the SCH pediatric emergency department (PED). Descriptive statistics were performed to explore differences between the two groups, then conditional logistic regression and multivariate linear regression using geometric means of outcome values were applied to compare the binary and continuous outcomes between the matched patients. Further details and the results are reported in ***Chapter 6*** of this thesis.

2.2.4 Distance and Time Calculation

We adopted the following methods to calculate transport ***distance*** and ***time*** in this thesis.

For the calculation of ***distance***, we calculated straight-line distances for air transport from either the geolocated 6-character postal codes of patients' residences or referral hospitals to the air ambulance base, accounting for the locational change of the air ambulance base in March 2013, from a city airport which was closer to SCH than the international airport currently used. Road distances were calculated when ground ambulances were used.

We defined transport-related ***times*** as follows; ***Total transport time***: Time from referral call to arrival at SCH; ***Dispatch time***: Time from referral call to dispatch of the transport team from SCH; ***Stabilization time***: Time from arrival at the referral hospital to departure from referral hospital (Figure 4). Thirty minutes were subtracted from total transport time for transports after March 2013, taking into account the relocation of the air ambulance base (***Rationale of the calcuration*** is described following the Figure 4). Heat maps documented distribution of the cohort over time using ArcGIS® version 10.5 (Esri, CA, USA). Kernel density with a radius of 100 km was applied to show where there were concentrations of patient residences. Distance calculations relied on the Network Analyst extension.

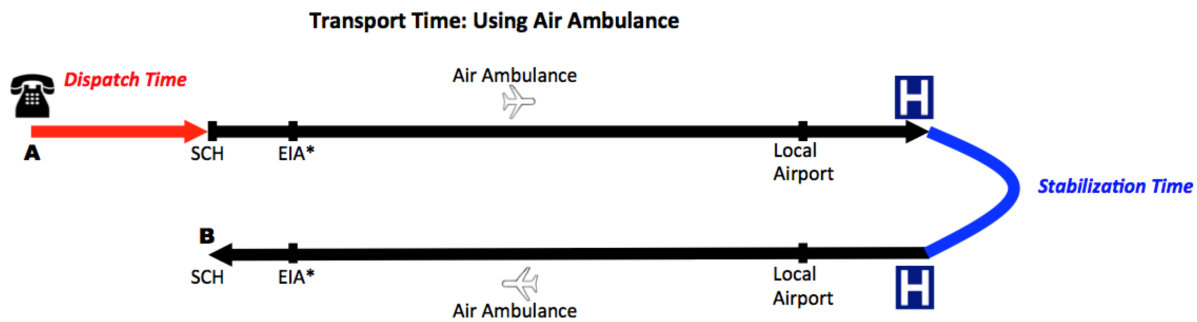


Figure 4: Schema of Transport Times in Transport using Air Ambulance.

Referral call to SCH, Referral Hospital

A-B Total Transport Time, *EIA: location of dispatch base of the air ambulance was changed to Edmonton International Airport (EIA) in March 2013, from a city municipal airport which was closer to SCH than EIA.

Rationale of the calculation

Thirty minutes were adopted for the following reason. The one-way road distance from SCH to the location of dispatch base of the air ambulance in Edmonton International Airport (EIA) is 30km; whereas, that from SCH to the base in the Municipal Airport is 8km. We could estimate the average speed of the ground ambulance is 90km/hour, considering the most part of the increase of distance is highway. This gives us 29.3 minutes increase for a round-trip (i.e., {(30-8)/90}*60*2).

CHAPTER 3

*Cross-sectional Survey of Canadian PCC Transport**

The content of this Chapter has been published as "A. Kawaguchi, A. Gunz, and A. de Caen, "Cross-sectional Survey of Canadian Pediatric Critical Care Transport" in *Pediatric Emergency Medicine,* August 20, 2016, [Epub ahead of print]"[33]

3.1 ABSTRACT

3.1.1 Objectives

To better understand the unique aspects of pediatric critical care transport programs across Canada by characterizing the current workforce of each transport program.

3.1.2 Methods

A cross-sectional questionnaire was sent to the 13 medical directors of Canada's pediatric critical care transport teams, and to two non-hospital affiliated transport services. If a children's hospital

did not have a dedicated team for pediatric transport, the regional transport team providing this service was identified.

3.1.3 Results

All the 13 directors responded to the survey. Eight out of the 13 PICUs surveyed have unit-based pediatric transport teams. The median annual transport volume for the 8 hospital-based teams was 371 (range; 45-2,300) with a total of 5,686 patients being transported annually. Among patients transported by the 8 teams, 45% (2,579 patients) were pediatric patients (older than 28 days and less than 18 years old) and 40% (1,022 patients) of the pediatric patients were admitted to the PICUs. Eighty-eight percent of the responding teams also transported neonates (less than 28 days old), and 38% transported premature infants. A team composition of RN-RT-Physician was used by 6/8 teams (75%), however, it accounted for only a small proportion of the transports for most of the teams (median 2%; range 2%-100%). The average transport time from dispatch (from team home site) to arrival at receiving facility was reported by 6 teams, and was a median of 195 minutes (range 90-360minutes). The median distance from home site to the farthest referral site in the catchment area was 700km (range 15-2,500km).

3.1.4 Conclusions

This is the first Canadian nationwide study of pediatric critical care transport programs. It revealed a complexity and variability in transport team demographics, transport volume, team composition, and decision-making process.

3.2 INTRODUCTION

To assess and manage critical illness and injury requires special training and experience. Intensive care services for severely ill children have undergone substantial centralization throughout Canada in recent decades. Recent studies of specialized medical services have shown that the centralization of patients to high-volume centers is associated with improved cost-effectiveness and patient outcome [1-5].

The goal of inter-hospital critical care transport is not only to transport patients from community hospitals to tertiary care centers, but also to provide patient care during transport at a standard as close as possible to that provided in a PICU. Specialist pediatric retrieval teams are recognized as providing safer patient transport than non-specialized teams, including improved patient outcomes [15, 17, 21].

The catchment areas for Canada's children's hospitals cover large geographic areas, necessitating the transport of critically ill children over distances of up to hundreds of kilometers [52]. Over the last 30 years, a small number of Canadian PICUs have developed unit-based pediatric critical care transport teams. Due to the differences in geography, referral patterns, and locally available transport system resources, programs for the transport of critically ill children have evolved very differently across the country.

The purposes of this survey were two-fold: 1) to better understand the unique needs of pediatric critical care transport programs across Canada; and 2) to characterize the current workforce of each transport program, including team demographics, composition, decision making processes, and quality assurance activities. These findings will inform the various Canadian transport-programs, with the purpose of enhancing system efficiency and patient safety. In addition, it will facilitate future prospective research and benchmarking, including the development of a common national transport database.

3.3 METHODS

A cross-sectional survey was provided to the medical directors of Canada's pediatric critical care transport teams, and to two non-hospital-affiliated transport services (Figure 5). The draft of the questionnaire was developed in the following manner. A previously performed Canadian neonatal transport demographic survey was reviewed (unpublished), and common elements were adapted to make it relevant to pediatrics [53]. The survey was then further expanded to answer pediatric critical care-relevant questions (e.g. demographics, team composition, quality measures). We defined pediatric patients as children older than 28 days and less than 18 years old in this survey. The final draft was reviewed by three PICU transport experts for content validity. The survey consisted of 41 multiple-choice or multiple-answer items (Appendix2). Participants were not required to answer every question. This study was approved by the Health Research Ethics Board of University of Alberta, Canada.

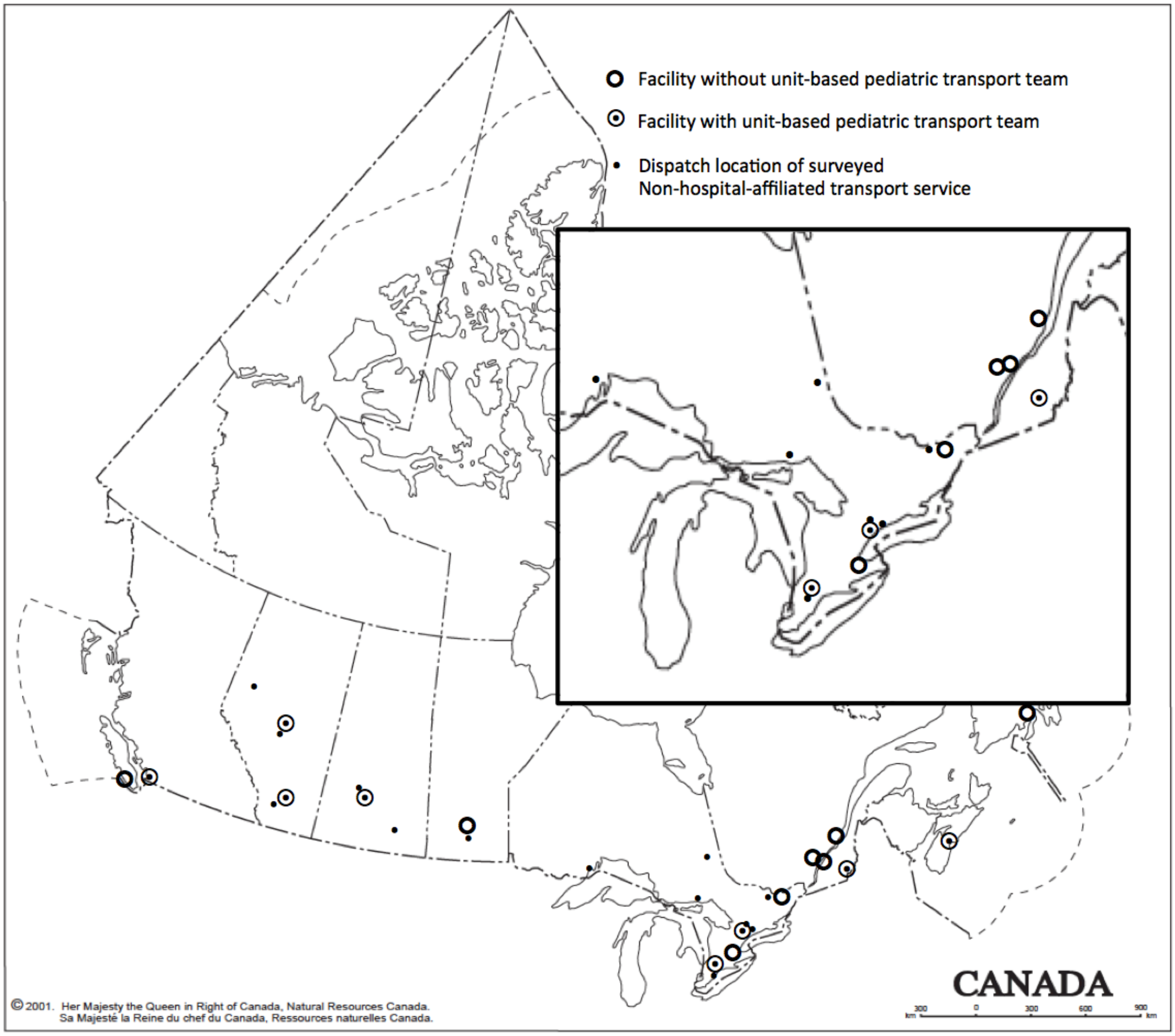


Figure 5: Location of 16 Canadian PICUs and Dispatch locations of Surveyed Non-hospital affiliated transport services.

Potential survey respondents were identified through known Canadian pediatric critical care transport content experts. This list included all of the medical directors of Children's hospital-based pediatric transport programs, as well as two non-hospital affiliated transport services (Shock Trauma Air Rescue Service (STARS) in Alberta, Saskatoon, Manitoba; and Ornge in Ontario) [46, 47]. Email addresses were obtained by personal communications and through Canadian pediatric transport networks. A maximum of three emails were sent in August 2015 to the contact person (transport team managers and medical directors) for each program, inviting them to participate in the survey. The survey results were collected via email on 31st August 2015. If a children's hospital did not have a dedicated team for pediatric transport, the regional transport team providing this service was identified, and annual activity of pediatric transport obtained.

Results were reported and analyzed with median values. Percentages of answers calculated for each survey item were reported. When exact numbers were not provided, estimated values were calculated by using provided values as a proportion for certain questions and results. For instance, if the exact number of pediatric transports and the percentage of admissions to the PICU were provided, the approximate number for PICU admission was calculated by using those numbers.

3.4 RESULTS

3.4.1 Demographics of Participating PICUs

Thirteen medical directors of pediatric critical care transport teams were identified and all participated in the survey. In these 13 PICUs, a total of 184 PICU beds (median 12 per PICU; range 6-36 per PICU) were operational as of August 2015. Eleven of these thirteen PICUs (85%) answered that they utilize a non-hospital affiliated transport team and 4 PICUs responded that their pediatric critical care transports were only performed by the non-hospital affiliated transport teams. Eight out of the 13 PICUs (62%) have unit-based pediatric transport teams (Vancouver, Edmonton, Calgary, Saskatoon, London, Toronto, Halifax, Sherbrooke) (Figure 5). The median number of PICU beds in those 8 PICUs is 13 (range; 6-36 per PICU) and each unit is staffed by a median of 6 full time pediatric intensivists (range 3-14 per PICU). Four units have a pediatric cardiac surgical program and two (Edmonton and Toronto) have separate pediatric cardiac intensive care units.

3.4.2 Transport Team Demographics and Activities

The median annual transport volume for the hospital-based teams was 371 transports per year (range 45-2,300). A total of 5,686 patients were transported by the 8 transport teams (Table 1). All three teams with more than 500 total transports per year are combined NICU/PICU teams. Among patients transported by the 8 teams, 45% (2,579 patients) were pediatric patients, and 40% (1,022 patients) of the pediatric patients were admitted to PICUs. The proportion of patients that were admitted to the PICUs by these teams ranged from 18% to 100% (median 63%) (Table 1). We did not analyze the proportion of patients assessed in emergency departments and their subsequent disposition in this survey.

Ornge (air and ground ambulance service in the province of Ontario) performed 18,482 transports in 2014/15, of which 3,133 cases (17%) were pediatric transports (<18 years). 2,416 (77%) were performed using their air resources (helicopter and fixed wing), and 8% of these patients were mechanically ventilated. The proportion of their patients that were admitted to a PICU was not provided.

STARS (total numbers for Alberta, Saskatchewan, and Manitoba) transported 3,084 patients in 2014, of which 204 (6.6%) were pediatric (including NICU) cases. 137 out of 204 cases were inter-facility transports, and 80 (58%) of these transports were performed without the use of the hospital-based PICU transport team. Only 18 of 204 cases (9%) were endotracheally intubated before/during the transport.

Table 2 shows the patient populations transported by the 8 hospital-based teams. Thirty-eight percent of the responding teams transport premature infants and 88% transport neonates (except premature infants) as their mandate. Five (63%) teams claim to have the ability to transport patients receiving Extra-Corporeal Membrane Oxygenation (ECMO).

Thirty-five percent of the patients transported by responding teams (range 15%-50%) were invasively ventilated. Seven teams have the ability to provide non-invasive mechanical ventilation on transport. High Flow Nasal Cannula (HFNC)) was used for 7.5% of all patients (range 0%-30%), and is a therapy provided on transport by five (63%) of the surveyed teams. A small proportion of patients were transported with arterial waveform monitoring, central venous catheters, or ECLS (Extracorporeal Life Support), accounting for 0.5% (range 0%-10%), 1% (range 0%-10%), and 1% (range 0%-5%) of transports, respectively (Table 3).

The average transport time from dispatch (from team home site) to arrival at the receiving facility (of the 6 responding teams) was a median of 195 minutes (range; 90-360 minutes). The median distance from home site to the farthest referral site in the catchment area was 700 kilometers (km; range 15-2,500km).

3.4.3 Team Composition

Physicians, registered nurses (RNs), respiratory therapists (RTs), and paramedics were identified as the transport providers for these teams. These providers were combined to create 4 different team compositions (Table 4). Team composition with RN-RT-Physician was the most common team composition across Canada (used by 6/8 teams (75%)), however, it accounts for only a small proportion of the total transports performed by most of the teams (median 2%; range 2%-100%), meaning that physicians were only accompanying RNs and RTs on a minority of transports. RN-RT is the next most common team composition (63%), and makes up the largest proportion of the transports performed by those teams (median 85%; range 70%-98%). Six teams (75%) have dedicated RN and RT resources identified for transport, and report employing a median of 6.6 FTE (Full Time Equivalent) positions (range 0-11.8) for RNs and 4.7 (range 0-11.8) FTEs for RTs.

3.4.4 Transport Triage Process

Pediatric critical care physicians (including PICU subspecialty fellows) are the individuals most commonly identified as being responsible for deciding the mode of transport as well as team composition (7/8 teams - 87%). No program answered that pediatric emergency physicians were involved in the transport decision process; however, Emergency Medical Services are engaged as part of two programs. Pediatric intensivists are most commonly identified as fielding the initial consultation calls from referral centers (6/8 teams - 75%). PICU fellows, transport RNs or RTs are also included in the consultation call for some programs (PICU fellows 37%; RNs 50%; RTs 25%, respectively) (Table 5).

3.4.5 Transport Mode

Two unit-based teams (25%) have ground ambulances or/and helicopters dedicated to the transport team. Five teams (63%) use planes that are not dedicated to their teams (Table 6). Only one team has a jet dedicated to the team. Ground transport is the most common transport mode (median 43%; range 15%-100%), followed by fixed wing /propeller (median 38%; range 0-65%). Six (75%) of the teams have on-site takeoff/landing platforms for helicopters. However, only one team has an on-site hanger/runway for planes. Three (38%) have their fixed wing hanger/runway within 15 minutes of their base hospital by ground transport, and 4 teams (50%) are within 15 - 30 minute by ground transport of their base hospital. One of the teams has the hanger/runway more than a 30-minute ground transport time from their base hospital (Table 7). All teams set a target time for team mobilization for transport (dispatch from their home site), ranging between 10 and 30 minutes (median 25 minutes). Five teams identify a target maximum stabilization time (arrival at referral site to departure from referral site), ranging between 50 and 60 minutes.

3.4.6 Database and Quality Assurance Activity

All the teams have computer-based transport-specific databases, although the teams use varying database platforms, including File-maker® (FileMaker Inc., CA, USA), Access® (Microsoft, CA, USA), Excel® (Microsoft, CA, USA). Only one team has dedicated personnel responsible for inputting data, with data entry for the remaining teams being performed by transport team members, including RNs, RTs, or Physicians. All the databases record patient and transport demographics, while only half record clinical variables (Table 8). All teams have established continuing education and quality assurance programs for transport. Seven (87%) of the teams identify critical incidents that occur on transport by flagged charts, while one reviews all of their transport charts.

Table 1: Annual Transport Volume by Team

Transport Program	Number of total transports*	Pediatric transports*	% of pediatric transport /total transports	Number of admissions to PICU*	% of PICU admissions /total transports	% of PICU admissions /total pediatric transports
A	2300	1100	48	198	9	18
B	1300	200	15	150	12	75
C	714	117	16	60	8	51
D	462	462	100	208	45	45
E	350	150	43	45	13	30
F	265	265	100	172	65	65
G	250	240	96	144	58	60
H	45	45	100	45	100	100

* per year

Table 2: Number of Teams Serving Various Patient Populations

Categories	Within team mandate ; N (%)	Occasionally transported** ; N (%)	Outside of team mandate ; N (%)
Premature infants	3 (38)	2 (25)	3 (38)
Neonates (≤28 days old)	7 (88)	1 (13)	0 (0)
Attendance at high risk delivery	3 (38)	2 (25)	3 (38)
Pediatric	8 (100)	0 (0)	0 (0)
Adults (>18 years old)	2 (25)	2 (25)	4 (50)

Patient Populations Served by the 8 Unit-Based Transport Teams. N indicates the number of respondents. % in parenthesis indicates the proportion of the teams out of the 8 teams.**Not mandate but have serviced on case by case basis.

Table 3: Proportions of Transport for which a Transport Team Performed Procedures

Procedures	Proportions; % (range)
Invasive Mechanical Ventilation	35 (15-50)
Non-invasive Mechanical Ventilation	7.5 (0-30)
High Flow Nasal Cannula	3.5 (0-30)
Arterial Line placement	0.5 (0-10)
Central Line Placement	1 (0-10)
ECLS	1 (0-5)

Table 4: Team Composition

Team Composition	Number of Team: N (%)	% of transports operated by the team composition
RN; one only	0 (0)	n/a
RT; one only	0 (0)	n/a
Paramedic only	1 (13)	85%
RN - RN	2 (25)	20% and 99%
RN - RT	5 (63)	Median 85%, range; 70-98%
RN - paramedic	0 (0)	n/a
RN - physician	0 (0)	n/a
RN - RT - Physician	6 (75)	Median 2%, range; 2-100%
Other	3 (38)	n/a

Table 5: Personnel on Initial Referral Consult Call

Personnel on initial transport call	N (%)
Non-Clinical administrative personnel: n (%)	1 (13)
Pediatric Intensivist: n (%)	6 (75)
Pediatric Emergency Physician: n (%)	0 (0)
PICU fellow: n (%)	3 (38)
RN in transport team: n (%)	4 (50)
Non-specified RN: n (%)	0 (0)
Others: n (%)	5 (63)

Table 6: Mode of Transport Utilized by Programs*

Mode of Transport	Modes Utilized by Program; N (%)
Ground - local EMS	8 (100)
Ground - private transport service	2 (25)
Ground - dedicated to TT	2 (25)
Helicopter (not dedicated to TT)	4 (50)
Helicopter (dedicated to TT)	2 (25)
Fixed wing propeller (not dedicated to TT)	4 (50)
Fixed wing propeller (dedicated to TT)	2 (25)
Fixed wing jet (not dedicated to TT)	5 (63)
Fixed wing jet (dedicated to TT)	1 (13)
Mode of Transport	**Proportion of Transport: Median (range)**
Ground	43% (15-100)
Helicopter	10% (0-39)
Fixed Wing jet/propeller	38% (0-65)

EMS: Emergency medical Services, TT: Transport Team

*Mode of Transport utilized in Programs in the 8 Unit-Based Transport Teams

Table 7: Distance to Takeoff/Landing Platform from Transport Home Site*

Distance to takeoff/landing platform	Fix wing; N (%)	Rotor; N (%)
On-site	0 (0)	6 (75)
Within 15 min distance (Off-site)	3 (38)	1 (13)
15-30 min distance (Off- site)	4 (50)	0 (0)
>30min distance (Off- site)	1 (13)	0 (0)

*Distance to takeoff/landing platform for fixed wing/jet/propeller planes from transport home site

Table 8: Data Recorded in Transport Database*

Data Recorded	N (%)
Patients Demographics (ID, Name etc.)	8 (100)
Information of referral site (Name, Postal Code etc.)	7 (87)
Details of transport times/dates of transport	8 (100)
Vital Signs during transport	5 (63)
Blood Work result (Blood gas etc.)	4 (50)

*Data Recorded in Transport Database in the 8 Unit-Based Transport Teams

3.5 DISCUSSIONS

Intensive care services for severely ill and injured children have undergone substantial centralization in Canada since the 1980's, with these services currently being coordinated through Pediatric Intensive Care Units (PICU) in tertiary hospitals in major Canadian cities.

In the United States (US), medical transport systems were developed in the early 1970s to provide care for the critically ill neonate [54-57]. Transport programs for older children began to emerge in the 1980s' [58]. The first guidelines for pediatric inter-facility transport were developed in the late 1980s'. There are now transport standards suggesting that critically ill children should ideally be transported by specialized transport teams, assuring a high quality of patient care and improved patient outcomes [15-17, 21]. Starting in the 1980s', Canadian PICUs began to establish ICU-based pediatric critical care transport teams. In 2009, the Canadian Association of Pediatric Health Centers established a National Transport Systems Steering Committee and initiated working groups to develop specific national standards [59]. Despite this, our study found that many regions in Canada are still under-serviced when it comes to pediatric critical care transport.

Canadian pediatric transport teams vary in the pediatric patient volumes transported as well as the percentage of these patients requiring PICU admission. A similar pattern is seen in the US, although overall patient numbers transported annually are greater [60], likely due to differences in population.

Our survey identified that RN-RT is the most commonly used team composition in Canada (62%; 2,099/3,386 transports), and physicians were only accompanying RNs and RTs on a minority of transports. It is interesting to note that only 30% of pediatric inter-facility transport teams in the US use an RN-RT composition, and that paramedics are more often used (>30%) to partner with other team members [60]. Two programs, each performing more than 500 transports (including neonatal and adult patients) annually, use other team compositions (RN-RN team, Paramedic only team) more frequently. Little evidence exists to support an ideal pediatric critical care transport team composition [15-17, 20-22].

Our survey also found that air transport was used as frequently as ground transport for pediatric critical care transport in Canada. In order to serve their large catchment areas, more than half of the Canadian programs surveyed used fixed wing resources. This differs from the US, where the maximum transport distance travelled by half of the US pediatric transport programs was 241 km (150 miles), and the most common transport distance for unit-based neonatal transport teams in the US was 82 km (51 miles) to 161 km (100 miles) (35.4%), with only 4.4% reported traveling >805 km (500 miles) [7, 60].

We also found that a significant number of pediatric critical care transports in Canada are conducted by non-hospital affiliated transport teams. In Ontario, the non-hospital affiliated service (Ornge) plays a major role in pediatric critical care transport, whereas, in Western Canadian provinces hospital-based transport teams make up a greater percentage of transport activity when compared to non-hospital affiliated teams. Although we asked if the transport teams transported adults or neonates, we did not specifically ask if there were regional dedicated neonatal or other (non-pediatric) transport team that transported children as well.

Finally, we found that while all the unit-based teams had their own databases, significant variability exists in their structure, and in the specific data elements that are being recorded. This will create a challenge if attempts are made in the future to study any associations between individual programs/systems and patient outcomes. We believe that creating a national pediatric critical care transport database, composed of common data elements and data definitions is the first step necessary to be taken in order to overcome this barrier. Quality assurance programs were commonly present in the unit-based teams that were surveyed. Knowledge derived from these activities should be shared through the national pediatric transport network, to allow for benchmarking as well as to raise the standard of care being provided during the inter-facility transport of critically ill and injured Canadian children [23].

There are limitations to our study. This survey did not track inter-facility transports performed by local Emergency Medical Services or some other transport team models (i.e. adult transport teams, transport teams from other countries). Although almost all the questions were completed by all the respondents, some of the figures were provided as the best estimates, so discrepancies might be observed if exact numbers were available. It can also be said that the survey respondents' recall might not always match actual team practices.

3.6 CONCLUSION

This is the first nation-wide study of Canadian pediatric critical care transport programs. It revealed a complexity and variability in transport teams demographics, volumes, team composition, decision-making process, and database and quality assurance activity.

CHAPTER 4

*Epidemiology of PCC Transport in Northern Alberta and the Western Arctic**

* The content of this Chapter has been published as "Atsushi Kawaguchi, Charlene C. Nielsen, Gonzalo G. Guerra, L. Duncan Saunders, Yutaka Yasui, and Allan de Caen, "Epidemiology of Pediatric Critical Care Transport in Northern Alberta and the Western Arctic." in *Pediatric Critical Care Medicine*, in June 2018 [48]

4.1 ABSTRACT

4.1.1 Objective

Specialized Pediatric Critical Care (PCC) transport teams are essential to pediatric retrieval systems. This study aims to describe the contemporary transports performed by a Canadian PCC transport team and to compare the treatment and outcomes of children referred from High-Level Care (HLC: hospitals offering pediatric services where an adult intensive care unit exists) and Non-High-Level Care (NHLC: all other hospitals) hospitals.

4.1.2 Methods

Design: A descriptive cohort study

Setting: The Stollery Children's Hospital (SCH) in Edmonton, Alberta, Western Canada.

Patients: Children under 17 years of age transported by the transport team from referral hospitals within the SCH catchment area to SCH between 1998 and 2015.

Interventions: None

4.1.3 Measurements and Results

Characteristics of transports, patient demographics, presenting vital signs, and outcomes were described overall and compared by transport-related time and referral hospital types (HLC and NHLC). In total, 3,352 transports met the inclusion criteria; 1,049 were retrieved from 8 HLC hospitals and 2,303 from 53 NHLC hospitals; the median one-way transport distance was 383 kilometers and 70% of the transports were air transports. The annual number of transports has increased during the study period. The pediatric intensive care unit (PICU) admission rate was between 40-55%. Transports from HLC hospitals had significantly higher odds of being admitted to the PICU (OR: 1.96, 95%CI: 1.31 to 2.93). The odds of intubation at the referral hospital were higher in the HLC group, but the odds of intubation upon PICU admission was similar between the two groups. Mortality during or after transport was not significantly different between HLC and NHLC hospitals.

4.1.4 Conclusions

The current transport system has multiple priorities with respect to efficiency and quality. The medical services at referral hospitals may affect the likelihood of PICU admission and subsequent PICU length of stay; however, no negative impact was observed in other outcomes including mortality.

4.2 INTRODUCTION

Communities in Western Canada's provinces and territories are scattered over a large geographic area, necessitating the transport of their critically ill or injured children over long distances in order to access regional tertiary-level hospitals. A highly skilled and specialized Pediatric Critical Care (PCC) transport team based at Stollery Children's Hospital (SCH) in Edmonton, Alberta services Canada's Western Arctic and the northern half of the province of Alberta and has played a central role in the region's pediatric retrieval system. SCH provides services to at least 750,000 children under 16 years of age throughout Western Canada [41]. The SCH pediatric intensive care units (PICUs) provides critical care support to 800-1,000 admissions annually; About 60% of the PICU admissions including post operation needed endotracheal intubation.

The SCH created a dedicated PICU-based transport team in 1996. Patient transport is coordinated through RAAPID (Referral, Access, Advice, Placement, Information, and Destination) in Alberta Health Services (AHS) [39]. RAAPID is a call center that serves as a single point of contact for healthcare providers to access the best resources to meet the needs of their patients. RAAPID's triage nurses connect referring hospital practitioners (i.e., clinics, regional hospitals) with tertiary-care specialists by telephone-consult. The PCC transport teams were initiated by physicians (consultants of PCC, PICU fellows, or senior residents in emergency medicine or anesthesia that have completed their training/rotation in pediatric critical care and were endorsed by the PCC team director) and respiratory therapists and nurses, all with extensive experience and training in the assessment and management of critically ill or injured children. Since 2008, the SCH PCC transport team has increasingly sent transport teams without an accompanying physician, driven by a need to maximize the efficiency of resource utilization (critical care physicians) associated with the expanding intra-hospital workload of critical care physicians.

The objectives of this study were to (a) Characterize PCC transport activity and trends over time, distance, and the modality of transports used by the SCH PCC transport team and (b) Explore the differences in transport characteristics, treatments at referral hospitals, risk of PICU admission, and PICU treatments and outcomes, between the High Level Care (HLC) hospitals which have adult ICUs and the Non-High Level Care (NHLC) hospitals without adult ICUs.

4.3 METHODS

4.3.1 Study Population

We included children under 17 years of age, transported by the SCH PCC transport team from hospitals in the SCH's primary catchment area to SCH between 1998 and 2015. In the analysis of transport outcomes, children admitted between August 2002 and December 2015 were included. Data was not available for children admitted to the PICU in 2009 due to the lack of funding for a data administrator. We excluded newborn infants transported by the SCH neonatal transport team, and pre-planned non-emergent transports.

4.3.2 Study Design and Data Sources

We adopted descriptive and cohort designs as part of this study. We accessed two independent databases in this study: (i) a hospital-based transport database, which was developed for all transports performed by the SCH PICU transport team since 1998; and (ii) a hospital-based SCH PICU discharge summary database, established in August 2002. The proportions of missing values for any of recorded variables were less than 1%, except those for vital signs on physical examinations during transports in the hospital-based transport database), for which approximately 5% of the recorded transports had missing values. The two datasets were merged by using the individual identifiers and the transports' dates. We also identified patients (transports) who were admitted to the PICU within 24 hours of referral call, by referral call and PICU admission dates and times. The list of medical care services provided in each referral hospital was created by referring to the AHS website and through personal correspondence with referral physicians [45].

4.3.3 Statistical Analysis

First, we described characteristics of the transports including time (i.e., total transport time, stabilization time, and dispatch time), distance, and modality of the transports and transported patients' demographics, treatments and outcomes. Each variable's distribution was described by mean and standard deviation (SD); for asymmetrical distributions, we used median and inter-quartile range (IQR).

In addition, we compared HLC hospitals (hospitals offering pediatric services where adult ICUs exist) and NHLC hospitals (all other hospitals) with respect to patient demographics, treatments and outcomes and transport characteristics. Student's t-test or Mann-Whitney U test if needed, and Chi-Square test or Fisher's exact test if needed, were used to compare the continuous and nominal categorical variables, respectively, between the two groups.

Logistic regression models with the referral hospitals as random effects were employed to estimate hospital effects on the likelihood of PICU admission, death before/during transport or in the PICU, death before/during transport or in the hospital, endotracheal intubations at the referral hospital and endotracheal intubations after PICU admissions, adjusted for propensity scores (Please refer to the next section). Linear regression with random effects was also utilized for the outcome of PICU and hospital length of stay (LOS) and invasive ventilation days, for which logarithmic transformations were employed to remove skewness for the analyses (Figure 6-8). The adjusted odds for each hospital for PICU admission and endotracheal intubation at referral hospitals were compared to the referral hospitals' average, and were plotted to examine hospital-specific effects.

We performed analyses with adjustment by applying propensity scores. Propensity scores were produced in the following manner. First, we performed an unadjusted logistic regression of whether the transports were from HLC hospitals or not to assess unadjusted associations with age, weight, vital signs (Glasgow coma scale, respiratory rate, SpO_2, heart rate, systolic blood pressure, and capillary refilling time), time of the transport (i.e., Day or Night), triage intensivists (7 pediatric intensivists and "the others" who had less than 50 of transport triage experiences as of January 2010), and time from referral call to arrival at referral hospital. We applied vital signs measured at the first physical assessment by the PCC transport team, which were the nearest available vital sign values to the triage calls. The 5-category propensity scores were then created by using the predicted log odds of the transport from an HLC hospital for the final model [61-63].

To examine year effects on the transport time, linear regression analyses were performed adjusting for triage intensivists, categorized working diagnoses during the transports, transport modalities, and initial vital signs measured when the PCC transport team arrived at the referral hospital.

A two-sided p-value of less than 0.05 was considered statistically significant. All statistical analyses were conducted with Stata version 13® (Stata Corp LP, 2013). Heat maps documented distribution of the cohort over time using ArcGIS® version 10.5 (Esri, CA, USA). Kernel density with a radius of 100 km was applied to show where there were concentrations of patient residences. Distance calculations relied on the Network Analyst extension. This study was approved by the Health Research Ethics Board of University of Alberta, Canada.

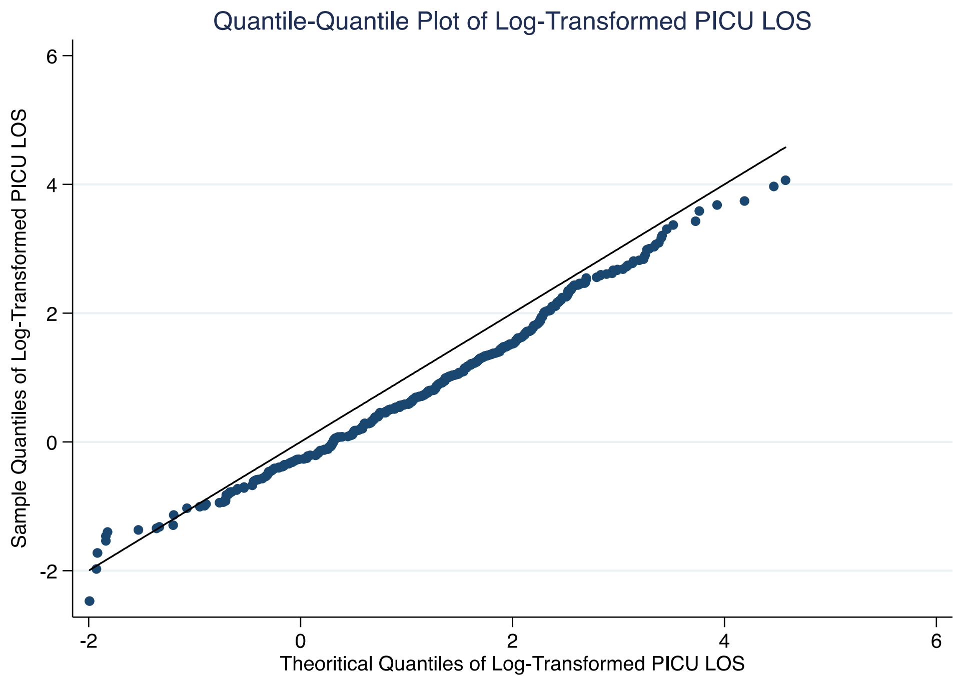


Figure 6: Quantile-Quantile Plot of Log-Transformed PICU Length of Stay.

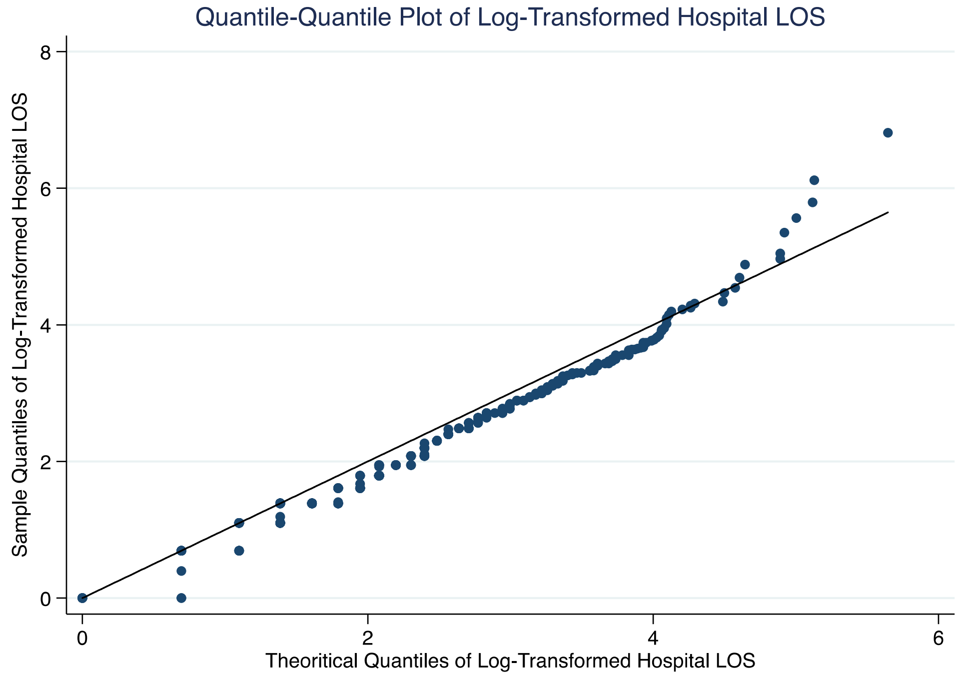


Figure 7: Quantile-Quantile Plot of Log-Transformed Hospital Length of Stay.

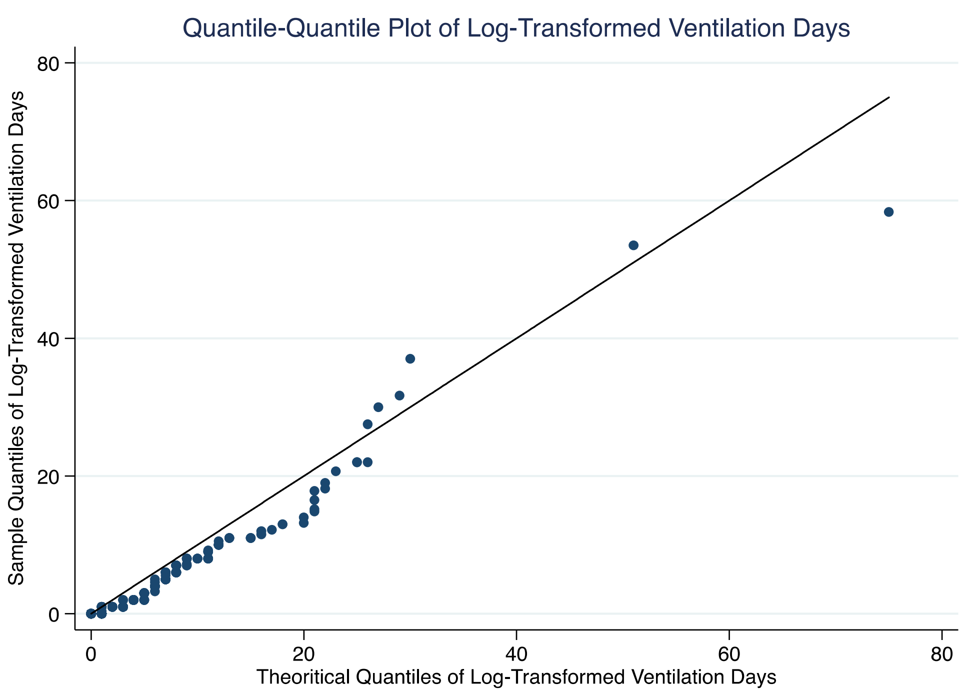


Figure 8: Quantile-Quantile Plot of Log-Transformed Invasive Ventilation Days.

4.4 RESULTS

4.4.1 Trend in Number of Transports

In total, 3,682 transports were performed by the PCC transport team during the study period, of which 3,352 transports (91%) met our inclusion criteria (Figure 9). Transport activity gradually increased over the study period, with the relative number of physician-accompanied transports falling significantly in 2008. The PICU admission rate has remained steady at 40-55% (Figure 10).

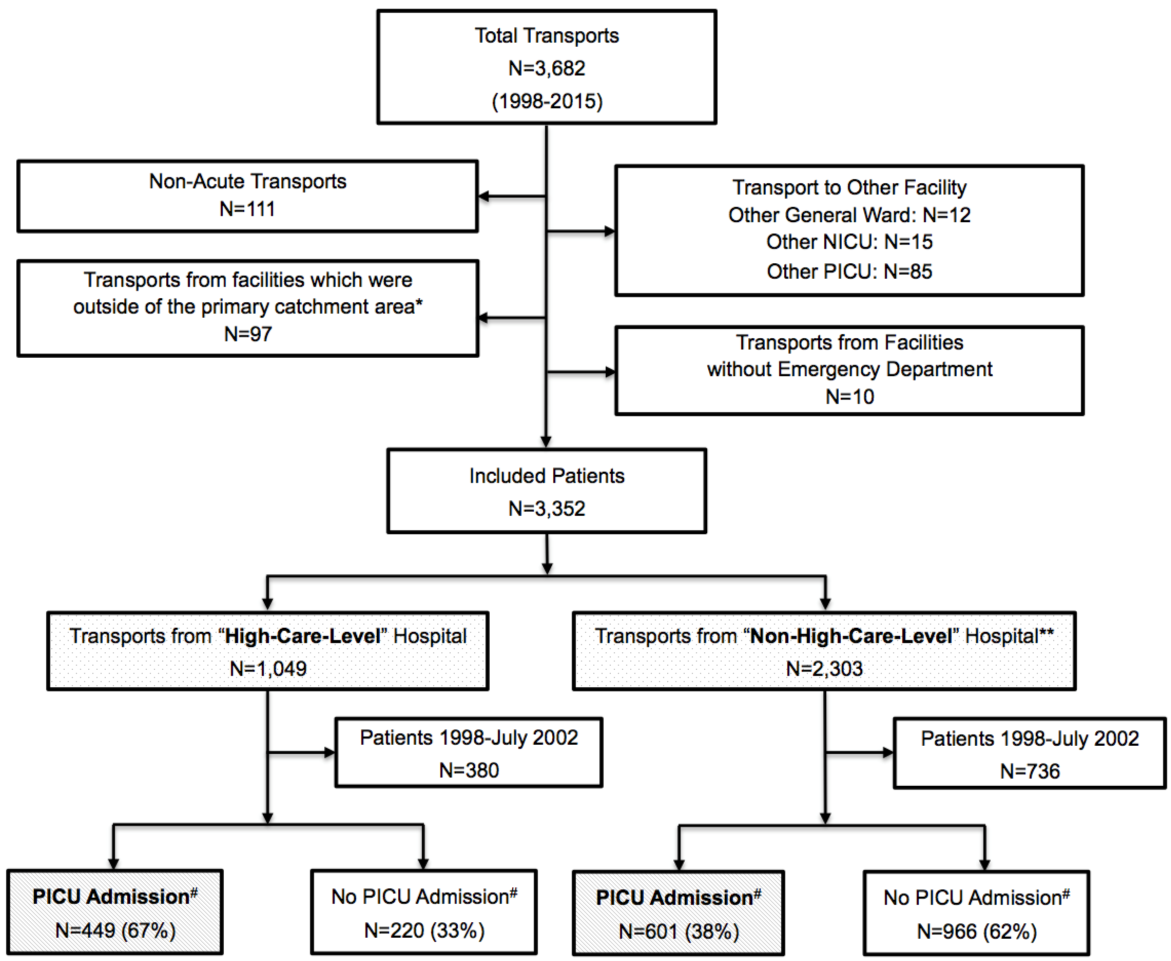


Figure 9: Patients' Flow Chart: 1998 to 2015.

**All the hospitals offered 24-7 emergency medical services (e.g., emergency department)

#PICU admission within 24 hours from the referral call

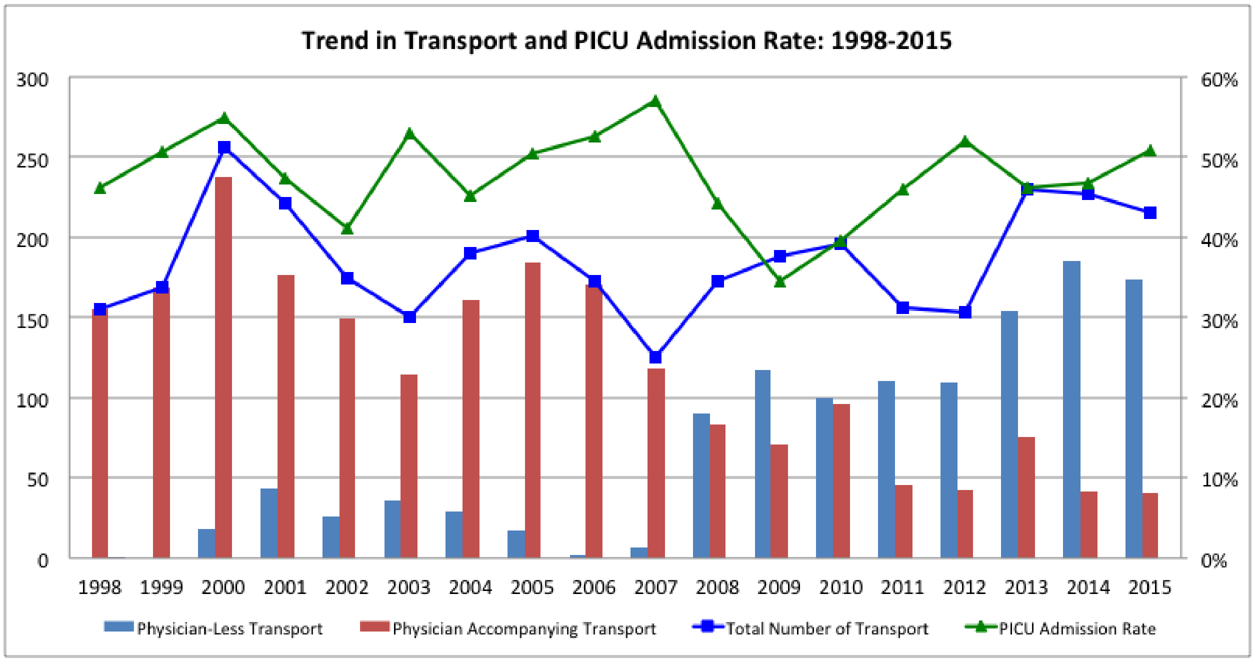


Figure 10: Trend of Number of Transports and PICU Admission Rate in 1998 - 2015. PICU Admission Rate: (PICU admitted patients within 24 hours from the referral calls) / (patients who were transported to the university children's hospital with unplanned emergency reasons).

Transport activity was higher between autumn and the end of spring. Seasonal fluctuations in transport activity were greatest during that period (Figure 11). A similar seasonal trend in PICU admission rates was observed over the study period.

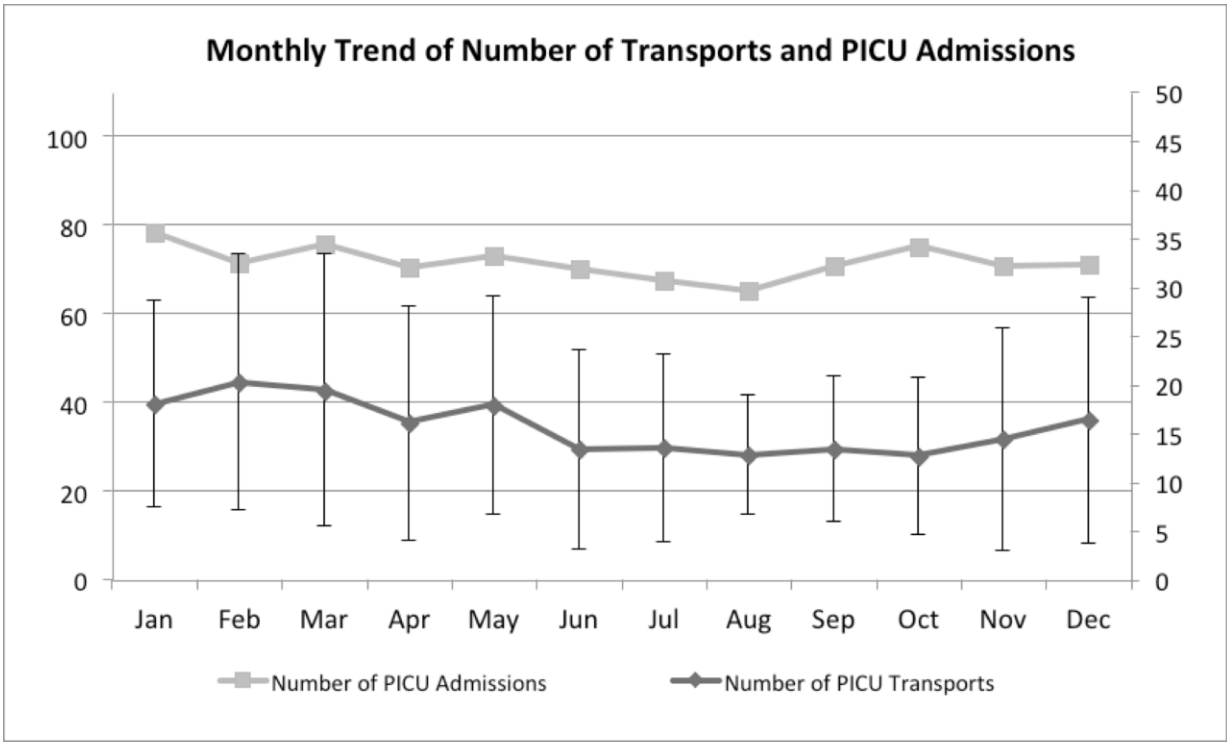


Figure 11: Monthly Trend of Number of Transports and PICU Admissions in 1999 - 2015. Left Y-axis: Number of All PICU Admissions, Right Y-axis: Number of Transports. Patients in 1998 are excluded due to the lack of data in a monthly number of PICU admissions.

4.4.2 Demographics of Transports and Transported Patients

Patients' median (IQR) body weight was 11.0 (6.5 to17.5) kg with a median age of 1.4 (0.4 to 4.5) years. More than 60% of the transports were performed with an accompanying physician (Table 9). The median (IQR) of the total transport time, stabilization time, and dispatch time were 270 (170 to 375) minutes, 50 (37 to 70) minutes, and 30 (20 to 45) minutes, respectively (Figure 12-14). The total transport time and the dispatch time increased statistically significantly over the study period (Adjusted linear coefficients: 4.1 minutes/year for the total transport time and 1.2 minutes/year for the dispatch time, respectively). The median (IQR) transport distance (one-way) from the referral hospitals to the SCH was 383 (114 to 431), kilometers (km) and that from the patients' residence to the SCH was 377 (129 to 730) km. In total, more than 70% of the transports were conducted by air modalities. The heat maps showed significant geographic scatter of our transported patients, which has been further expanding to remote areas/communities over the study period (Figure 15, 16).

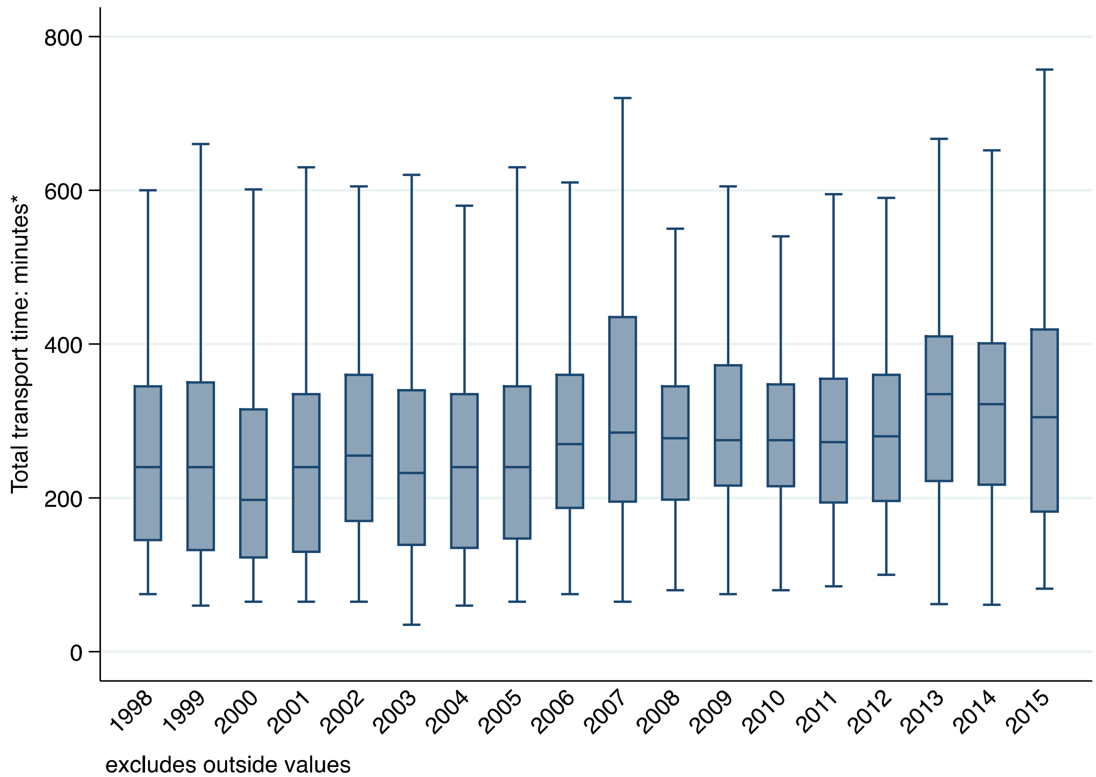


Figure 12: Total Transport Time.

Time from referral call to arrival at SCH

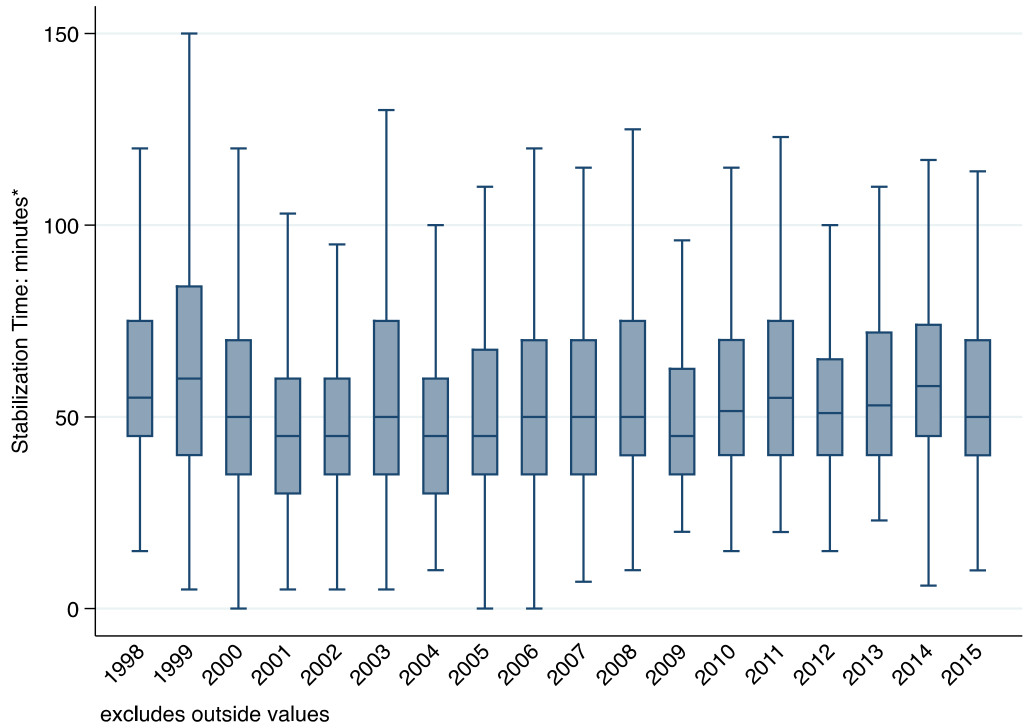


Figure 13: Stabilization Time.

Time from arrival at referral hospital to departure from referral hospital

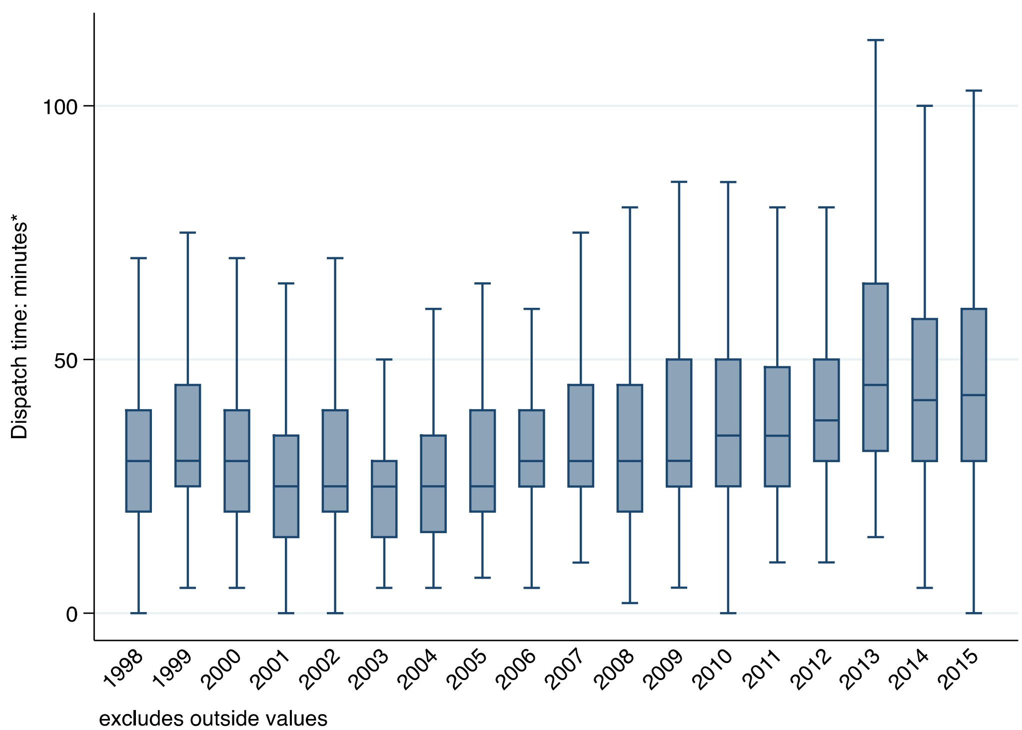
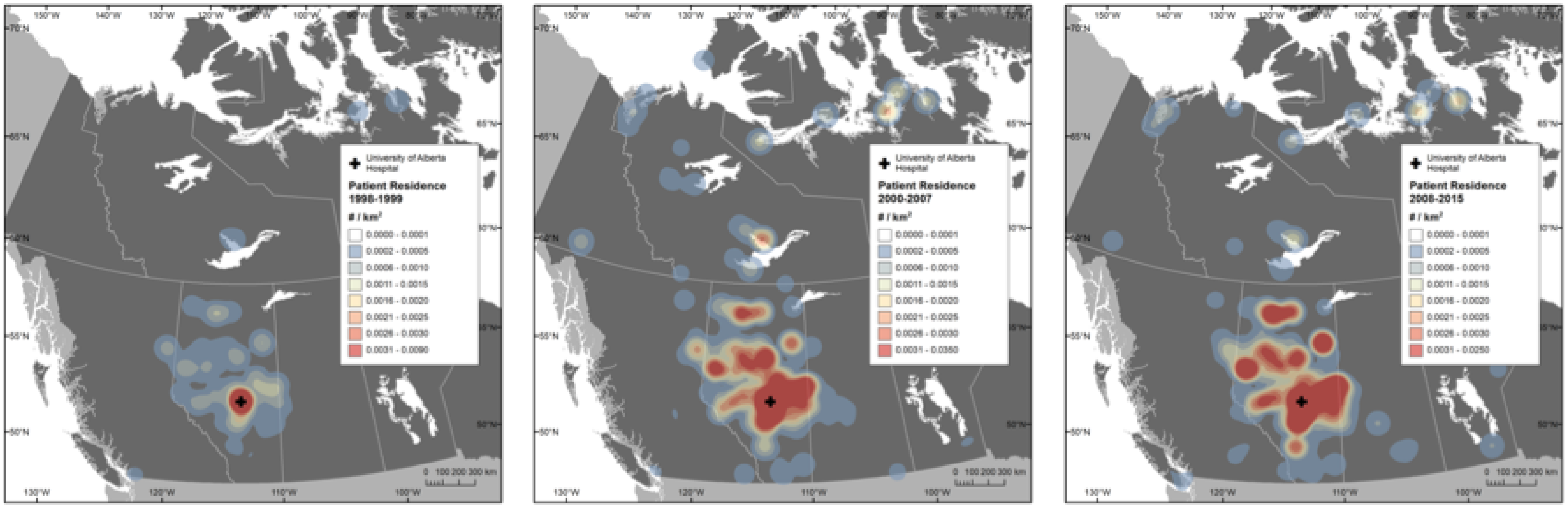


Figure 14: Dispatch Time.

Time from referral call to dispatch of the transport team from SCH



1998-1999 **2000-2007** **2008-2015**

Figure 15: Distributions of Transport Patients' Residences in Three Different Periods.

*All the 3,682 transported cases

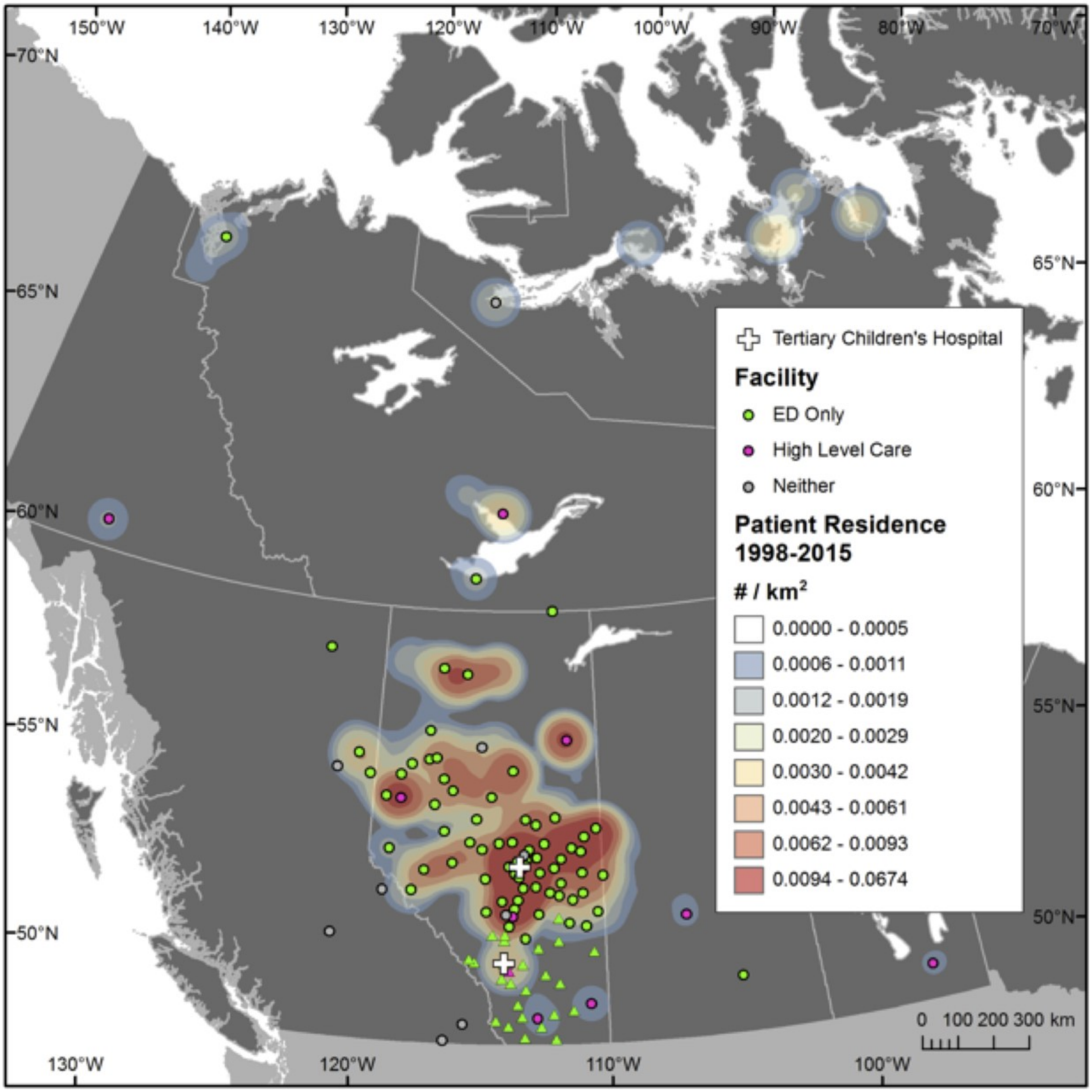


Figure 16: Distribution of residences of All the Transported Cases and Locations of Referral Hospitals.

*Including all the transported cases from 1998 to 2015 (N=3,682). Green circle dots: NHL Hospitals from where there were transports operated by the PICU transport team, Purple circle dots: HL Hospitals from where there were transports operated by the PICU transport team, Green triangular dots: NHL Hospitals from where there were no transports operated by the PICU transport team. Gray circle dots: Hospitals, which were not categorized into either HLC or NHLC hospitals

4.4.3 Differences by the Level of Care/Service in Referral Hospitals

During the study period, 1049 transports were conducted from the 8 HLC hospitals, and 2,303 were from the 53 NHLC hospitals (Figure 6). There were no clinically significant differences in baseline patient demographics and the vital signs; however, transports from HLC hospitals had longer median (IQR) stabilization time (NHLC: 50 (35 to 65) minutes, HLC: 55 (40 to 80) minutes, P<0.001), total median (IQR) transport time (265 (190 to 345) minutes vs. 321 (120 to 470) minutes, P=0.001), and median transport distance (206 (105 to 289) km vs. 383 (114 to 431) km, P=0.029). The modality used also differed significantly between the two groups, with helicopters being used more often in transports from NHLC hospitals (Table 9). Treatments/procedures were performed more often at HLC hospitals (Table 10).

In total, 449 (67%) patients transported from HLC hospitals were admitted to SCH PICU, in contrast to 38% (601 transports) from NHLC hospitals (p<0.001). The HLC group had a significantly higher risk of mortality (Pediatric Risk of Mortality III: PRISM III) at PICU admission, and more patients received treatments and procedures during their PICU admission (Table 11).

The regression analysis showed that patients transported from HLC hospitals had twice the odds of being admitted to the PICU as compared to those from NHLC hospitals (OR: 1.96, 95%CI: 1.31 - 2.93, p=0.001). Mortality during/after the transports were not statistically significantly different between the two groups. The risk of being endotracheally intubated at referral hospitals was higher in the HLC group albeit not statistically significant (OR: 1.61, 95%CI: 0.84 - 3.11), but the likelihood of intubation after PICU admission did not differ statistically between the two groups

(Table 12, Figure 17 and 18). Patients from HLC hospitals also had a longer PICU LOS (average 1.3 days, p=0.016), although no statistically significant differences were seen in the hospital LOS and invasive ventilation days.

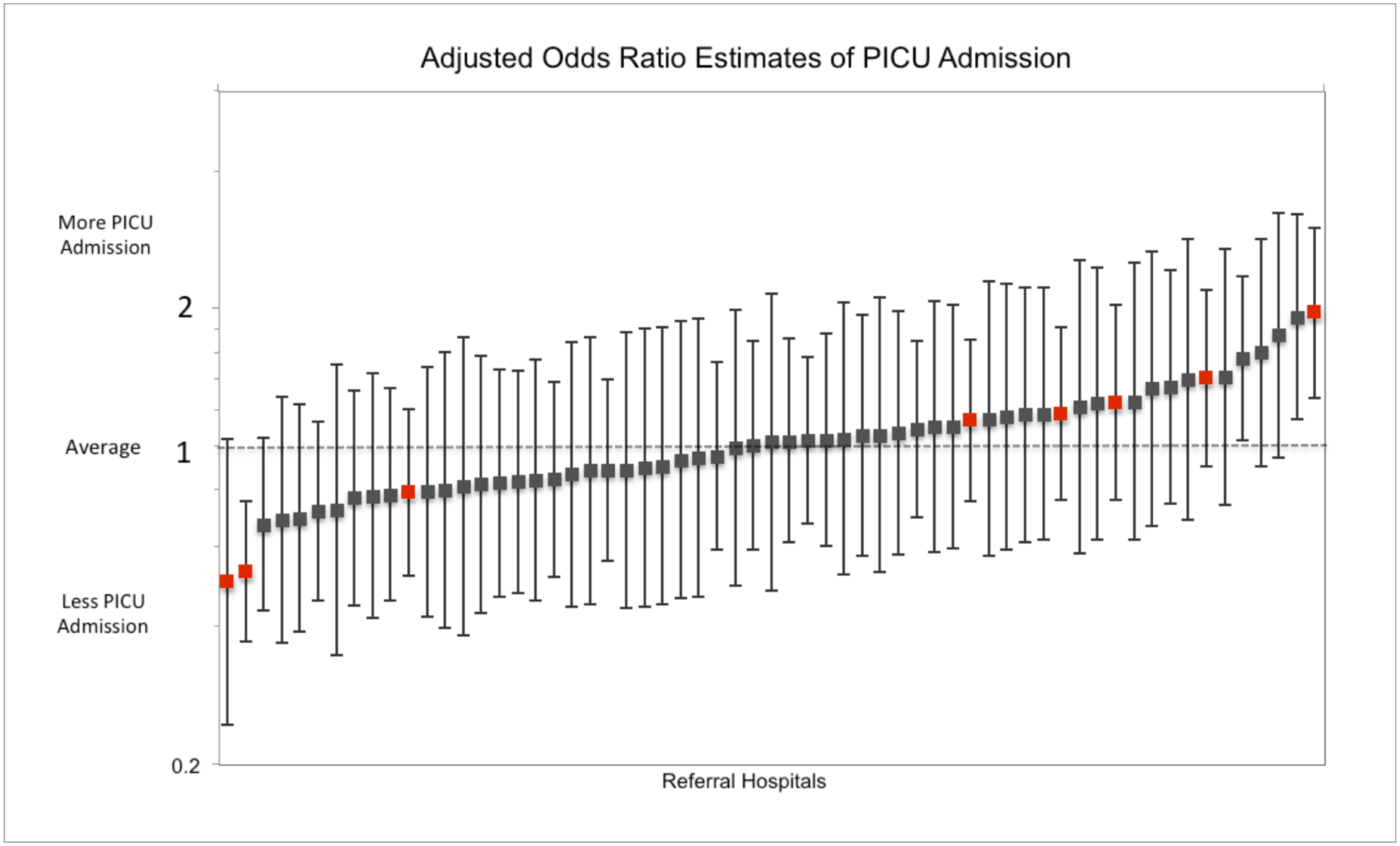


Figure 17: Adjusted Odds Ratio Estimates of PICU Admission among Referral Hospitals.
Red: HLC Hospitals, Black: NHLC Hospitals, --- Average of the referral hospitals

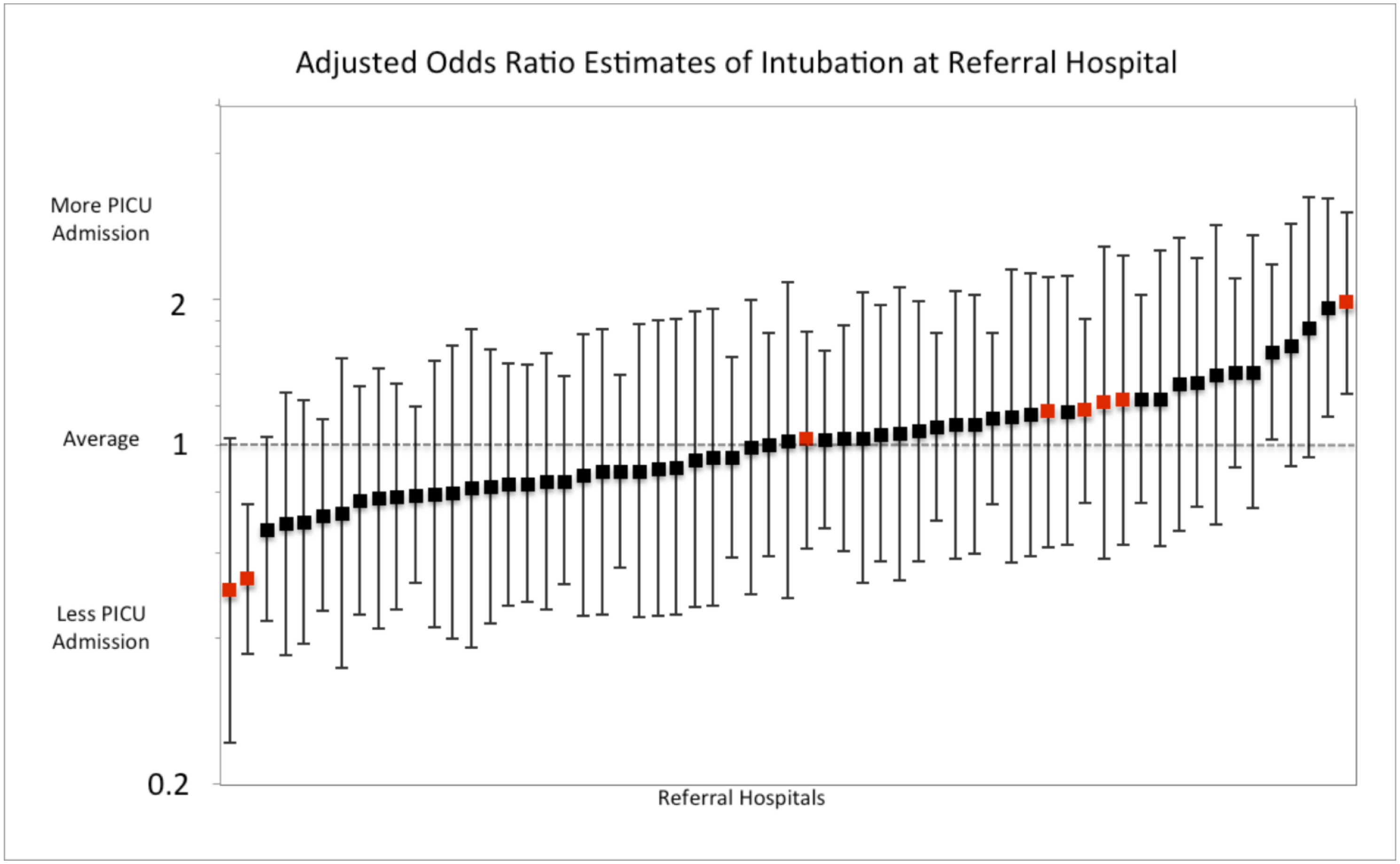


Figure 18: Adjusted Odds Ratio Estimates of Intubation at Referral Hospitals.

Red: HLC Hospitals, Black: NHLC Hospitals, --- Average of the referral hospitals

Table 9: Comparison of Transports' Characteristics and Patients' Demographics between Two Types of Facilities

Variables	NHLC Hospitals	HLC Hospitals	P-values
Transport Characteristics	N=2,303	N=1,049	
Distance from Residence: km [IQR]	209 [99 - 320]	377 [129 - 730]	0.028
Day Time 7AM -7PM Transport: n (%)	1,288 (56)	580 (55)	0.73
Physician Accompanying Transport: n (%)	1,391 (60)	741 (71)	<0.001
Transport Mode			
Fixed Wing: n (%)	1,362 (59)	544 (52)	
Helicopter: n (%)	456 (20)	51 (5)	
Ground Ambulance: n (%)	465 (20)	435 (42)	
Lear Jet: n (%)	20 (1)	18 (2)	
Time of Transport			
Dispatch Time: minute [IQR]	30 [22 45]	30 [20 50]	0.98
Stabilization Time: minute [IQR]	50 [35 65]	55 [40 80]	<0.001
Total Transport Time: minute [IQR]	265 [190 345]	321 [120 470]	0.001
Transport Distance: km [IQR]	206 [105 289]	383 [114 431]	0.29
Total number of treatments/procedures* (SD)	3.8 (2.3)	5.4 (2.9)	<0.001
Patients' Demographics			
Gender: male: n (%)	1,356 (59)	594 (57)	0.22
Weight: kg [IQR]	11.0 [7.0 17.0]	10.0 [6.0 18.0]	0.09
Age: year [IQR]	1.4 [0.4 4.3]	1.3 [0.3 5.0]	0.31
Primary Diagnoses at time of Transport: n (%)			
Respiratory**: n (%)	631 (27)	343 (33)	
Trauma: n (%)	223 (10)	65 (6)	
Sepsis/Septic Shock: n (%)	173 (8)	102 (10)	
Cardiac Disease: n (%)	31 (1)	25 (2)	
Others#: n (%)	345 (15)	180 (17)	
Unknown: n (%)	900 (39)	334 (32)	
Vital Signs at Referral Hospitals			
Glasgow Coma Score (SD)	13 (4)	12 (4)	<0.001
Heart Rate: beats/minute (SD)	145 (33)	147 (31)	0.21
Mean Blood Pressure: mmHg (SD)	76 (16)	74 (17)	<0.001
Respiratory Rate: /minute (SD)	39 (17)	38 (18)	0.59
Oxygen Saturation: % (SD)	97.3 (6.7)	97.0 (7.9)	0.24
Normal Capillary Refilling Time: ≤2 sec. (%)	1,169 (51)	484 (46)	0.013

*Treatments or procedures performed at the referral hospitals before the PICU transport team arrived. **Including bronchiolitis, pneumonia, acute respiratory distress syndrome, croup, and other primary respiratory related disease. #Including neurological disease (e.g., seizures), metabolic disease (e.g., DKA), drug ingestion/overdose.

Table 10: Comparison of Treatments and Procedures at Referral Hospitals

Treatments/Procedures	NHLC Hospitals	HLC Hospitals	Relative Risks#	95%CIs	P-values
	N=2,303	N=1,049			
Narcotics use: n (%)	213 (9)	218 (21)	2.25	1.89 2.67	<0.001
Benzodiazepine use: n (%)	380 (17)	264 (25)	1.53	1.33 1.75	<0.001
Fluid bolus use: n (%)	921 (40)	511 (49)	1.22	1.12 1.32	<0.001
Antibiotics: n (%)	1,164 (51)	610 (58)	1.15	1.08 1.23	<0.001
Peripheral IV placement: n (%)	1,848 (80)	925 (88)	1.10	1.07 1.13	<0.001
Nasal gastric tube placement: n (%)	288 (13)	306 (29)	2.33	2.02 2.69	<0.001
Bladder catheter placement: n (%)	347 (15)	328 (31)	2.08	1.82 2.37	<0.001
Blood culture: n (%)	680 (30)	468 (45)	1.52	1.38 1.66	<0.001
Inotropes use: n (%)	49 (2)	58 (6)	2.60	1.79 3.77	<0.001
Arterial line placement: n (%)	2 (0)	26 (2)	14.68	3.49 61.79	<0.001*
Central venous line placement: n (%)	9 (1)	26 (2)	6.34	2.98 13.49	<0.001*
Intraosseous line placement: n (%)	131 (6)	86 (8)	1.44	1.11 1.87	0.006
Chest X-ray: n (%)	1,424 (62)	755 (72)	1.16	1.11 1.22	<0.001
Blood gas**: n (%)	336 (15)	535 (51)	3.50	3.12 3.92	<0.001

*Fisher's Exact Test, **Include samples from an artery, venous, and capillary.

#Relative Risk in HLC group compared to the NHLC group.

Table 11: Comparisons of PICU Demographics and Treatments conducted in Two Types of Facilities: Aug. 2002 - Dec. 2015

Variables	**NHLC Hospitals**	**HLC Hospitals**	**Relative Risks#**	**95%CIs**	**P-values**
	N=601 (38)	N=449 (67)			
Pediatric Risk of Mortality score [IQR]	4.0 [0 8.0]	5.0 [1.0 8.0]			0.15
Pediatric Risk of Mortality: % [IQR]	1.0 [0.4 3.8]	1.7 [0.5 3.8]			0.014
Treatments in the PICU					
Inotropes use: n (%)	135 (23)	141 (31)	1.39	1.14 1.70	0.001
ECMO use: n (%)	7 (1)	9 (2)	1.71	0.64 4.56	0.28
Arterial line placement: n (%)	246 (41)	247 (55)	1.34	1.18 1.52	<0.001
Central venous line placement: n (%)	194 (33)	195 (44)	1.34	1.15 1.57	<0.001
Bladder catheter placement: n (%)	382 (64)	341 (76)	1.19	1.10 1.29	<0.001
Antibiotics use: n (%)	434 (73)	368 (82)	1.13	1.06 1.21	<0.001
Systemic steroid use: n (%)	187 (31)	169 (38)	1.20	1.02 1.42	0.032
H_2 blocker use: n (%)	170 (29)	147 (33)	1.15	0.96 1.38	0.14
Parenteral nutrition use: n (%)	30 (5)	37 (8)	1.64	1.03 2.62	0.035

Data after PICU admissions were only available from August 2002 to December 2015 (Cases in 2009 were excluded due to the lack of the necessary data). #Relative Risk in HLC group compared to the NHLC group. Extra-Corporeal Membrane Oxygenation: ECMO.

Table 12: Comparison of Patients' Outcomes in Two Types of Facilities

Outcomes	NHLC Hospitals	HLC Hospitals	Adjusted ORs	95%CIs	P-values
	N=1,567[a]	N=669[a]			
PICU admission within 24 hours: n (%)	601 (38)	449 (67)	1.96	1.31 2.93	0.001
Death Before/During Transport: n (%)	14 (1)	10 (1)	n/a	n/a	0.26*
Death Before/During Transport or at the PICU: n (%)	47 (3)	38 (6)	1.03	0.52 2.03	0.94
Intubation at Referral Hospitals: n (%)	203 (13)	213 (32)	1.61	0.84 3.11	0.15
Intubation at the PICU[¶]: n (%)	180 (30)	135 (30)	1.04	0.70 1.55	0.83
			Adjusted Diff.[b]		
PICU Length of Stay[¶]: days [IQR]	2.4 [1.1 4.9]	3.6 [1.6 7.7]	1.3	n/a	0.016
Hospital Length of Stay[¶]: days [IQR]	7 [4 15]	9 [5 18]	1	n/a	0.26
Invasive Ventilation[¶]: days [IQR]	3 [1 7]	4 [2 7]	1	n/a	0.42

[a]Transports from August 2002 to December 2015 (transports in 2009 were excluded due to the lack of necessary data). [¶]Analyzed for patients who admitted to the PICU.

[b]Linear regressions using logarithmic transformation were used. *Fishers exact test.

4.5 DISCUSSION

Our study is the first detailed report of the activities of a Canadian PCC transport program, characterized by long transport distances and times when compared to existing literature from other countries [15, 32, 64, 65].

We found that our transport activity has increased in number and distance over the study period, while the PICU admission rate has remained relatively low. In the United Kingdom, regional children's acute transport systems with independent PCC transport teams have been in operation since the 1990's [11], and have reported higher ICU admission rates than our study; 70-75% of their patients were endotracheally intubated and required ICU level of care following transport [11, 34]. A study from New Zealand also reported the proportion of transported children requiring invasive ventilation within one hour of PICU admission was over 70% [64]. This may reflect possible differences, which may or may not be interlinked, such as a different burden of critical illness or model of health care system due to regionalization of critical care, population and geographical distribution, and referral and retrieval thresholds. There might be another potential explanation, which might be quite unlikely to be a case, that our longer transport distances and times are associated with changes in patient condition, as demonstrated in the past transport studies [64-66].

We found several other notable findings such as monthly variations in transport activities and expanding areas/communities of transport. This needs to be considered in the future management/ design of our transport system [18, 67-70], such as staffing and availability of specific transport modalities. There was also an increasing trend in transport times such as dispatch times. It might be biased with a different reporting of times from the transport team members over the study period; nonetheless, it might be worth to evaluate a potential underlying cause such as other hospital-based responsibilities of the PCC transport team members.

We found that patients transported from HLC hospitals had a higher probability of requiring PICU admission than those from NHLC. This could be due in part to the higher acuity of the patients referred from the HLC hospitals. In other words, patients from the NHLC hospitals might have been less sick but were referred earlier out of the facility. This could reflect different referral or retrieval thresholds between the two groups. Here, given that more patients from the HLC group received interventions/treatments at the referral hospitals, there is a possibility that patients managed initially at the NHLC hospitals did not receive necessary interventions /treatments as compared to the patients referred from the HLC hospitals. Moreover, the difference was not homogeneous among hospitals; some HLC hospitals showed a significantly lower likelihood of requiring PICU admission. This might suggest that certain hospital-level factors affect the likelihood of requiring PICU admission or performing endotracheal intubation, which we were unable to capture in this study.

At the same time, considering the non-significant differences in patient outcomes after PICU admissions (i.e., mortality and endotracheal intubation risk), patients from the NHLC hospitals were safely retrieved, without apparent negative impact on their outcomes [24, 29, 71, 72].

There are several potential limitations of this study, mostly stemming from the retrospective nature of the data collection. First, our cohort did not capture patients not transported by the PCC transport team, e.g., patients who died before or without activating referral calls, or who were transported by the non-PCC transport teams. It is possible that patients from hospitals a short distance from the SCH were transported by Advanced Life Support teams (paramedics), particularly when the transport perceived o be time sensitive such as with trauma cases. Second, the distance or the transport time could have contributed to decision-making such as in upper airway management (transport with or without an endotracheal intubation). Hence, we adjusted for the time from referral call to the arrival of the team. Third, the availability of medical services in a particular hospital did not necessarily imply that a patient benefitted directly from the high-level medical services (e.g., adult ICU care) [73]. We imposed a strict definition for HLC hospitals, which had 24-7 adult ICU availability as well as the 24-7 availability of pediatric consultants. Also, our definition of HLC hospital (i.e., Adult ICU + Pediatric services in 24/7 basis) might just be a proxy for more specialist services being available, which might have skewed the patient case mix and caused biases. We would emphasize that there are no facilities in the northern part of the province providing high acuity surgical or anesthetic procedures regularly for pediatric patients. The similarity in patient diagnoses between the two groups at the time of transport also suggests that any bias from this is minimal (Table 1). Fourth, given the greater number of treatments/procedures performed at HLC hospitals and the longer stabilization time, these patients might have appeared sicker than the patients from NHLC hospitals. We applied propensity score adjustment as well as excluded transports from other tertiary children's hospital in the province, which included patients requiring extracorporeal life support or solid organ transplants, who are more likely to need PICU admission.

4.6 CONCLUSION

We described the characteristics and activity of a PCC transport program in a regionalized pediatric health care system covering a large geographical region. It was found that the medical services provided at referral hospitals could affect the likelihood of patients' PICU admission and subsequent PICU LOS; however, no negative impact was observed in other PICU outcomes such as mortality, when comparing the level of medical services offered at referral hospitals. We found that the current transport system has multiple priorities in regards efficiency and quality, specifically with respect to the transport time and allocation of the health care resources, in the context of the complexity of the expanding program.

CHAPTER 5

*Impact of Physician-less PCC Transport: Making a Decision on Team Composition**

*The content of this Chapter has been published in *Journal of Critical Care* in May 2018, as "Atsushi Kawaguchi, Charlene C. Nielsen, L. Duncan Saunders, Yutaka Yasui, and Allan de Caen, "Impact of Physician-less Pediatric Critical Care Transport: Making a Decision on Team Composition".[51]

5.1 ABSTRACT

5.1.1 Objectives

To explore the impact of a physician non-accompanying pediatric critical care transport program, and to identify factors associated with the selection of specific transport team compositions.

5.1.2 Methods

Children transported to a Canadian academic children's hospital were included. Two eras (Physician-accompanying Transport (PT)-era: 2000-07 when physicians commonly accompanied the transport team; and Physician-Less Transport (PLT)-era: 2010-15 when a physician non-accompanying team was increasingly used) were compared with respect to transport and PICU outcomes. Transport and patient characteristics for the PLT-era cohort were examined to identify factors associated with the selection of a physician accompanying team, with multivariable logistic regression with triage physicians as random effects.

5.1.3 Results

In the PLT-era (N=1,177), compared to the PT-era (N=1,490) the probability of PICU admission was significantly lower, and patient outcomes including mortality were not significantly different. Associations were noted between the selection of a physician non-accompanying team and specific transport characteristics. There was appreciable variability among the triage physicians for the selection of a physician non-accompanying team.

5.1.4 Conclusions

No significant differences were observed with increasing use of a physician non-accompanying team. Selection of transport team compositions was influenced by clinical and system factors, but appreciable variation still remained among triage physicians.

5.2 INTRODUCTION

The majority of pediatric primary acute care is not provided by specially-trained healthcare providers or performed in dedicated pediatric facilities. Patient outcomes are improved by building access to regionalized specialty services [1,5] and are often accessed through inter-hospital medical transport services [32, 33, 69, 70, 74, 75]. Transport standards suggest that critically ill children should ideally be moved by specialized pediatric transport teams, assuring improved patient care and outcomes [76, 77].

In recent years, specialized pediatric critical care (PCC) transport teams without an accompanying physician have become commonplace in many North American programs [32, 33]. Little evidence exists to support an ideal transport team composition, in particular when it comes to the need for a physician-presence on a PCC transport team.

Referral physicians in Alberta, Canada consult pediatric intensivists in one of two provincial children's hospitals to aid in the stabilization and transfer of critically ill or injured children. The intensivists have to decide, based on the information provided by the referral physicians, the most appropriate team to transport the individual pediatric patient: an Advanced Life Support (ALS: paramedic) team; a transport team based in an independent rotary transport organization (STARS; Shock Trauma Air Rescue Service), which consists of a dedicated transport nurse, a flight paramedic, and the option for an emergency medicine physician (either senior resident or fully trained emergency medicine physician); a PCC physician non-accompanying transport team; or a PCC transport team accompanied by a physician [44].

The Stollery Children's Hospital (STOL) (Edmonton, Canada) is an academic children's hospital and a Western Canadian quaternary care center with a large catchment area that includes Central and Northern Alberta, Northwest Territories, eastern Yukon, and western Nunavut, including at least 750,000 children under 17 years of age. It built a Pediatric Intensive Care Unit (PICU)-based, dedicated PCC transport team in 1996. The transport team was staffed by physicians with added emphasis on pediatric critical care in the interhospital setting (PICU consultants, senior PICU fellows, or senior residents in anesthesiology or emergency medicine who had completed their PCC training for 1-2 months), respiratory therapists and nurses, all with extensive experience and training in the assessment and management of critically ill or injured children. Since January 2008, the transport team has increasingly sent physician non-accompanying transport teams as opposed to physician accompanying transport teams. For the study purpose, we defined 2000 to 2007 as a Physician Transport Era (PT-era) and 2010-2015 as a Physician-Less Transport Era (PLT-era).

The purposes of this study were 2-fold: 1) To explore the impact of the increasing use of physician non-accompanying PCC transport teams on patient outcomes (i.e., PT-era to PLT-era); and 2) to identify factors associated with the selection of a PCC transport team that did or did not include a physician in the PLT-era cohort.

5.3 Materials and Methods

5.3.1 Data Used

We accessed two databases: (1) a hospital-based transport database (existed since 1998); and (2) a hospital-based PICU discharge summary database (existed since August 2002). Less than 1% of values for recorded variables are missing, except those for vital signs during transports in the transport database, for which approximately 5% of recorded variables had missing values.

5.3.2 Patients and Transports

We included children under 17 years of age who were transported by the PCC transport team to the STOL from STOL's primary catchment area between 2000 and 2015. We excluded transports from other provinces, international transports, newborn infants transported by a neonatal transport team, non-emergent pediatric transfers, and patients who were transported from other hospitals to the STOL by non-PCC transport teams such as ALS (paramedic) or STARS. We excluded transports in 2008 and 2009 as a washout period. For the analysis of outcomes after PICU admissions, transports (patients) admitted between August 2002 to December 2015 were examined. For the second study purpose, we examined the differences in transport and patient demographics between physician non-accompanying transports and physician accompanying transports in the PT-era (2010-2015).

5.3.3 Vital Sign Changes during Transports

For vital sign changes (heart rate (HR); respiratory rate (RR); oxygen saturations (SpO_2); and systolic blood pressure (SBP)), we classified all vital sign values measured at the beginning and end of transport relative to age-appropriate normal values for the given patients [78]. We then categorized the patients into three groups: (a) patients whose vital sign values improved (from the outside of the normal range to within the normal range) or remained within the normal range (from the normal range to the normal range) during transport; (b) patients whose vital sign values deteriorated during transport (from the normal range to the outside of the normal range); and (c) Others (remained outside of the normal range throughout the transport) [78].

5.3.4 Statistical Analysis

We adopted a retrospective cohort design in this study. First, we compared characteristics of the transports and the transported patients' demographics, including times of the transport, day, distances, modalities of the transports (i.e., Fixed wing propeller, Helicopter, Ground ambulance, and Fixed wing lear jet), procedures/treatments provided at the referral hospitals between the two time periods: (i) PT-era (2000-2007, when physicians regularly accompanied the transport team); and (ii) PLT-era (2010-2015, when physician non-accompanying transport team was increasingly used). Each variable's distribution was described by its median and inter-quartile range (IQR). Mann-Whitney U test and Chi-Square test (or Fisher's exact test if needed) were used to compare the continuous and nominal variables, respectively, between the two eras.

Logistic regression was employed to compare the two eras, so as to estimate odds ratios, with 95% confidence intervals (CIs), of having the following transport-related outcomes in the PT-era relative to the PLT-era: admission to the PICU within 24 hours of referral call; having unsuccessful procedures performed during the transports; the need for endotracheal intubation at the referral hospital; and vital sign changes (i.e., improved/remained the same or deteriorated; please refer supplemental document) during transports. The median regression was employed to evaluate the differences in the continuous outcome variables (i.e., transport-related times) by the two eras. We performed the regression analyses above, adjusting for propensity scores created as described in the supplemental document [61, 63].

For the transports (patients) admitted to the PICU within 24 hours of referral call, PICU and hospital outcomes were compared with respect to the two eras. Logistic regression was employed to estimate odds of death during transport or after PICU admission, endotracheal intubation at the referral hospital or after PICU admission, pediatric risk of mortality (PRISMIII), and treatments/procedures provided in the PICU. The median regression was employed to evaluate differences in the PICU length of stay (LOS), hospital LOS, and the number of invasive ventilation days, between the two eras.

For the second part of our study, transport and patient characteristics and treatments/procedures performed at the referral hospitals before the transport team arrival were examined to identify factors associated with selection of transport team compositions. The examined variables included patient's weight, prior transport experience of each PCC transport practitioner (respiratory therapists (RTs) and nurses (RNs)), modality of the transport, level of care available at the referral hospital (with adult ICU or not), transport distances (supplementary document), vital sign values in the age-appropriate normal values (Y/N) for the four vital signs (HR, RR, SpO_2, and SBP; measured at the transport team's arrival), and treatments/procedures performed at the referral hospitals prior to the team arrival in which significant differences (p-values <0.001) were observed, with relatively high incidence between the two transport-team compositions. Multivariable logistic regressions with the triage physicians as random effects were employed to estimate odds of sending a physician accompanying transport team in each triage physician. All those variables were kept in the final model. We have also conducted a subgroup analysis for the children who were admitted to the PICU within 24 hours, which might imply a higher acuity cohort. The adjusted odds of each triage physician sending a physician accompanying transport team was calculated: these estimated odds were plotted to examine the triage physician-specific effects adjusting for the case-mix variables.

A two-sided p-value of less than 0.05 was considered statistically significant. All statistical analyses were conducted with Stata version 13® (Stata Corp LP, TX USA). The distances of the transport were calculated by using ArcGIS® version 10.5 (Esri, CA, USA). This study was approved by the Health Research Ethics Board of University of Alberta, Canada.

5.3.5 Procedure to create propensity scores

First, we performed an unadjusted logistic regression with whether the transports were conducted in the PT-era or not as the outcome to assess unadjusted associations of these variables for the following variables: age, weight, vital signs (RR, SpO_2, HR, SBP, and capillary refilling time (Normal or Not)), time of the transport (Day or Night), 7 triage intensivists, time from the referral call to team arrival to the referral hospital, distance from the referral hospital to the SCH, referral hospital level of care (i.e., whether having adult ICU or not), and treatments at referral hospital (fluid bolus, antibiotics use, glucose level check, blood culture(s), blood gas, chest x-ray) in which significant differences (p-values <0.001) were observed between the two eras, with relatively high incidence. Vital signs measured at the time of initial assessment by the PICU transport team were the closest available vital sign measurements to the triage referral call. The 5-category propensity score was then created by using the predicted log odds as if transports were exposed to the PT-era from the final model [61, 63].

5.4 RESULTS

5.4.1 Patient and Transport Demographics

In total, 2,667 transports met our inclusion criteria (Figure 19). The proportion of physician accompanying transports fell in 2008; after having been stable, the proportion of physician non-accompanying transports had been 80% for the PT-era (Figure 10). In the PLT-era, 834 (71%) of the transports were performed by the physician non-accompanying transport team. In the univariate analyses comparing patient and transport characteristics between the two eras, no clinically significant differences were observed except for the proportion of the physician accompanied transports (88% vs. 29%; $p<0.001$) (Table 13). Clinically significant differences were found between the PT and PLT eras in the certain treatments and procedures performed at the referral hospitals (Table 14).

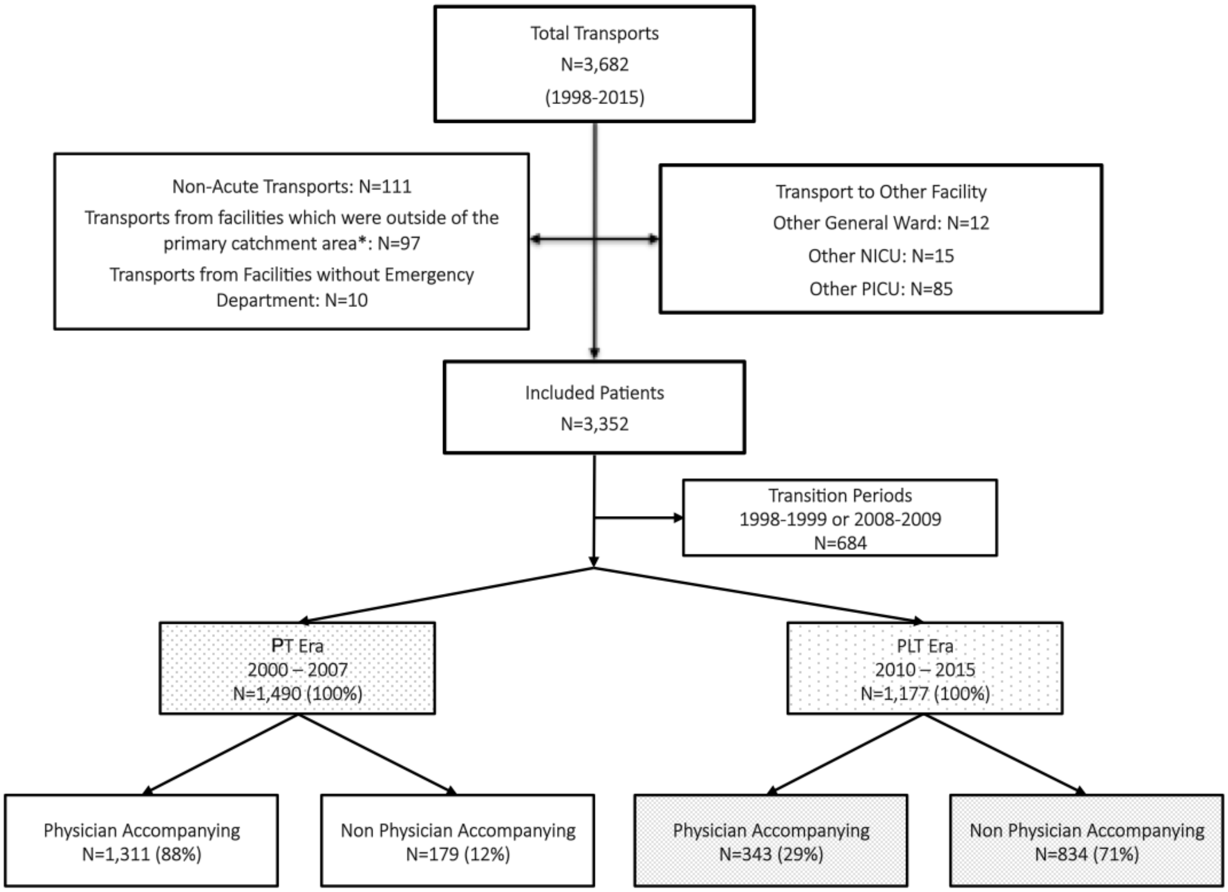


Figure 19: Patients' Flow Chart.

5.4.2 Difference in Outcomes

Table 15 and 16 showed transport and PICU related outcomes. The probability of PICU admission was significantly lower (OR: 0.78, 95% CI 0.65 to 0.94) and the risk of death during the transport and intubation were significantly lower in the PLT-era compared to the PT-era: Death during transport or at the PICU: OR: 0.47, 95% CI 0.25 to 0.89; PICU LOS: Relative Difference: -0.02day, 95% CI -0.65 to 0.61, respectively. Transport times, including the dispatch time (i.e., from the time of the referral call to the time of the transport team's dispatch from the STOL), the stabilization time at the referral hospitals, and the total transport time (i.e., from the time of referral call to the arrival of the PCC transport team back at the STOL), were statistically significantly increased from the PT-era to the PLT-era (Dispatch time: 10.0 minutes, 95% CI 8.0 to 11.9 minutes; Stabilization time: 5.0 minutes, 95% CI 2.7 to 7.3 minutes; total transport time: 25.0 minutes, 95% CI 9.8 to 40.2 minutes, respectively). In the PLT-era compared to the PT-era, more patients had their respiratory rates deteriorate (OR: 1.31, 95% CI 1.01 to 1.71). Albeit not being statistically significant, fewer patients had their heart rates improve or remain within age-appropriate normal ranges during transport in the PLT-era compared to the PT-era (OR: 0.85, 95% CI 0.70 to 1.03).

5.4.3 Factors Distinguishing Team Composition

In the PLT-era, significant associations were noted between a greater likelihood of selection of a physician non-accompanying transport team and characteristics such as more experienced transport team members (respiratory therapists and nurses), helicopter use (as compared to the transports with ground ambulance), absence of systolic hypotension or pressor/ intraosseous use in the referring center, and less hypoxic patients (Table 17). The subgroup analysis for the children eventually admitted to the PICU within 24hours showed a similar trend of the result (Table 18). There was appreciable variability among the seven-triage physicians (all the seven triage physicians had more than 200 triage experience at the end of study period) in the decision-making for selecting a physician non-accompanying transport team, adjusting for patient characteristics. Specifically, triage physicians with less triage experience (<50 events at the beginning of the study period) had a significantly higher likelihood of sending a physician-accompanied transport team than the average (Figure 20). All the triage physicians except one did have more than 50 triage events during the study period.

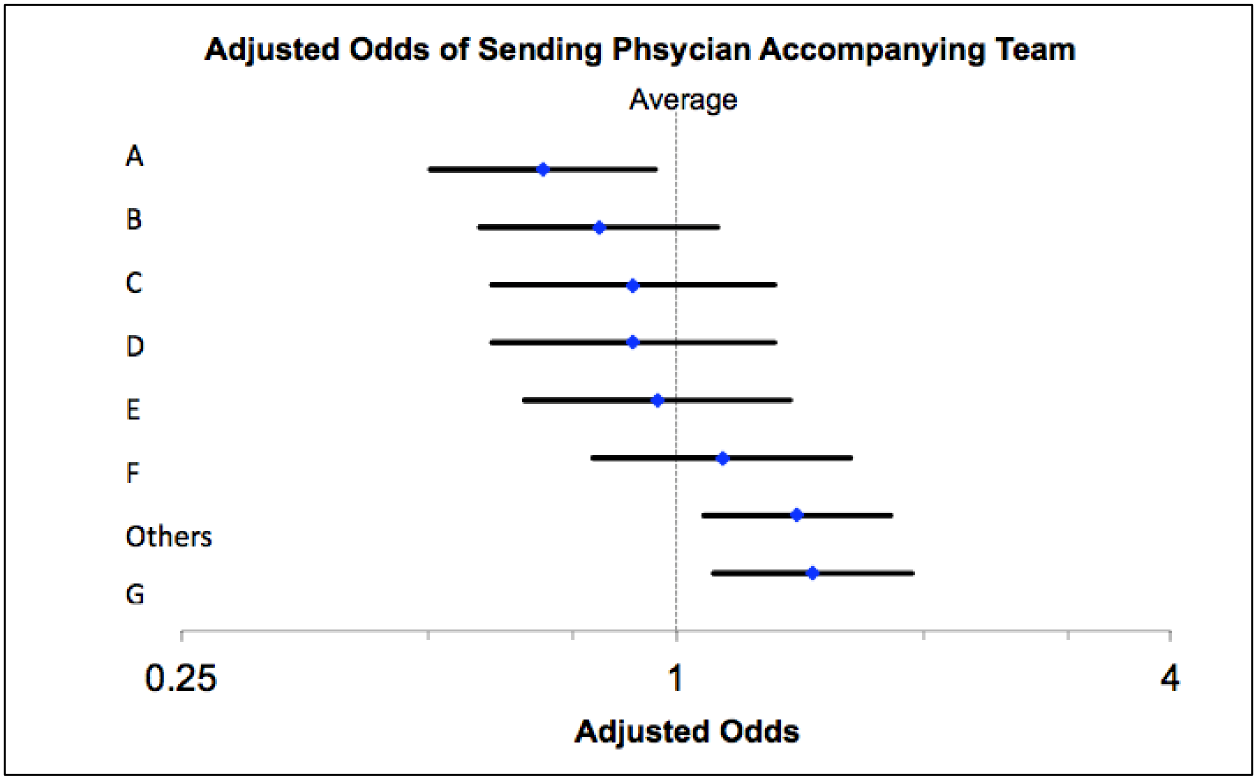


Figure 20: Adjusted Odds of Tendancy of Sending Physician Accompanying Transport Team Others: Triage intensivists who had conducted transport triages with more than 50 times at the beginning of the study period (January 2010).

Table 13: Comparisons of Patients' and Transports' Demographics between Two Eras

Variables[#]	**PT-Era: 2000-2007**	**PLT-Era: 2010-2015**
	N=1,490	N=1,177
Gender: male (%)	899 (60)	676 (57)
Weight: kg [IQR]	10.7 [6.0 18.0]	11.0 [7.7 18.0]
Age: year [IQR]	1.3 [0.3 4.6]	1.5 [0.6 4.5]
Distance from referral hospitals: km [IQR]*	197 [65 383][a]	220 [109 383][a]
Distance from residences: km [IQR]**	203 [66 390][b]	242 [111 421][b]
Daytime 7AM -7PM transport (%)	805 (54)	664 (56)
Referral hospital with adult ICU[¶] (%)	493 (33)	321 (27)
Vital signs[#]		
Glasgow coma score [IQR]	14 [9 15]	15 [10 15]
Heart Rate: bpm [IQR]	150 [125 168]	146 [124 166]
Body temperature: °C [IQR]	37.0 [36.6 37.9]	37.0 [36.6 37.7]
Systolic blood pressure: mmHg [IQR]	105 [93 117]	106 [94 119]
Diastolic blood pressure: mmHg [IQR]	61 [52 73]	63 [52 74]
Mean blood pressure: mmHg [IQR]	76 [66 88]	75 [64 85]
Respiratory rate: bpm [IQR]	36 [25 51]	35 [25 45]
Oxygen saturation: % [IQR]	99 [97 100]	99 [96 100]
Normal capillary refilling time:≤2 seconds (%)	693 (47)	589 (50)
Physician accompanying transport: n (%)	1,311 (88)	343 (29)
Transport mode		
Fixed wing propeller: n (%)	807 (54)	694 (59)
Helicopter: n (%)	262 (18)	147 (12)
Ground ambulance: n (%)	405 (27)	314 (27)
Fixed wing lear jet: n (%)	16 (1)	21 (2)

[#]All the continuous variables are shown in median and IQR, *Distance from referral hospitals to the university hospital **Distance from residences to the university hospital [¶]Hospitals with adult Intensive Care Unit. a, b: P-values<0.001 with Mann–Whitney U test.

Table 14: Treatments and Investigations at the Referral Hospitals

Treatments and Procedures	PT-Era	PLT-Era	RRs[#]	95%CIs	P-values
	N=1,490	N=1,177			
Intravenous fluid bolus: n (%)	545 (37)	625 (53)	1.45	1.33 1.58	<0.001
Antibiotics use: n (%)	709 (48)	744 (63)	1.33	1.24 1.42	<0.001
Peripheral iv catheter placement: n (%)	1,210 (81)	1,002 (85)	1.05	1.01 1.08	0.008
Nasal gastric tube placement: n (%)	280 (19)	185 (16)	0.84	0.71 0.99	0.038
C-spine precaution: n (%)	94 (6)	35 (3)	0.47	0.32 0.69	<0.001*
Blood culture: n (%)	488 (33)	465 (39)	1.21	1.09 1.34	<0.001
Inotropic agent use: n (%)	47 (3)	34 (3)	0.92	0.59 1.41	0.73*
Arterial line placement: n (%)	17 (1)	9 (1)	0.67	0.30 1.50	0.43*
Central venous line placement: n (%)	21 (1)	8 (1)	0.48	0.21 1.08	0.09*
Intraosseous needle placement: n (%)	58 (4)	93 (8)	2.03	1.48 2.79	<0.001
Endotracheal intubation: n (%)	272 (18)	199 (17)	0.93	0.78 1.09	0.37
Chest X-ray: n (%)	889 (60)	827 (70)	1.18	1.11 1.25	<0.001
Blood gas: n (%)	313 (21)	417 (35)	1.69	1.49 1.91	<0.001

*Fisher's exact test

Table 15: Transports' Related Outcomes between Two Eras

Outcomes	**PT-Era : 2000-2007**	**PLT-Era : 2010-2015**	**Adjusted ORs**	**95%CIs**		**P-values**
Transport Related Outcomes	N=1,490	N=1,177				
PICU admission within 24 hours: n (%)	739 (50)	526 (45)	0.78	0.65	0.94	0.01
Unsuccessful procedures (Yes): n (%)	196 (14)	198 (17)	1.11	0.86	1.44	0.42
Vital Signs						
HR improved/remained: n (%)	916 (61)	667 (57)	0.85	0.70	1.03	0.09
HR deteriorated: n (%)	88 (6)	83 (7)	1.28	0.87	1.88	0.20
RR improved/remained: n (%)	778 (52)	657 (56)	1.01	0.84	1.21	0.95
RR deteriorated: n (%)	183 (12)	185 (16)	1.31	1.01	1.71	0.043
SBP improved/remained: n (%)	573 (38)	469 (40)	1.04	0.86	1.25	0.71
SBP deteriorated: n (%)	187 (13)	158 (13)	0.98	0.75	1.28	0.90
SpO_2 improved/remained: n (%)	1,410 (95)	1,088 (92)	0.81	0.55	1.20	0.30
SpO_2 deteriorated: n (%)	36 (2)	37 (3)	1.32	0.73	2.38	0.36
Time of Transport			**Adjusted Diff.****			
Time to dispatch: minute [IQR]	25 [20 40]	40 [30 55]	10.0	8.0	11.9	<0.001
Stabilization time: minute [IQR]	47 [35 65]	54 [40 70]	5.0	2.7	7.3	<0.001
Total transport time: minute [IQR]	245 [145 350]	302 [205 390]	25.0	9.8	40.2	0.001

*Transports (patients) from August 2002 to 2007 were examined. ** Median regression was fitted.

Table 16: PICU Related Outcomes between Two Eras

Outcomes	PT-Era : 2000-2007	PLT-Era : 2010-2015	Adjusted ORs	95% CIs		P-values
PICU Related Outcomes	N=886*	N=1,177				
Death During Transport or at the PICU¶: n (%)	37 (4)	41 (3)	0.47	0.25	0.89	0.020
Death During Transport or at SCH¶¶: n (%)	41 (5)	42 (4)	0.47	0.26	0.87	0.017
Intubation at PICU: n (%)	161 (36)	120 (23)	0.63	0.47	0.85	0.003
Intubation at referral hospital or at PICU: n (%)	335 (74)	293 (56)	0.54	0.43	0.68	<0.001
			Adjusted Diff.**			
PRISM III: % [IQR]	1.3 [0.5 3.9]	1.0 [0.4 2.9]	-0.3	-0.66	0.02	0.039
PICU Length of Stay: days [IQR]	2.8 [1.2 7.4]	2.8 [1.4 5.5]	-0.02	-0.65	0.61	0.942
Hospital Length of Stay: days [IQR]	9.0 [5.0 18.0]	7.0 [4.0 15.0]	-2.0	-3.46	-0.54	0.007
Invasive Ventilation: days [IQR]	3.0 [1.0 7.0]	3.0 [1.0 7.0]	1.0	0.2	1.8	0.011

*Transports (patients) from August 2002 to 2007 were examined. ** Median regression was fitted. ¶Median (IQR) time from referral calls to deaths in the PICU: 1.9days (0.5 4.2) in the PT-era and 1.8 days (0.4 4.1) in the PLT-era. ¶¶Median (IQR) time from referral calls to deaths in the hospital: 3days (1 5) in the PT-era and 3 days (2 5) in the PLT-era.

Table 17: Difference in Patient and Transport Demographics between Physician accompanying and Physician Non-accompanying Transport team in the PLT-Era (2010-15)

Variables	**Physician Accompanying**	**Physician Non-Accompanying**	**Adjusted ORs**	**95%CIs**	**P-values**
Weight: kg [IQR]	12.0 [8.7 20.0]	11.0 [7.3 17.0]	1.04[a]	0.99 1.09	0.11
Experience of RTs*: times [IQR]	18 [3 85]	53 [19 125]	0.93[b]	0.91 0.95	<0.001
Experience of RNs*: times [IQR]	21 [5 51]	40 [18 78]	0.97[b]	0.95 0.99	0.001
Transport modes					
Ground ambulance: n (%)	81 (24)	233 (28)	Ref.	n/a	n/a
Helicopter: n (%)	54 (16)	93 (11)	1.79	1.11 2.91	0.018
Fixed wing propeller: n (%)	202 (59)	492 (59)	1.35	0.91 2.01	0.13
Fixed wing lear jet: n (%)	6 (2)	15 (2)	1.17	0.34 4.05	0.81
Referral hospital with adult ICU (Yes): n (%)	112 (33)	209 (25)	1.07	0.76 1.51	0.69
Night transport (Yes): n (%)	138 (40)	375 (45)	0.84	0.63 1.11	0.22
Transport distance: km [IQR]	242 [106 392]	216 [111 369]	1.01[c]	0.95 1.07	0.80
Vital signs[§]					
HR within normal range (Yes): n (%)	171 (50)	452 (54)	1.00	0.74 1.34	0.99
RR within normal range (Yes): n (%)	192 (56)	453 (54)	1.13	0.85 1.51	0.39
SBP within normal range (Yes): n (%)	106 (31)	347 (42)	0.71	0.52 0.98	0.035
SpO_2 >90% (Yes): n (%)	324 (94)	813 (97)	0.37	0.18 0.77	0.008
Treatments/procedures at referral hospitals					
Endotracheal Intubation: n (%)	91 (27)	108 (13)	1.41	0.44 2.46	0.93
Systemic presser use: n (%)	29 (8)	5 (1)	9.63	3.25 28.51	<0.001
Bladder catheter placement: n (%)	95 (28)	127 (15)	1.45	0.96 2.20	0.08
Intraosseous needle placement: n (%)	53 (15)	40 (5)	2.97	1.79 4.93	<0.001
Nasogastric tube placement: n (%)	79 (23)	106 (13)	1.03	0.64 1.64	0.91

*RTs: respiratory therapists, RNs: transport nurses, [§]Vitals signs measured at the first contact of the transport team were applied, a: by 5kg of body weight increase, b: by 10 times more transport experience (e.g., Adjusted odds ratio of a physician non-accompanying transport team to be sent with a RN with 20 times the amount of transport experiences, when compared to the RN with 10 times experience was 0.93), c: by 100km increase of the one-way transport distance.

Table 18: Subgroup Analysis**: Difference in Patient and Transport Demographics between Physician accompanying and Physician Non-accompanying Transports in the PLT-Era (2010-15)

Variables	Physician Accompanying	Physician Non-accompanying	Adjusted ORs	95%CIs	P-values
	N=175 (33%)	N=351 (67%)			
Weight: kg [IQR]	13.0 [9.5 23.5]	11.2 [7.5 22.7]	1.05[a]	0.98 1.11	0.17
Experience of RTs*: times [IQR]	35 [6 121]	58 [23 142]	0.96[b]	0.93 0.98	0.003
Experience of RNs*: times [IQR]	26 [5 58]	44 [20 81]	0.97[b]	0.95 0.99	0.049
Transport modes					
Ground ambulance: n (%)	44 (25)	104 (30)	Ref.	n/a	n/a
Helicopter: n (%)	28 (16)	42 (12)	1.79	0.89 3.59	0.10
Fixed wing propeller: n (%)	99 (57)	193 (55)	1.63	0.91 2.94	0.10
Fixed wing lear jet: n (%)	4 (2)	12 (3)	0.99	0.21 4.84	0.99
Referral hospital with adult ICU (Yes)	78 (45)	142 (40)	0.98	0.76 1.51	0.94
Night transport (Yes): n (%)	71 (41)	161 (46)	0.84	0.55 1.28	0.42
Transport distance: km [IQR]	247 [86 431]	242 [91 392]	1.01[c]	0.93 1.09	0.89
Vital signs[§]					
HR within normal range (Yes): n (%)	75 (43)	186 (53)	0.91	0.59 1.42	0.68
RR within normal range (Yes): n (%)	89 (51)	177 (50)	1.06	0.70 1.60	0.79
SBP within normal range (Yes): n (%)	50 (29)	128 (42)	0.81	0.51 1.30	0.38
SpO_2 >90% (Yes): n (%)	162 (93)	341 (97)	0.21	0.08 0.54	0.001
Treatments/procedures at referral hospitals					
Endotracheal Intubation: n (%)	73 (41)	100 (28)	1.10	0.62 1.95	0.42
Systemic pressor use: n (%)	18 (10)	4 (1)	7.98	2.38 26.79	0.001
Bladder catheter placement: n (%)	70 (40)	96 (27)	1.27	0.76 2.11	0.36
Intraosseous needle placement: n (%)	37 (21)	26 (7)	3.22	1.72 6.04	<0.001
Nasogastric tube placement: n (%)	64 (37)	76 (22)	1.36	0.77 2.39	0.29

**Subgroup analysis for the children who admitted to the PICU within 24 hours from the consult calls. *RTs: respiratory therapists, RNs: transport nurses, [§]Vitals signs measured at the first contact of the transport team were applied, a: by 5kg of body weight increase, b: by 10times increase of experience of transport, c: by 100km increase of the one-way transport distance.

Table 19: Comparisons of Treatments in the PICU between Two Eras

Treatments in the PICU	**PT-Era***	**PLT-Era**	**Adjusted ORs**	**95%CIs**		**P-values**
	N=450 (51%)	N=526 (45%)				
Inotropic agent use: n (%)	146 (33)	110 (21)	0.51	0.36	0.71	<0.001
ECMO use: n (%)	4 (1)	12 (2)	1.53	0.44	5.35	0.51
Arterial line placement: n (%)	207 (46)	244 (46)	0.90	0.67	1.20	0.47
Central venous line placement: n (%)	165 (37)	185 (35)	0.90	0.66	1.23	0.52
Bladder catheter placement: n (%)	333 (75)	329 (63)	0.52	0.38	0.72	<0.001
Antibiotics use: n (%)	330 (74)	413 (79)	1.19	0.84	1.85	0.12
Systemic steroid use: n (%)	160 (36)	163 (31)	0.82	0.60	1.12	0.21
H_2 blocker use: n (%)	159 (36)	130 (25)	0.52	0.38	0.72	<0.001
Parenteral nutrition: n (%)	26 (6)	34 (6)	1.31	0.72	2.39	0.38

ECMO: Extracorporeal Membrane Oxygenation, *Transports (patients) from August 2002 to 2007 were examined.

Table 20: Outcomes of PICU Admitted Patients during the Study Periods

Outcomes	**2002-2007**	**2010-2015**	**Adjusted ORs**	**95%CIs**		**P-values**
	N=4,352	N=6,366				
Death at the PICU: n (%)	147 (3)	227 (4)	0.99	0.76	1.28	0.92
Death at the University hospital: n (%)	209 (5)	269 (4)	0.76	0.61	0.95	0.015
Invasive Ventilation at PICU: n (%)	3,302 (76)	3,466 (54)	0.36	0.33	0.39	<0.001
			Adjusted Diff.**			
PICU Length of Stay: days [IQR]	3 [1 6]	2 [1 5]	-0.6	-0.8	-0.5	<0.001
Hospital Length of Stay: days [IQR]	10 [5 24]	10 [5 24]	-0.6	-1.2	- 0.03	0.040
Invasive Ventilation: days [IQR]	2 [1 5]	1 [0 3]	-1	-1	-0.9	<0.001

**Median regression was fitted, adjusting for PRISMIII (%), Postoperation (Y/N), Emergency Admission (Y/N), and Primary Diagnosis (Cardiovascular disease (aquired and congenital), Respiratory disease (Asthma, Pneumonia, and Bronchiolitis), Trauma, Transplant, and Others).

Table 21: Vital Sign Changes during the Transports: Physician Non-accompanying vs. Physician accompanying Transports in the PLT-Era

Vital Signs	Physician Non-Accompanying	Physician Accompanying	Adjusted ORs	95%CIs		P-values
	N=834*	N=343*				
HR improved/remained: n (%)	491 (59)	176 (51)	0.84	0.64	1.10	0.21
HR deteriorated: n (%)	59 (7)	24 (7)	1.08	0.64	1.80	0.78
RR improved/remained: n (%)	466 (56)	191 (56)	0.91	0.70	1.20	0.52
RR deteriorated: n (%)	134 (16)	51 (15)	0.89	0.62	1.27	0.51
SBP improved/remained: n (%)	362 (43)	107 (31)	0.68	0.51	0.90	0.007
SBP deteriorated: n (%)	109 (13)	49 (14)	1.20	0.82	1.76	0.34
SpO_2 improved/remained: n (%)	778 (93)	310 (90)	0.65	0.41	1.04	0.07
SpO_2 deteriorated: n (%)	26 (3)	11 (3)	1.39	0.66	2.94	0.39

*Transports (patients) from 2010 to 2015 were examined. **Median regression was fitted, adjusting for PRISMIII (%), Postoperation (Y/N), Emergency Admission (Y/N), and Primary Diagnosis (Cardiovascular disease (aquired and congenital), Respiratory disease (Asthma, Pneumonia, and Bronchiolitis), Trauma, Transplant, and Others).

Table 22: Comparisons of Treatments and Procedures at the Referral Hospitals between Physician Non-accompanying vs. Physician accompanying Transports in the PLT-Era (2010-2015)

Treatments & Procedures at referral hospitals	Physician Non-Accompanying	Physician Accompanying	P-values
	N=834**	N=343**	
Narcotics use: n (%)	93 (11)	55 (16)	0.022
Benzodiazepine use: n (%)	141 (17)	78 (23)	0.019
Intravenous fluid bolus: n (%)	422 (51)	203 (59)	0.007
Antibiotics use: n (%)	543 (65)	201 (59)	0.035
Glucose monitoring: n (%)	518 (62)	215 (63)	0.85
Peripheral iv catheter placement: n (%)	717 (86)	285 (83)	0.21
Nasal gastric tube placement: n (%)	106 (13)	79 (23)	<0.001
C-spine precaution: n (%)	18 (2)	17 (5)	0.014*
Foley catheter placement: n (%)	127 (15)	95 (28)	<0.001
Blood culture: n (%)	342 (41)	123 (36)	0.10
Inotropic agent use: n (%)	5 (1)	29 (8)	<0.001*
Arterial line placement: n (%)	5 (1)	4 (1)	0.30*
Central venous line placement: n (%)	1 (0)	7 (2)	0.001*
Intraosseous line placement: n (%)	40 (5)	53 (15)	<0.001*
Endotracheal intubation: n (%)	108 (13)	91 (27)	<0.001
Chest X-ray: n (%)	593 (71)	234 (68)	0.33
Blood gas: n (%)	280 (34)	137 (40)	0.038

*Fisher's exact test, **Transports (patients) from 2010 to 2015 were examined.

5.5 DISCUSSIONS

This is the first report exploring a Canadian PCC transport program's demographics and transport outcomes from the context of team composition. We have found that in the PLT-Era mortality during or after PICU admission was significantly lower and that PICU LOS and invasive ventilation days were significantly shorter. These considerable differences may have been due to temporal changes in PICU practice during the study periods, as opposed to stemming from transport team practice (Table 19 and 20). Here, we also need to note that more patients in the PLT-era had respiratory deterioration, and fewer patients had improvements or maintaining of HR during transport. We have conducted additional analyses, examining vital sign changes between physician accompanying transports and physician non-accompanying transports for the PLT-Era cohort; no statistically significant differences were seen except SBP, for which fewer patients had improvements or maintaining of normal values in the physician accompanying transport group (Table 21). Given those inconsistencies and the small effect sizes, we could infer that the program with increasing use of a physician non-accompanying transport team was at least functioning similarly in terms of transport outcomes when compared to its practice in the PT-era.

Another interesting finding was that more procedures and investigations were performed at the referral hospitals in the PLT-era. This might have resulted from implementation of the new/updated practice guidelines such as pediatric advanced life support or the Surviving Sepsis campaign [79, 80] (Table 22). It might also be conceivable that increased absence of physicians led to a greater dependence on laboratory investigations to create an adequate clinical picture. Regardless, these changes might have influenced transport outcomes between the two eras.

A Canadian study reported that transport-related significant events (such as physiological deteriorations) could be used to evaluate the quality of PCC transports by applying a Delphi method [23]. In recent a randomized controlled trial in the Netherlands, critical events during transports were compared between nurse-led and physician-led interhospital critical care transport. It found that the number of patients with critical events did not markedly differ between the two critical care transport groups, suggesting that treatments and procedures were implemented in an appropriate and timely manner by both teams [81]. We have focused on the vital signs changes during transport, but it might be worth further exploring the events for the effect of physician presence in a PCC transport cohort, as well as to reconsider whether having physician-accompaniment improves patients care during transport.

Many factors can influence the choice of transport team composition, including transport distance, patient's medical condition, and medical services available at referring hospitals. Long transport distances and often-limited rural (referral) health care resources in our catchment area make it difficult to use triage decision models developed in other parts of the world [15, 17, 18, 20, 21, 35]. At present, decisions surrounding patient retrieval in our system (i.e., whether to transport and admit children to a PICU, what clinical expertise is required in the transport team, and what level of inpatient care is appropriate for a given pediatric patient) are made in an ad-hoc subjective manner, as opposed to with the use of a consistent systematic approach. This might explain the variability among the triage physicians in their decision-making with respect to team composition. A recent study from the United States presented pediatric transport team dispatch decision-making discordance by PCC physicians by using a script concordance testing with scenarios [42]. An objective decision-making tool might assist in making consistent decisions in regards to transport team composition for a given critically ill patient [36, 37, 43]. We have identified factors that should be taken into account in the future study of pediatric transport triage tools.

Although the study utilized prospectively collected datasets, the retrospective manner of the study design could have caused several biases. First, biases could have occurred due to the selection of the patients. Our cohort did not capture and include those patients that the PICU transport team did not transport, e.g., patients who died before or without referral calls, or were transported by a non-PICU transport team such as an ALS team (paramedics). There is also a possibility that patients from hospitals that are a shorter distance from the STOL might have been transported more often by the ALS team, particularly when the transport time was critical (e.g., trauma cases) [64-66]. Second, the distance or the transport time could also have been a factor in the decision-making of upper airway security (transport with or without endotracheal intubation) for a given transport. Hence, we applied the propensity-score adjustment to include the distance of the transports to adjust for this. Third, since the vital signs at the time of the initial triage calls were not recorded, we substituted vital sign values that were measured at the time of the transport team arrival at the patient bedside. Although these were the nearest temporally available values to the triage referral calls, the changes in vital sign values that potentially occur while patients await transport team arrival might lead to these values not correlating with those vital signs present at the time of initial team dispatch, contributing to bias. Fourth, temporal changes in transport team practice might have affected our findings. Transport team members or their practice could have changed over the study period, with subsequent effects on patient outcome. Referral hospitals could also have changed during the study periods, whether it be the referral physicians themselves or health care services available/ being provided, all being potential confounders. Lastly, the triage physician could have directed the care remotely even if a patient was transported by a physician non-accompanying PCC team. As we did not quantify and adjust for the amount of direction provided by the triage physician, the findings could be biased.

5.6 CONCLUSION

There were no significant differences in patient outcomes in increasing use of a physician non-accompanying transport team in a Canadian pediatric retrieval system. Selection of transport team composition is influenced by clinical and system factors, and appreciable variation among triage physicians exists even after adjusting for them. Our findings suggest that while equivalence of patient transport related outcomes may occur with the use of physician non-accompanying transport teams, transport systems should exam whether there are other system costs higher (e.g., laboratory costs) that might be associated with this model of care.

CHAPTER 6

Effects of Medical Transport On Outcomes in Children Requiring Intensive Care

The content of this Chapter has been submitted to *Journal of Intensive Care Medicine* as of June 2018, as Atsushi Kawaguchi, L. Duncan Saunders, Yutaka Yasui, and Allan de Caen, "Effects of Medical Transport On Outcomes in Children Requiring Intensive Care".

6.1 ABSTRACT

6.1.1 Background and Objectives

Patient transport may delay access to specialist services and compromise outcomes, particularly in a large geographic area. The aim of this study to explore the effects of inter-facility medical transport on the outcomes in children requiring intensive care in a Canadian regionalization model.

6.1.2 Methods

A retrospective cohort design with a matched pair analysis was adopted to compare the outcomes in children under 17 years old admitted to a Pediatric Intensive Care Unit (PICU) of a Canadian children's hospital by a specialized transport team (PCCT group) and those children admitted directly to PICU from its pediatric emergency department (PED group). The outcomes of interest included mortality 72 hours from initial contact with the critical care team (i.e., either PICU transport team or intra-hospital PICU team).

6.1.3 Results

In total, 680 (27%) transports met our inclusion criteria, whereas 866 (7%) cases out of 11,570 total PICU admissions were admitted directly from the ED. A total of 493 pairs were formed for the matched analyses. Odds of mortality within 72 hours in the PCCT group were significantly higher than in the PED group (OR; 2.18, 95%CI; 1.07 to 4.45, P=0.032). When excluding cases who had at least one episode of cardiac arrest before involvement of the PCC transport team, the OR dropped to 1.66 (95%CI: 0.77 to 3.46).

6.1.4 Conclusions

Children transported from non-pediatric hospitals had a higher 72-hour mortality when compared to those children admitted directly to a children's hospital PICU from its own PED in a Canadian regionalized health care model. It was unclear whether outcomes were worse based upon the specific patient population presenting to the rural sites, the care provided prior to the arrival of the PCC transport team, or the care provided by the PCC transport teams themselves.

6.2 INTRODUCTION

Evidence suggests that the regionalization of pediatric specialty services, including critical care, improves patient outcomes [1, 4, 5, 82]. In order for this kind of system to function effectively, critically ill or injured children have to be safely and efficiently moved to the tertiary care hospital from referring hospitals. Studies also suggest that patient transport by specialist retrieval teams is associated with better patient outcomes [15, 17, 21]. Nonetheless, prolonged patient transport times may delay access to specialist services and compromise outcomes, particularly in a large geographic area such as Canada.

Referral physicians in Alberta consult pediatric intensivists in one of two children's hospitals (Edmonton and Calgary) to aid in the stabilization and transfer of critically ill or injured children. The pediatric intensivists have to decide, based on the information provided by the referral physicians, the most appropriate team to transport the individual pediatric patient: an Advanced Life Support (ALS: paramedic) team; an adult transport team which is based in an independent rotary transport organization (STARS; Shock Trauma Air Rescue Service); a Pediatric Critical Care (PCC) physicianless transport team; or a PCC transport team accompanied by a physician [44]. More details addressing the transport program can be found in the following study [83].

The Stollery Children's Hospital (SCH, Edmonton Canada) is a quaternary academic children's hospital with a large catchment area that includes Central and Northern Alberta, Northwestern Territories, eastern Yukon, and western Nunavut, and includes at least 850,000 children under 17 years of age [41]. More than 30,000 visits are made to the pediatric emergency department in the SCH annually.

SCH launched a Pediatric Intensive Care Unit (PICU)-based, dedicated PCC transport team in 1996 as a part of on-going regionalization of provincial pediatric care. The transport team has been staffed by physicians (trained in pediatric critical care, anesthesiology, or emergency medicine), respiratory therapists and nurses. Since January 2008, the transport team has increasingly sent physicianless transport teams as opposed to teams accompanied by a physician.

This study aims to explore the impact of patient transport on the outcomes of critically ill or injured children. Although this will not be able to assess the impact of the PCC transport team specifically, this will assess the impact of a pediatric retrieval system using a PCC transport team.

6.3 METHODS

6.3.1 Data Used

We accessed two independent databases: (I) a hospital-based transport administrative database, which includes all transports performed by the PCC transport team since 1998; and (II) a hospital-based PICU discharge summary database, which has existed since August 2002. We extracted transport characteristics, individual patient's identifiers and demographics, and vital signs during the transports from database (I). The following data were extracted from the database (II): dates and times of the PICU admission, discharge from the PICU and hospital, and death if a patient died, the individual patient's identifiers, demographics, care unit prior to the PICU admission, vital sign values originally collected to calculate Pediatric Risk of Mortality (PRISM-III) score, and treatments given and procedures performed during the PICU stay.

6.3.2 Patients and Transports

We included children under 17 years of age who were admitted to the SCH PICU either by being transported by the PCC transport team (August 2002 and December 2015) or were directly admitted from the SCH pediatric emergency department (PED) (August 2002 - March 2016). All cases in 2009 were excluded due to a system issue in database (II). Patients/transports which met the following criteria were also excluded from analyses: (a) transports which did not lead to PICU admission within 24 hours from the contact calls; (b) transports from hospitals in Southern Alberta (catchment area of another provincial children's hospital), Manitoba, Saskatchewan, PICUs in other Canadian provinces; (c) international transports; (d) newborn infants who were transported by the SCH's neonatal transport team; (e) non-emergent pediatric transfers; (f) patients who were admitted to the general pediatric ward after transport; (g) patients who were admitted to PICU after a procedure/surgery in the operating room; (h) patients who died before the PCC transport team's arrival at the referral hospital or those patients transported without the involvement of the PCC transport team; and (i) patients who were transported from other hospitals to the PED in the SCH by non-PCC transport team such as ALS or STARS.

6.3.3 Outcomes

The primary outcome was 72-hour mortality from initial contact with the "PCC team", which was defined as the time of arrival of the PCC transport team at referral hospitals for transported cases, and the time of PICU admission for the PED cases. We applied 72 hours based on the idea that physicians generally make a decision on withdrawal of life-supporting cares (i.e., goal of care) within 48 hours of PICU admissions (Figure 21) [84-86]. We classified patients as "deceased before transport" when vital sign values during the transports were not recorded in the dataset (I). The secondary outcomes were 24-hour mortality (after initial contact with the PCC team), PICU and hospital length of stay (LOS), and endotracheal intubation during the course of care (i.e., either before transport team's involvement or in the PED, during the transport, or during the PICU admission).

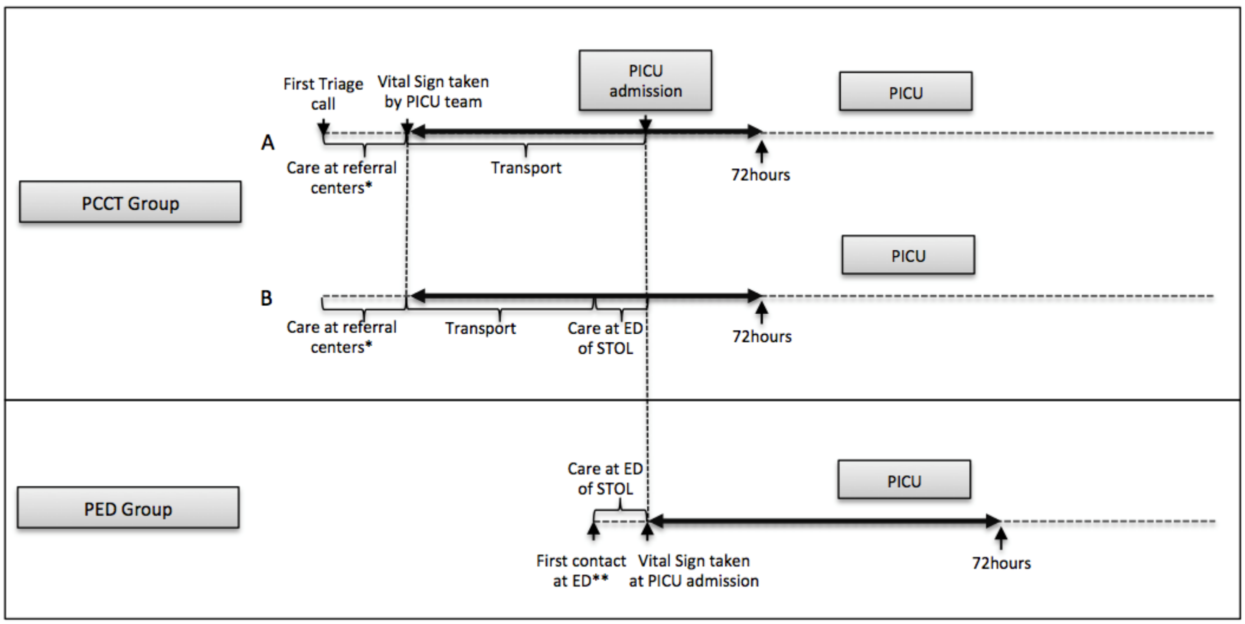


Figure 21: Diagram of Practice Flow and Outcomes.

*Provided by General Practitioners, Family physician, Emergency Physician, or other health care providers **By Pediatric Emergency Physician.

6.3.4 Statistical Methods

First, for each patient in dataset (I), we selected matching patients in dataset (II). We applied 1:1 propensity score matching. Propensity scores were produced by performing an unadjusted logistic regression for the known potential confounding variables (please see the next section), with the PICU admission with transports as the outcome to assess unadjusted associations. We used nearest-neighbor matching of the logit of the propensity scores using caliper widths equal to 0.2 of the standard deviation of the logit of the propensity score, without replacement [61, 62].

The variables used for the propensity score creation included patients' age, time of consult calls (daytime: 7AM-7PM or night: 7PM-7AM) for which "PICU admission time" was applied to the patients in (II), duration until the PICU team started patient' care (i.e., time from consult call to the PCC transport team's arrival for (I) and waiting time at PED for (II)), patients' vital signs including systolic blood pressure (SBP), respiratory rate (RR), heart rate (HR), and body temperatures (BT) where the vital signs at the first contact by the PCC transport team for the patients (I) and those at the PICU admission for the patients (II). We categorized age by applying prespecified categories (<3 months, 3 to <12 months, 1 to 4 years, 5 to <12 years, and ≥12 years). For four other continuous variables (i.e., SBP, HR, RR, and BT), we categorized them into age-appropriate severity levels from 1, 2, or 4, by applying the cut-off values in a pre-existing pediatric early warning (PEW) scoring system [87]; and we utilized the sum values for the propensity score creation. For the study purpose, we classified the diagnoses into the following five categories: (i) primary respiratory disease such as bronchiolitis, asthma, and pneumonia; (ii) trauma; (iii) seizure; (iv) sepsis or/and shock (i.e., including patients with any clinically defined etiology of shock; cardiogenic, hypovolemic, distributive, and obstructive); and (v) others.

Descriptive statistics were performed to explore differences between the two groups, e.g., PCC Transported group (PCCT group) vs. Directly admitted from the PED group (PED group). Each variable's distribution was described by mean and standard deviation (SD); for asymmetrical distributions, we used median and Interquartile Range (IQR). We then examined the 72-hour mortality and secondary outcomes. Conditional logistic regression and multivariate linear regression using geometric means of outcome values were applied to compare the binary and continuous outcomes between the matched patients.

6.3.5 Sensitivity and Subgroup Analyses

We conducted a sensitivity analysis, excluding those patients who died prior to PICU admission who had an initial cardiac arrest before the PCC transport team's arrival, or with an unclear history of cardiac arrest at referral hospitals. This analysis is also based on the assumption that no patients in the PED group had a cardiac arrest prior to the PICU admissions. We also performed subgroup analyses for the primary outcome for those cases transported by the PCC transport team and accompanied by a physician, and for those cases transported from hospitals where adult ICU care was available.

A two-sided p-value of less than 0.05 was considered statistically significant. All statistical analyses were conducted with Stata version 13® (Stata Corp LP, TX USA). This study was approved by the Health Research Ethics Board of University of Alberta, Canada.

6.4 RESULTS

6.4.1 Patient and Transport Demographics

In total, 680 (27%) of 2,518 transports during the study period met our inclusion criteria, whereas 866 (7%) cases out of 11,570 total PICU admissions were admitted directly from the PED and met the inclusion criteria (Figure 22). Patients and transport characteristics are shown in Table1. All the variables except gender presented statistically significant differences between the two groups, in which the PCCT group was younger and had lower PEW scores than the PED group.

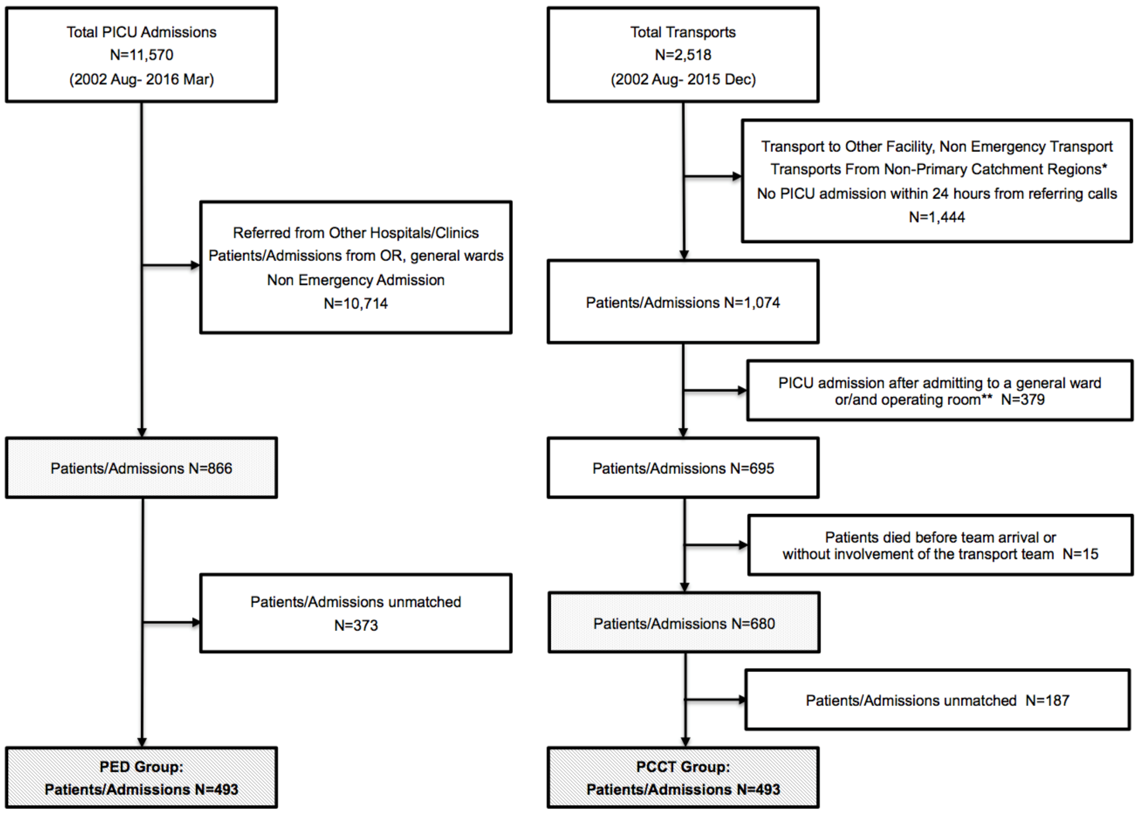


Figure 22: Flow Chart Detailing Sample Selection Criteria.

A total of 493 pairs were formed for the matched analyses. The distribution of the propensity scores was shown in the Figure 23. All the variables were equally balanced after the matching procedure except four variables (i.e., waiting time, SBP, BT, and the total PEW scores), albeit none of them being clinically significantly different (Table 23).

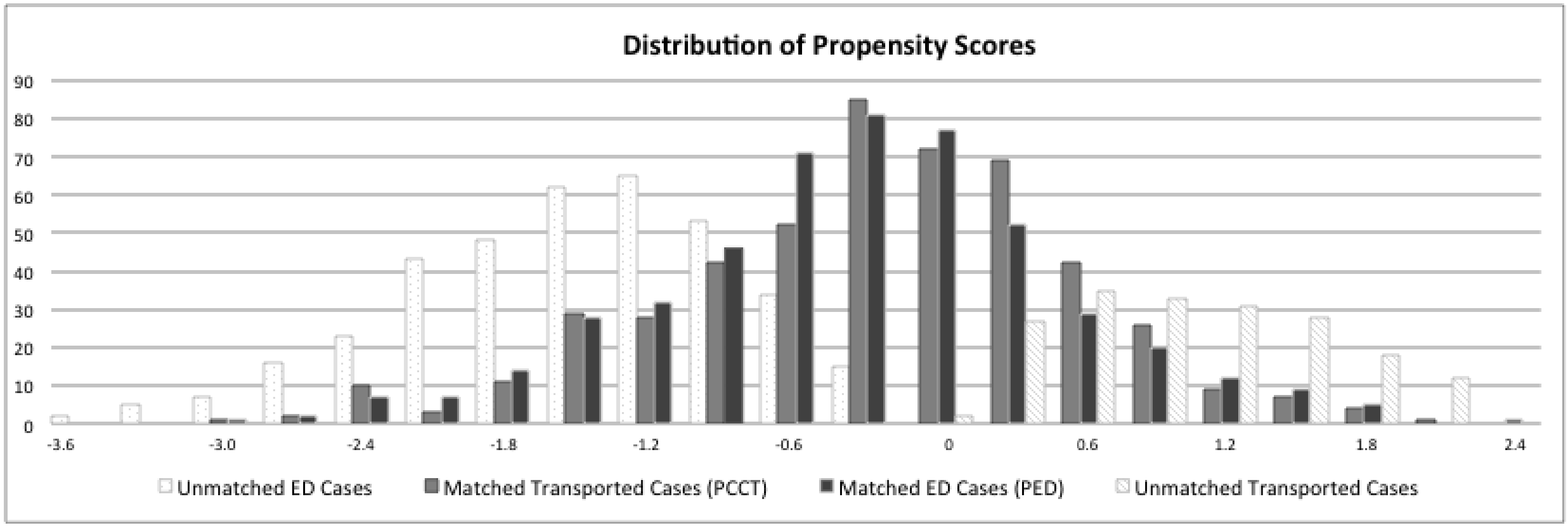


Figure 23: Distribution of Propensity Scores.

Odds of mortality within 72 hours in the PCCT group were significantly higher than the PED group (OR; 2.18, 95%CI; 1.07 to 4.45, P=0.032). No statistically significant difference in mortality within 24 hours of PCC contact and mortality before or at the PICU were observed (Table 24). Table 25 showed primary diagnoses of the deceased cases in the matched cohorts, which did not present significant differences between the two groups.

A significantly higher risk of endotracheal intubation in the PICU or before the PICU admission was observed in the PCCT group (OR; 2.91, 95%CI; 2.19 to 3.85, P<0.001). While hospital LOS did not differ between the two groups, a statistically significant difference was detected in the PICU LOS, in which the PCCT group had a longer PICU LOS (geometric mean difference; 1.2 days, P=0.001). Patients in the PCCT group required more therapeutic intervention(s) such as vasopressors use, arterial line placement, and central venous line placement (Table 26)

6.4.3 Sensitivity and Subgroup Analyses

Table 27 presented the details of the nine patients, for whom the PCC transport team were involved in management but died prior to PICU admission. Seven patients had at least one cardiac arrest or unclear history about cardiac arrest before the PCC transport team took over management at the referral hospital. When we excluded those seven patients, the OR for 72-hour mortality fell to 1.66 (95%CI; 0.77 to 3.46, P=0.20). For the entire study cohort before matching, there were fifteen cases for whom the PCC transport team was dispatched to the referral hospital, but the team did not initiate management due to the patients' death.

The analyses for the subgroup transported by a PCC transport team accompanied by a physician showed a consistent result with the entire matched cohort; which is to say, a significantly higher odds of mortality at 72 hours was observed in the PCCT group as compared to the PED group (OR; 4.0, 95%CI; 1.3 to 12.0, P=0.013). For the patients transported from high-level care hospitals (those hospitals with adult ICU support), 72-hour mortality was higher in the PCCT group than in the PED group albeit not being statistically significant (Table 28).

Table 23: Demographics of the Entire Cohort

	Whole Cohort			Matched Cohort		
Variables	**PED**	**PCCT**	**P-values**	**PED**	**PCCT**	**P-values**
	N=866	N=680		N=493	N=493	
Gender: male: n (%)	495 (57)	365 (54)	0.17	283 (57)	270 (55)	0.40
Age: year (IQR)	3.5 (0.8 11.5)	1.9 (0.5 7.2)	<0.001	2.3 (0.7 7.6)	2.0 (0.6 7.9)	0.66
Age Category						
<3month (%)	116 (13)	108 (16)		69 (14)	77 (16)	
3 - 12month: n (%)	126 (15)	118 (17)		88 (18)	86 (17)	
1 - 4year: n (%)	216 (25)	217 (32)	<0.001	149 (30)	143 (29)	0.94
4-12year: n (%)	205 (24)	142 (21)		112 (23)	108 (22)	
12year<: n (%)	203 (23)	95 (14)		75 (15)	79 (16)	
Weight: kg (IQR)	15 (8 38)	12 (8 24)	<0.001	13 (7 27)	13 (8 26)	0.86
Waiting Time: min (IQR)§§	3.7 (2.2 7.0)	2.2 (1.2 3.0)	<0.001	3.1 (1.8 6.0)	2.4 (1.5 3.4)	<0.001
Night Transport: n (%)§	514 (59)	355 (52)	0.005	278 (56)	274 (56)	0.80
Primary Diagnosis						
Respiratory Disease: n (%)	240 (28)	164 (24)		127 (26)	125 (25)	
Seizure: n (%)	68 (8)	105 (15)		56 (11)	53 (11)	
Sepsis/Shock: n (%)	74 (9)	54 (8)	<0.001	40 (8)	37 (8)	0.95
Trauma: n (%)	89 (10)	96 (14)		60 (12)	68 (14)	
Others: n (%)	395 (46)	261 (38)		210 (43)	210 (43)	
Vital Signs						
HR* (SD)	2.2 (1.3)	1.7 (1.4)	<0.001	1.9 (1.2)	1.9 (1.4)	0.87
RR* (SD)	1.3 (1.4)	0.9 (1.3)	<0.001	0.9 (1.1)	1.1 (1.4)	0.26
SBP* (SD)	1.6 (1.0)	0.9 (1.0)	<0.001	1.5 (0.9)	1.0 (1.1)	<0.001
BT* (SD)	0.5 (0.7)	0.2 (0.5)	<0.001	0.4 (0.6)	0.3 (0.6)	0.007
PEWS** (SD)	5.6 (2.5)	3.8 (2.6)	<0.001	4.6 (2.2)	4.4 (2.7)	0.015

*Mean of Pediatric Early Warning Score; Category and Scoring are adopted from *Paediatr Child Health* 2011;16(3):e18-e22.

**Average of sum of the four elements. §Transports for which the PCC transport team arrived the referral hospital between 7:00PM-7:00AM

Table 24: Demographics of the Entire Cohort

Outcome Variables	PED	PCCT	Odds Ratios	95%CIs	P-values
	N=493	N=493			
Mortality within 72 hours: n (%)	15 (3)	28 (6)	2.18¶	1.07 4.45	0.032
Mortality within 24 hours: n (%)	9 (2)	10 (2)	1.13	0.43 2.92	0.81
Mortality before or at PICU§: n (%)	24 (5)	35 (7)	1.67	0.93 2.99	0.09
Endotracheal Intubation*: n (%)	185 (38)	304 (63)	2.91	2.19 3.85	<0.001
			Mean Diff.§§		
PICU LOS: days (IQR)	2 (1 - 4)	3 (1-6)	1.2	n/a	0.001
Hospital LOS: days (IQR)	7 (4 - 13)	7 (3 - 14)	1.0	n/a	0.57

*Intubation in the PICU or prior to the PICU admission. § Mortality prior or during the stay at the PICU, and Mortality prior or during the stay at the SCH. §§Geometric Means was used. ¶Sensitivity Analysis with excluding cases who had at least one episode of cardiac arrest before the PCC transport team started involving: Odds Ratio; 1.66, 95%CI; 0.77 to 3.46, P-value; 0.20. When body temperature and SBP were added in adjustment: Odds Ratio; 3.77, 95%CI; 0.48 - 29.42, P-value; 0.21.

Table 25: Primary Diagnosis for Deceased Cases

Diagnosis	PED	PCCT
Respiratory Disease**	1 (7)	0 (0)
Seizure	1 (7)	0 (0)
Sepsis/Shock	1 (7)	2 (7)
Trauma	6 (40)	7 (25)
Others	6 (40)	19 (68)

In matched cohort, who died within 72 hours. **including bronchiolitis, asthma, and pneumonia.

Table 26: Therapeutic Interventions in the PICU for the Matched Cohort

Outcomes	PED	PCCT	P-values
	N=484	N=484**	
Vasopressor use: n (%)	73 (15)	142 (29)	<0.001
ECMO: n (%)	6 (1)	10 (2)	0.32
Continuous Renal replacement Therapy: n (%)	2 (1)	6 (1)	0.18
Arterial line: n (%)	158 (33)	247 (51)	<0.001
Central venous line: n (%)	116 (24)	185 (38)	<0.001
Bladder catheter: n (%)	216 (45)	337 (70)	<0.001
Intracranial pressure line (%)	11 (2)	18 (4)	0.20
Systemic antibiotic use: n (%)	326 (67)	355 (74)	0.042
Systemic steroid use: n (%)	104 (22)	170 (35)	<0.001
Systemic H_2blocker use: n (%)	131 (27)	165 (34)	0.020
Total Parenteral nutrition: n (%)	26 (5)	31 (6)	0.49

*Conditional logistic regression. **Nine cases who died before PICU admission were excluded.

Table 27: Characteristics and Etiologies of Deceased Cases before PICU Admissions

Case	HLCH*	Night Transport**	Call to Arrival: >200min	Cause of Death/Etiology	Arrested Only After the team Arrival[#]
1	N	Y	N	Septic Shock	Y
2	Y	N	N	Septic Shock	N
3	N	Y	N	Septic Shock	N
4	N	N	Y	Septic Shock	NA
5	Y	Y	N	Cardiogenic Shock	Y
6	N	N	N	Trauma	NA
7	Y	Y	Y	Near-Drowning	N
8	N	N	N	Unknown	N
9	Y	Y	Y	Unknown	NA
10	N	Y	N	Primary Respiratory Failure	N
11	N	Y	N	Primary Respiratory Failure	NA
12	N	Y	N	Septic Shock	N
13	N	N	N	Septic Shock	N
14	N	N	N	Septic Shock	NA
15	N	N	N	Septic Shock	N
16	Y	N	N	Septic Shock	N
17	Y	N	N	Cardiogenic Shock	NA
18	N	Y	Y	Cardiogenic Shock	N
19	N	Y	Y	Cardiogenic Shock	N
20	Y	N	N	Trauma	N
21	Y	N	Y	Near-Drowning	N
22	Y	Y	Y	Near-Drowning	N
23	N	N	N	Near-Drowning	N
24	Y	N	Y	Unknown	NA

Case 1-9: Cases whom the PCC transport team involved in the care at referral centers. Cases 10-24: Cases whom the PCC transport team dispatched to the referral hospital, however, the team did not involve the care (i.e. no measurements were recorded for vitals signs and treatments). *Y: referred from HLCH (High Level Care Hospitals: Hospitals with ICU level of care facility), **Y: Transports for which the PCC transport team arrived the referral hospital between 7:00PM-7:00AM. [#]Y: If patients had cardiac arrests after the PCC transport team arrived without cardiac arrests prior to the arrival. NA: Unclear from the dataset.

Table 28: Subgroup Analyses

Outcome	*MD Transports vs. Matched PED Patients	ORs (95%CI), P-values
	N=308	
Mortality in 72 hours: n (%)	19 (6)	4.0 (1.3 12.0), 0.013
	****Transports from HLCCs vs. Matched PED Patients**	**ORs (95%CI), P-values**
	N=214	
Mortality in 72 hours: n (%)	12 (6)	2.5 (0.78 7.97), 0.12

*Physician Accompanying Transport, **High Level Care Centers: Referral Hospitals with ICU level of care facility.

6.5 DISCUSSIONS

We found a significant difference in risk of mortality in 72 hours from the initial contacts of the "PCC team" between the children who were transported from referral hospitals and the children directly presented to the PED in a tertiary children's hospital. Our study is the first report exploring the PCC transport service operated with a specialized PCC transport team in a regionalized western Canadian health care model, which has a large geographical catchment area as compared to the previous studies from other countries or regions. Our study was also unique because we did apply mortality in an acute clinical phase as a primary outcome of the study; we believe that it reflected more directly the initial management of care prior to and including the care provided by a PCC transport team as opposed to a more remote outcome such as after PICU admission (PICU LOS or PICU mortality).

Relatively few reports have examined the PCC transport system for critically ill or injured children [15, 28-30]. A study from the United Kingdom examined the effect of regionalization of critical care on the outcomes of critically ill children transferred from referral hospitals, using a nation-wide PICU audit database. It reported that children retrieved from other hospitals had an equivalent PICU mortality to children admitted to the PICU from within a tertiary hospital; it also presented an increasing association between PICU mortality and longer transport travel distances [15]. Our findings may differ somewhat due to specific differences in the healthcare systems due to how critical care has been regionalized, including differences in referral thresholds. It should also be emphasized that transport distances in our model were significantly longer than those reported in previous studies [15, 16]. A retrospective cohort study from Scotland examined the transport distance with which a PCC transport team could travel to retrieve head injured children without an additional delay in reaching definitive critical care. Transport distances were significantly shorter (i.e., 108km) than our regionalization model's [16].

Recognizing the limitations in being able to adjust for patient acuity and etiology of disease prior to the PCC transport team arrival (Please refer to the following section for details), and that the care being provided by non-specialized healthcare teams (i.e., non-PCC team) prior to the arrival of the PCC transport team was likely not equivalent to that provided by the PCC "PICU in-house" team, it might not be surprising that the outcomes for the PCCT group were worse than the PED group. Regardless, the PCC transport team might not be able to provide totally equivalent care to that given to patients arriving through the PED, due to the limitation of healthcare resources (e.g., personnel, special life-saving equipment such as extracorporeal membrane oxygenation) that were not available in the transport setting, but were available in the PICU of the children's hospital. The sensitivity analysis, which was based on an extreme assumption that no patients in the PED group had a cardiac arrest before PICU admissions, presented the same trend of the effect for the entire matched cohort albeit being statistically insignificant. In other words, if we assumed that a certain number of patients in the PED group were admitted to the PICU after a cardiac arrest event, the effect size reported above should be even larger and significant, which could support this hypothesis.

How should we examine the effect of a transport system or the transport itself outopatient outcomes in a better way and what is the next target of study? It is impossible to randomize patients to assess the effect of remoteness or the effect of transport, necessitating the use of analytical procedures such as adjustment. Patient acuity at presentation to hospital and prior to actual transport needs to be adjusted for. An organized and standardized data collection system involving a larger cohort would be useful, by referring such as a population-based data [34, 88]. Outcome measures such as parental satisfaction and direct financial costs to families should also be considered in the future.

There are several other potential limitations in this study. First, although the study utilized prospectively collected datasets, the retrospective manner of the study design of the secondary data use could have led to several biases. Our study cohort did not capture the patients for whom the PCCT team was not activated. Those are the patients, for instance, who died before or without referral consult calls, or were transported by a non-PCCT team such as an ALS or STARS. Nonetheless, as a general practical rule, all the pediatric cases who had a return of spontaneous circulation after cardiac arrests in the PED should have been transferred to the PICU for subsequent management, suggesting that the number of these patients should be small. Second, we have adjusted for the severity of illness by applying vital sign values recorded to calculate the risk of mortality score (PRISM-III), including the worst values observed in the first 12 hours after PICU admission. Although we can assume that the majority of sick children were sickest at the time of their PICU admission, bias could still have occurred. Third, for the PCCT group, some patients received initial management in a different clinic/hospital from that recorded as the referral hospital. Duration of care and care providers involved prior to the involvement of the PCC transport team could have also been different; in the PCCT group, physicians such as family physicians, generally provide care at referral hospitals, whereas pediatric specialized emergency physicians usually lead the care for the PED group. Other possible confounding factors such as patient race, religion, and socioeconomic backgrounds could have skewed results. Specific to this, disparities in child mortality have been present in the indigenous Canadian population compared to the general Canadian population, which is one of our principal cohorts in Northern Alberta [89].

6.6 CONCLUSIONS

Children admitted to a PICU that were transported from another hospital by a PCC transport team had a higher mortality in the acute phase when compared to children presenting directly to a PED in a tertiary children's hospital and requiring PICU admission. It was unclear whether outcomes were worse based upon the specific patient population presenting to the rural sites, the care provided prior to the arrival of the PCC transport team, or the care provided by the PCC transport team themselves.

CHAPTER 7

Discussion

In this chapter, I will summarize the findings and important discussion points including future directions of this project.

7.1 Canadian PCC Transport

Our nation-wide survey reported in **Chapter 3** revealed a complexity and variability such as in transport teams demographics, volumes, team composition, decision-making process, and database and quality assurance activity. It also found that many regions in Canada were still under-serviced when it came to PCC transport.

There are several potential reasons to explain this situation. In the absence of evidence regarding the "best transport model" and due to the differences in geography, referral patterns, and locally available healthcare resources, programs for the transport of critically ill or injured children have historically evolved as occasion demands in each region. Given the heterogeneity of the healthcare context (e.g., population distribution, number of hospitals), it is challenging to examine or compare transport systems with respect to their efficiency or the quality. The heterogeneity of disease etiology (i.e., from trauma to respiratory failure) and the relatively small patient cohort in "Pediatrics" as compared to the "Neonatal" or "Adult" also can be a barrier to do a robust comparisons of these programs.

To overcome these barriers and provide generalizable quality evidence, we believe that creating a standardized transport database composed of common data elements and data definitions, is a necessary step. Analysis of data from this database can provide evidence and knowledge that should be shared through a national pediatric transport network, to allow for benchmarking as well as to raise the standard of care being provided during the inter-facility transport of critically ill or injured Canadian children.

7.2 PCC Transport in Northern Alberta

Low PICU Admission Rate (Please refer to **Chapter 4**)

The PICU admission rate following the transports in our program remained relatively low, which was considerably lower than the data previously published from other countries [34, 64]. However, it was unclear whether the low admission rate was a consequence of inefficient triage (e.g., referral and retrieval thresholds were inappropriately low) or reflected a different burden of critical illness and/or different model of healthcare system.

We found that patients transported from hospitals with an adult ICU had a higher probability of requiring PICU admission than those from others. This could reflect different referral or retrieval thresholds between the two groups. Here, we should take note of the fact that there was heterogeneity among these hospitals; some hospitals with an adult ICU showed a significantly lower likelihood of their patients requiring PICU admission after transports. This might suggest that specific hospital-level factors might affect the likelihood. These factors, for instance, could be unavailability of a particular medical specialty such as an anesthesiologist or a specific surgeon (e.g., general pediatric surgeon, ENT (ear nose throat)).

Again, the low admission rate does not necessarily dent an inefficient transport system. However, we need to examine whether healthcare resources (locally or provincially) are utilized appropriately and efficiently in a current system. To further discuss the efficiency of transport and use of PCC transport team, it is required to peruse the outcomes and/or underlining factors associated with transports (e.g., reason of requiring transports other than a patients' severity of illness) for whom ICU level of care is not required even after the PCC transports.

Increasing Demand (Please refer to **Chapter 4**)

The transport activity to the SCH increased in numbers and distance over the study period. Other notable findings included monthly variation in transport activity, and expansion of the referral areas/communities of transport. There was also an increasing trend in transport times such as time for the PCC transport team dispatch (Please refer to Figure 4). Given that the PCC transport team is limited in number, our findings could signify the need for team reorganization of staffing and the availability of specific modes of transport.

Team Component (Please refer to **Chapter 5**)

There were no significant differences in patient outcomes associated with the increasing use of a physician non-accompanying transport team in our pediatric retrieval system. The focus on increasing team efficiency did not come at the price of patient outcomes. Selection of transport team composition is influenced by clinical and system factors, and appreciable variation among triage physicians exists even after adjusting for them. Although we did not examine the heterogeniety in each physician affected patient outcomes such as mortality or cost efficiency, we believe that further study of how to standardize triage practice should be carried out before any attempt is made to study an implementation effect on patient outcomes

Effect of Transport on Patient Outcomes (Please refer to **Chapter 6**)

Children admitted to the SCH PICU who were transported from another hospital by a PCC transport team had higher mortality in the acute phase when compared to children presenting directly to the SCH PED and who subsequently required PICU admission. We need to further examine whether the discrepancy stemmed from the specific patient population presenting to the rural sites, the care provided prior to the arrival of the PCC transport team, or the care provided by the PCC transport teams themselves. A most recent study using a nation-wide data from the UK and Ireland reported that transports from an intensive care area (i.e., hospital with adult ICU, PICU, or NICU) were associated with lower PICU mortality [31]. Moreover, there were considerable variations in standardized mortality ratios as well as in the way of team organization across the PCC transport teams. In any case, this discrepancy or heterogeneity needs to be further investigated with a comprehensive understanding of each transport system (locally or provincially) in a future study.

7.3 Future Directions

Our studies have helped us to further understand the currently operating provincial pediatric retrieval system and hopefully to improve its operational efficiency and cost effectiveness. The elements discussed in this thesis (i.e., level of available healthcare resource, transport team composition selection, accessibility to a tertiary level of care facility) should be further examined for potential generalizability in other provinces or countries. Then, how should we further improve the system and practice in the future?

7.3.1 Challenges of Implementing a Triage Score/Tool

Objective patient triage using a decision-making tool might help us to make consistent and efficient PCC transport triage decisions. This is necessary not only for the selection of team components, but also to determine the need specifically for PCC transport team dispatch, whether to transport and admit children to a PICU, and what level of inpatient care is appropriate for the given critically ill or injured pediatric patient.

A decision-making tool could: provide more appropriate and efficient use of non-PCC transport teams (i.e., ALS paramedic, STARS) to move lower acuity patients so as to avoid the unnecessary use of the PCC transport team; identify lower risk patients, allowing for reduced patient transfers to the children’s hospitals and a greater use of regional pediatric beds. It may also reduce the movement of parents over long distances while accompanying their children, improving parental satisfaction, as well as of healthcare providers in referral hospitals.

We have proposed a future study to evaluate existing pediatric triage scoring systems and to design a new scoring system to help predict the need for PICU care for the children being consulted on by referral hospitals, in collaboration with Alberta Children's Hospital (Collaborators: Dr. Angelo Mikrogianakis: Director of Pediatric Emergency Medicine and Dr. Eli Gilad: Co-Director of ACH PCC transport team) (Appendix 3) [49, 50, 87, 90, 91]. We have already collected data from "RAAPID summary transcripts and audio record files." The transcript includes patients' identifiers, summaries of each transport referred through RAAPID (i.e., the name of the physician involved, modality of transport, accepting unit, and a summary note of triage call/discussion) [40]. The audio record files contain all the conversations among practitioners (i.e., intensivists, referring physicians, transport nurses). These data have been provided prospectively on a monthly basis over one year in collaboration with RAAPID (Collaborator: Dr. Praveen Jain: Director of RAAPID in AHS). As addressed in the ***Chapter* 5 and 6**, the cohort captured in the datasets used did not include patients that the PICU transport team did not transport, e.g., patients who died before or without referral calls, or were transported by a non-PICU transport team such as an ALS team (paramedics). This data from RAAPID could compensate the drawbacks and could help us to examine and discuss the system more throughly.

Over the course of the data collection, significant proportions of missing values for each assessment item were identified (i.e., vital sign variables), which were necessary to calculate the scores. In other words, our preliminary data inferred that implementing a scoring system based on our current data collection practice might not be easily implemented. This led to an amendment to the study purpose and design, to the described in the next section.

Other potential barriers to broad implementation of a triage tool to predict the need for PICU level of care (or not) could include: (1) real or perceived weaknesses in cognitive or technical skills of physicians providing care at referral hospitals, which may lead to poor reliability of tools/scores; (2) the potential for a change in the balance (i.e. number) of paramedic- to PICU-transports might not be viewed favorably by either paramedic or PICU teams due to workload issues (if transport workload increased) or concerns surrounding potential loss of skills maintenance (if transport volume falls); (3) referral hospital physicians might see the triage process as being a potential barrier to them being able to transfer those patients out of their hospitals that they feel require a higher-level of care; and (4) parents of children that are not transported, or are transported to secondary hospitals (as opposed to tertiary hospitals) might not be in favor of any potential barrier to the transfer of their children to tertiary hospitals.

These challenges and barriers need to be addressed in building and implementing a triage tool in order to have effective knowledge translation. We would also emphasize the importance of engagement of relevant stakeholders with experience in managing and organizing patient transport in the process, which could allow us to evaluate the outcomes and to monitor knowledge use during and after the implementation.

7.3.2 Study in Progress

Based on the findings stemming from the data collection from the RAAPID audio files, we have amended the study design to focus on how to improve "*triage quality.*" To be specific, we decided to further explore those factors potentially impacting negatively on *triage quality*, in particular with respect to the following: the proportion of missing values in the time/length of triage call; inappropriate patient transfer (e.g., a transport decision that leads to a patient being transferred to a non-tertiary hospital but still needing further transfer to a tertiary level PICU within 24 hours from the initial transport) [92-94]. Other potential factors to be examined include referring physician demographics (post-graduate year, international graduate, practice specialties, includingfamily medicine, general pediatrics, or emergency medicine).

7.3.3 Technological Aids to Patient Triage

Novel technological supports such as telemedicine or artificial intelligence or machine learning may need to be further studied in the context of transport triage [95-100]. A pilot randomized controlled study explored the feasibility and effect of video teleconferencing on triage, comparing to an ordinal "phone" triage. It suggested a benefit to the use of video teleconference to aid in the assessment and decision making surrounding patient disposition [95]. Another recent study that evaluated a machine-learning-based triage algorithm to predict the need for PICU level of care for newly hospitalized children suggested a higher sensitivity and specificity with its use as opposed to with using "pre-specified" PEW scores [97].

7.4 General Conclusions

This thesis project aimed to characterize PCC transports currently performed by the SCH PICU transport team in Northern Alberta and the Western Arctic, while also exploring the clinical impact of transport itself on the outcomes of critically ill children, in the hope of further understanding of the factors which could be used to provide objective pediatric transport triage decision-making in future local practice. This project can benefit our current pediatric transport system by assisting in the planning of future healthcare strategies such as of resource allocation or availability of transport modalities. It produced supportive evidence for our current pediatric retrieval system, but also could contribute to more efficient healthcare resource utilization and improved quality of care for critically ill and injured children in Northern Alberta, and potentially elsewhere.

REFERENCES

1. Karamlou T, Vafaeezadeh M, Parrish AM, et al. Increased extracorporeal membrane oxygenation center case volume is associated with improved extracorporeal membrane oxygenation survival among pediatric patients. *J Thorac Cardiovasc Surg* 2013;145(2):470-5. doi: 10.1016/j.jtcvs.2012.11.037

2. Marcin JP, Song J, Leigh JP. The impact of pediatric intensive care unit volume on mortality: a hierarchical instrumental variable analysis. *Pediatr Crit Care Med* 2005;6(2):136-41. doi: 10.1097/01.PCC.0000154962.73861.66

3. Ruttimann UE, Patel KM, Pollack MM. Relevance of diagnostic diversity and patient volumes for quality and length of stay in pediatric intensive care units. *Pediatr Crit Care Med* 2000;1(2):133-9.

4. Tasker RC, Fleming TJ, Young AE, et al. Severe head injury in children: intensive care unit activity and mortality in England and Wales. *Br J Neurosurg* 2011;25(1):68-77. doi: 10.3109/02688697.2010.538770

5. Tilford JM, Simpson PM, Green JW, et al. Volume-outcome relationships in pediatric intensive care units. *Pediatrics* 2000;106(2 Pt 1):289-94.

6. K. McCloskey RO. Pediatric Transport Medicine; Chapter2 History of medical Transport Systems: Air, Gournd, and Pediatric. 1995:5-14.

7. Karlsen KA, Trautman M, Price-Douglas W, et al. National survey of neonatal transport teams in the United States. *Pediatrics* 2011;128(4):685-91. doi: 10.1542/peds.2010-3796

8. Leslie A, Stephenson T. Neonatal transfers by advanced neonatal nurse practitioners and paediatric registrars. *Arch Dis Child Fetal Neonatal Ed* 2003;88(6):F509-12.

9. Karin A. L. McCloskey RAO. Pediatric Trasnport Medicine, Mosby Inc. 1995

10. American Academy of Pediatrics: Section on Transport Medicine, https://www.aap.org/en-us/about-the-aap/Committees-Councils-Sections/section-transport-medicine/Pages/default.aspx, Accessed January 2018.

11. Paediatric Intensive Care Society, Acute Trasnport Group: http://picsociety.uk/pics-subgroups/acute-transport-group/, Accessed on March 2018.

12. European Society of Paediatric and neonatal Intensive Care Medicine: http://espnic-online.org, Accessed on January 2018.

13. Donald H. Shaffner DGN. Rogers' Textbook of Pediatric Intensive Care 5th Edition, Wolters Kluwer. 2015

14. Canadian Association of Paediatric Health Centres: https://www.caphc.org, Accessed on January 2018.

15. Ramnarayan P, Thiru K, Parslow RC, et al. Effect of specialist retrieval teams on outcomes in children admitted to paediatric intensive care units in England and Wales: a retrospective cohort study. *Lancet* 2010;376(9742):698-704. doi: 10.1016/S0140-6736(10)61113-0

16. Dieppe C, Lo TY, McFadzean J, et al. Specialist team retrieval of head injured patients: fact, fiction, or formula? *Intensive Care Med* 2009;35(2):334-8. doi: 10.1007/s00134-008-1323-1

17. Orr RA, Felmet KA, Han Y, et al. Pediatric specialized transport teams are associated with improved outcomes. *Pediatrics* 2009;124(1):40-8. doi: 10.1542/peds.2008-0515

18. McCloskey KA, Johnston C. Pediatric critical care transport survey: team composition and training, mobilization time, and mode of transportation. *Pediatr Emerg Care* 1990;6(1):1-3.

19. Beyer AJ, 3rd, Land G, Zaritsky A. Nonphysician transport of intubated pediatric patients: a system evaluation. *Crit Care Med* 1992;20(7):961-6.

20. Rubenstein JS, Gomez MA, Rybicki L, et al. Can the need for a physician as part of the pediatric transport team be predicted? A prospective study. *Crit Care Med* 1992;20(12):1657-61.

21. Vos GD, Nissen AC, Nieman FH, et al. Comparison of interhospital pediatric intensive care transport accompanied by a referring specialist or a specialist retrieval team. *Intensive Care Med* 2004;30(2):302-8. doi: 10.1007/s00134-003-2066-7

22. King BR, King TM, Foster RL, et al. Pediatric and neonatal transport teams with and without a physician: a comparison of outcomes and interventions. *Pediatr Emerg Care* 2007;23(2):77-82. doi: 10.1097/PEC.0b013e318030083d

23. Gunz AC, Dhanani S, Whyte H, et al. Identifying significant and relevant events during pediatric transport: a modified Delphi study. *Pediatr Crit Care Med* 2014;15(7):653-9. doi: 10.1097/PCC.0000000000000171

24. Combes A, Luyt CE, Trouillet JL, et al. Adverse effect on a referral intensive care unit's performance of accepting patients transferred from another intensive care unit. *Crit Care Med* 2005;33(4):705-10.

25. Rosenberg AL, Hofer TP, Strachan C, et al. Accepting critically ill transfer patients: adverse effect on a referral center's outcome and benchmark measures. *Ann Intern Med* 2003;138(11):882-90.

26. Escarce JJ, Kelley MA. Admission source to the medical intensive care unit predicts hospital death independent of APACHE II score. *JAMA* 1990;264(18):2389-94.

27. Fan E, MacDonald RD, Adhikari NK, et al. Outcomes of interfacility critical care adult patient transport: a systematic review. *Crit Care* 2006;10(1):R6. doi: 10.1186/cc3924

28. Goh AY, Mok Q. Centralization of paediatric intensive care: are critically ill children appropriately referred to a regional centre? *Intensive Care Med* 2001;27(4):730-5.

29. Gregory CJ, Nasrollahzadeh F, Dharmar M, et al. Comparison of critically ill and injured children transferred from referring hospitals versus in-house admissions. *Pediatrics* 2008;121(4):e906-11. doi: 10.1542/peds.2007-2089

30. Pearson G, Shann F, Barry P, et al. Should paediatric intensive care be centralised? Trent versus Victoria. *Lancet* 1997;349(9060):1213-7. doi: 10.1016/S0140-6736(96)12396-5

31. Ramnarayan P, Dimitriades K, Freeburn L, et al. Interhospital Transport of Critically Ill Children to PICUs in the United Kingdom and Republic of Ireland: Analysis of an International Dataset. *Pediatric Critical Care Medicine* 2018;Publish Ahead of Print doi: 10.1097/pcc.0000000000001506

32. Tanem J, Triscari D, Chan M, et al. Workforce Survey of Pediatric Interfacility Transport Systems in the United States. *Pediatr Emerg Care* 2016;32(6):364-70. doi: 10.1097/PEC.0000000000000448

33. Kawaguchi A, Gunz A, de Caen A. Cross-sectional Survey of Canadian Pediatric Critical Care Transport. *Pediatr Emerg Care* 2016 doi: 10.1097/PEC.0000000000000853

34. National Health Services, Annual Resports from Chidlren's Acute Transport System in National health Services: http://site.cats.nhs.uk, Accessed on March 2018.

35. McCloskey KA, King WD, Byron L. Pediatric critical care transport: is a physician always needed on the team? *Ann Emerg Med* 1989;18(3):247-9.

36. Kandil SB, Sanford HA, Northrup V, et al. Transport disposition using the Transport Risk Assessment in Pediatrics (TRAP) score. *Prehosp Emerg Care* 2012;16(3):366-73. doi: 10.3109/10903127.2012.664246

37. Petrillo-Albarano T, Stockwell J, Leong T, et al. The use of a modified pediatric early warning score to assess stability of pediatric patients during transport. *Pediatr Emerg Care* 2012;28(9):878-82. doi: 10.1097/PEC.0b013e31826763a3

38. Orr RA, Venkataraman ST, Cinoman MI, et al. Pretransport Pediatric Risk of Mortality (PRISM) score underestimates the requirement for intensive care or major interventions during interhospital transport. *Crit Care Med* 1994;22(1):101-7.

39. Alberta Health Services: http://www.albertahealthservices.ca, Accessed January 2018.

40. Alberta Health Services Referral, Access, Advice, Placement, Information & Destination (RAAPID): http://www.albertahealthservices.ca/facilities.asp?pid=saf&rid=1059504, Assessed on June 2015.

41. Population Projection Alberta 2014-2040: Treasury Board Economics, Demography and Public Finance and Finance, Accessed Febuary 2018.

42. Rajapreyar P, Marcdante K, Zhang L, et al. Decision-Making in Pediatric Transport Team Dispatch Using Script Concordance Testing. *Pediatr Crit Care Med* 2017;18(11):e530-e35. doi: 10.1097/PCC.0000000000001327

43. Orr RA, Venkataraman ST, McCloskey KA, et al. Measurement of pediatric illness severity using simple pretransport variables. *Prehosp Emerg Care* 2001;5(2):127-33.

44. SHOCK TRAUMA AIR RESCUE SERVICE (STARS/Alberta): http://www.stars.ca/ab/, Accessed on December 2017.

45. Alberta Health Services: Health Care Locator, http://www.albertahealthservices.ca/FacilitySearch/?filter=facilities&city=Calgary Accessed Feburary 2018.

46. SHOCK TRAUMA AIR RESCUE SERVICE (STARS) https://www.stars.ca, Accessed March 2018.

47. Ornge https://www.ornge.ca/about Accessed on March 2018.

48. Kawaguchi A, Nielsen CC, Guerra GG, et al. Epidemiology of Pediatric Critical Care Transport in Northern Alberta and the Western Arctic. *Pediatr Crit Care Med* 2018 Jun;19(6):e279-e285.

49. Pollack MM, Holubkov R, Funai T, et al. The Pediatric Risk of Mortality Score: Update 2015. *Pediatr Crit Care Med* 2016;17(1):2-9. doi: 10.1097/PCC.0000000000000558

50. Pollack MM, Patel KM, Ruttimann UE. PRISM III: an updated Pediatric Risk of Mortality score. *Crit Care Med* 1996;24(5):743-52.

51. Kawaguchi A, Nielsen CC, Saunders LD, et al. Impact of physician-less pediatric critical care transport: Making a decision on team composition. *J Crit Care* 2018 Jun; 45: 209-214.

52. Canadian Institute for Health Information (CIHI). Geographic Distribution of Physicians in Canada: Beyond How Many and Where. 2005

53. Whyte HE, Jefferies AL, Canadian Paediatric Society F, et al. The interfacility transport of critically ill newborns. *Paediatr Child Health* 2015;20(5):265-75.

54. Cunningham MD, Smith FR. Stabilization and transport of severely ill infants. *Pediatr Clin North Am* 1973;20(2):359-66.

55. Ferrara A. Letter: Transportation of sick neonates. *Can Med Assoc J* 1974;110(11):1233-4.

56. Pettett G, Merenstein GB, Battaglia FC, et al. An analysis of air transport results in the sick newborn infant: Part I. The transport team. *Pediatrics* 1975;55(6):774-82.

57. Shepard KS. Air transportation of high-risk infants utilizing a flying intensive-care nursery. *J Pediatr* 1970;77(1):148-9.

58. Kleinman M. Rogers' testbook of pediatric intensive care, chapter 24:Transport. 2008:340-54.

59. Canadian Association of Pediatric Health Centers. Competencies Profile - Interfacility Critical Care Transport of Maternal, Neonatal, and Paediatric Patients (2014): http://ken.caphc.org/xwiki/bin/view/Other/Competencies+Profile+-+Interfacility+Critical+Care+Transport+of+Maternal,+Neonatal,+and+Paediatric+Patients - Attachments, Assessed on June 2018.

60. Tanem J, Triscari D, Chan M, et al. Workforce Survey of Pediatric Interfacility Transport Systems in the United States. *Pediatr Emerg Care* 2015 doi: 10.1097/PEC.0000000000000448

61. Garrido MM, Kelley AS, Paris J, et al. Methods for constructing and assessing propensity scores. *Health Serv Res* 2014;49(5):1701-20. doi: 10.1111/1475-6773.12182

62. Little RJ, Rubin DB. Causal effects in clinical and epidemiological studies via potential outcomes: concepts and analytical approaches. *Annu Rev Public Health* 2000;21:121-45. doi: 10.1146/annurev.publhealth.21.1.121

63. Rosenbaum PR, Rubin DB. The Central Role of the Propensity Score in Observational Studies for Causal Effects. *Biometrika* 1983;70(1):41-55. doi: 10.2307/2335942

64. Moynihan K, McSharry B, Reed P, et al. Impact of Retrieval, Distance Traveled, and Referral Center on Outcomes in Unplanned Admissions to a National PICU. *Pediatr Crit Care Med* 2016;17(2):e34-42. doi: 10.1097/PCC.0000000000000586

65. Perez A, Butt WW, Millar KJ, et al. Long-distance transport of critically ill children on extracorporeal life support in Australia. *Crit Care Resusc* 2008;10(1):34.

66. Valenzuela TD, Criss EA, Copass MK, et al. Critical care air transportation of the severely injured: does long distance transport adversely affect survival? *Ann Emerg Med* 1990;19(2):169-72.

67. Araz OM, Bentley D, Muelleman RL. Using Google Flu Trends data in forecasting influenza-like-illness related ED visits in Omaha, Nebraska. *Am J Emerg Med* 2014;32(9):1016-23. doi: 10.1016/j.ajem.2014.05.052

68. Rising WR, O'Daniel JA, Roberts CS. Correlating weather and trauma admissions at a level I trauma center. *J Trauma* 2006;60(5):1096-100. doi: 10.1097/01.ta.0000197435.82141.27

69. Ajizian SJ, Nakagawa TA. Interfacility transport of the critically ill pediatric patient. *Chest* 2007;132(4):1361-7. doi: 10.1378/chest.07-0222

70. Macnab AJ. Optimal escort for interhospital transport of pediatric emergencies. *J Trauma* 1991;31(2):205-9.

71. Ramnarayan P, Patel K, Pappachan J, et al. Characteristics and outcome of children admitted to adult intensive care units in England, Wales and Northern Ireland (1996-2011). *Intensive Care Med* 2013;39(11):2020-7. doi: 10.1007/s00134-013-3010-0

72. Joyce CN, Giuliano JS, Jr., Gothard MD, et al. Specialty pediatric transport in primary care or urgent care settings. *Air Med J* 2014;33(2):71-5. doi: 10.1016/j.amj.2013.12.003

73. Greenland S. Ecologic versus individual-level sources of bias in ecologic estimates of contextual health effects. *Int J Epidemiol* 2001;30(6):1343-50.

74. McCloskey KA, Orr RA. Pediatric transport issues in emergency medicine. *Emerg Med Clin North Am* 1991;9(3):475-89.

75. van Lieshout EJ, de Vos R, Binnekade JM, et al. Decision making in interhospital transport of critically ill patients: national questionnaire survey among critical care physicians. *Intensive Care Med* 2008;34(7):1269-73. doi: 10.1007/s00134-008-1023-x

76. Stroud MH, Trautman MS, Meyer K, et al. Pediatric and neonatal interfacility transport: results from a national consensus conference. *Pediatrics* 2013;132(2):359-66. doi: 10.1542/peds.2013-0529

77. American Academy of Pediatrics Committee on Hospital Care: Guidelines for Air and Ground Transportation of Pediatric Patients. *Pediatrics* 1986;78(5):943-50.

78. Association AH. American Heart Association: Handbook of Emergency Cardiovascular Care for Healthcare Providers. American Heart Association. 2015;Nov:77.

79. de Caen AR, Berg MD, Chameides L, et al. Part 12: Pediatric Advanced Life Support: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2015;132(18 Suppl 2):S526-42. doi: 10.1161/CIR.0000000000000266

80. Rhodes A, Evans LE, Alhazzani W, et al. Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016. *Intensive Care Med* 2017;43(3):304-77. doi: 10.1007/s00134-017-4683-6

81. van Lieshout EJ, Binnekade J, Reussien E, et al. Nurses versus physician-led interhospital critical care transport: a randomized non-inferiority trial. *Intensive Care Med* 2016;42(7):1146-54. doi: 10.1007/s00134-016-4355-y

82. Thompson DR, Clemmer TP, Applefeld JJ, et al. Regionalization of critical care medicine: task force report of the American College of Critical Care Medicine. *Crit Care Med* 1994;22(8):1306-13.

83. Kawaguchi A, Nielsen C, Guerra G, et al. Epidemiology of Pediatric Critical Care Transport in Northern Alberta and the Western Arctic. *Pediatr Crit Care Med* 2018 Jun;19(6):e279-e285.

84. Althabe M, Cardigni G, Vassallo JC, et al. Dying in the intensive care unit: collaborative multicenter study about forgoing life-sustaining treatment in Argentine pediatric intensive care units. *Pediatr Crit Care Med* 2003;4(2):164-9.

85. Devictor DJ, Nguyen DT, Groupe Francophone de Reanimation et d'Urgences P. Forgoing life-sustaining treatments: how the decision is made in French pediatric intensive care units. *Crit Care Med* 2001;29(7):1356-9.

86. Launes C, Cambra FJ, Jordan I, et al. Withholding or withdrawing life-sustaining treatments: an 8-yr retrospective review in a Spanish pediatric intensive care unit. *Pediatr Crit Care Med* 2011;12(6):e383-5. doi: 10.1097/PCC.0b013e31820aba5b

87. Parshuram CS, Bayliss A, Reimer J, et al. Implementing the Bedside Paediatric Early Warning System in a community hospital: A prospective observational study. *Paediatr Child Health* 2011;16(3):e18-22.

88. Kawaguchi A, DeCaen A. Need of Data Collection in the Pre-PICU Setting for Transport Research. *Pediatr Crit Care Med* 2018;19(3):279. doi: 10.1097/PCC.0000000000001441

89. Smylie J, Fell D, Ohlsson A, et al. A review of Aboriginal infant mortality rates in Canada: striking and persistent Aboriginal/non-Aboriginal inequities. *Can J Public Health* 2010;101(2):143-8.

90. Straney L, Clements A, Parslow RC, et al. Paediatric index of mortality 3: an updated model for predicting mortality in pediatric intensive care*. *Pediatr Crit Care Med* 2013;14(7):673-81. doi: 10.1097/PCC.0b013e31829760cf

91. Warren DW, Jarvis A, LeBlanc L, et al. Revisions to the Canadian Triage and Acuity Scale paediatric guidelines (PaedCTAS). *CJEM* 2008;10(3):224-43.

92. Mohammed MA, Clements G, Edwards E, et al. Factors which influence the length of an out-of-hours telephone consultation in primary care: a retrospective database study. *BMC Health Serv Res* 2012;12:430. doi: 10.1186/1472-6963-12-430

93. Ong RS, Post J, van Rooij H, et al. Call-duration and triage decisions in out of hours cooperatives with and without the use of an expert system. *BMC Fam Pract* 2008;9:11. doi: 10.1186/1471-2296-9-11

94. Smits M, Keizer E, Ram P, et al. Development and testing of the KERNset: an instrument to assess the quality of telephone triage in out-of-hours primary care services. *BMC Health Serv Res* 2017;17(1):798. doi: 10.1186/s12913-017-2686-1

95. Patel S, Hertzog JH, Penfil S, et al. A Prospective Pilot Study of the Use of Telemedicine During Pediatric Transport: A High-Quality, Low-Cost Alternative to Conventional Telemedicine Systems. *Pediatr Emerg Care* 2015;31(9):611-5. doi: 10.1097/PEC.0000000000000544

96. Ellenby MS, Marcin JP. The Role of Telemedicine in Pediatric Critical Care. *Critical Care Clinics* 2015;31(2):275-90. doi: 10.1016/j.ccc.2014.12.006

97. Zhai H, Brady P, Li Q, et al. Developing and evaluating a machine learning based algorithm to predict the need of pediatric intensive care unit transfer for newly hospitalized children. *Resuscitation* 2014;85(8):1065-71. doi: 10.1016/j.resuscitation.2014.04.009

98. Yager PH, Clark ME, Dapul HR, et al. Reliability of circulatory and neurologic examination by telemedicine in a pediatric intensive care unit. *J Pediatr* 2014;165(5):962-6 e1-5. doi: 10.1016/j.jpeds.2014.07.002

99. Yager PH, Cummings BM, Whalen MJ, et al. Nighttime telecommunication between remote staff intensivists and bedside personnel in a pediatric intensive care unit: a retrospective study. *Crit Care Med* 2012;40(9):2700-3. doi: 10.1097/CCM.0b013e3182591dab

100. Awadallah S, Halaweish I, Kutayli F. Tele-echocardiography in neonates: utility and benefits in South Dakota primary care hospitals. *S D Med* 2006;59(3):97-100.

101. Shann F, Pearson G, Slater A, et al. Paediatric index of mortality (PIM): a mortality prediction model for children in intensive care. *Intensive Care Med* 1997;23(2):201-7.
102. Kanter RK, Edge WE, Caldwell CR, et al. Pediatric mortality probability estimated from pre-ICU severity of illness. *Pediatrics* 1997;99(1):59-63.
103. Edwards ED, Powell CV, Mason BW, et al. Prospective cohort study to test the predictability of the Cardiff and Vale paediatric early warning system. *Arch Dis Child* 2009;94(8):602-6. doi: 10.1136/adc.2008.142026
104. Duncan H, Hutchison J, Parshuram CS. The Pediatric Early Warning System score: a severity of illness score to predict urgent medical need in hospitalized children. *J Crit Care* 2006;21(3):271-8. doi: 10.1016/j.jcrc.2006.06.007
105. Monaghan A. Detecting and managing deterioration in children. *Paediatr Nurs* 2005;17(1):32-5. doi: 10.7748/paed2005.02.17.1.32.c964
106. Roland D, Oliver A, Edwards ED, et al. Use of paediatric early warning systems in Great Britain: has there been a change of practice in the last 7 years? *Arch Dis Child* 2014;99(1):26-9. doi: 10.1136/archdischild-2012-302783
107. Gold DL, Mihalov LK, Cohen DM. Evaluating the Pediatric Early Warning Score (PEWS) system for admitted patients in the pediatric emergency department. *Acad Emerg Med* 2014;21(11):1249-56. doi: 10.1111/acem.12514
108. Parshuram CS, Duncan HP, Joffe AR, et al. Multicentre validation of the bedside paediatric early warning system score: a severity of illness score to detect evolving critical illness in hospitalised children. *Crit Care* 2011;15(4):R184. doi: 10.1186/cc10337
109. Parshuram CS, Hutchison J, Middaugh K. Development and initial validation of the Bedside Paediatric Early Warning System score. *Crit Care* 2009;13(4):R135. doi: 10.1186/cc7998
110. Yates MT, Ishikawa T, Schneeberg A, et al. Pediatric Canadian Triage and Acuity Scale (PaedsCTAS) as a Measure of Injury Severity. *Int J Environ Res Public Health* 2016;13(7) doi: 10.3390/ijerph13070659
111. Mirhaghi A, Heydari A, Mazlom R, et al. The Reliability of the Canadian Triage and Acuity Scale: Meta-analysis. *N Am J Med Sci* 2015;7(7):299-305. doi: 10.4103/1947-2714.161243
112. Al-Hindi AA, Al-Akhfash AA, Fareed AM, et al. Efficacy of implementation of a 5 scale pediatric triage and acuity scale in pediatric emergency, Saudi Arabia. *Saudi Med J* 2014;35(9):999-1004.

113. Gravel J, Fitzpatrick E, Gouin S, et al. Performance of the Canadian Triage and Acuity Scale for children: a multicenter database study. *Ann Emerg Med* 2013;61(1):27-32 e3. doi: 10.1016/j.annemergmed.2012.05.024
114. Chang YC, Ng CJ, Wu CT, et al. Effectiveness of a five-level Paediatric Triage System: an analysis of resource utilisation in the emergency department in Taiwan. *Emerg Med J* 2013;30(9):735-9. doi: 10.1136/emermed-2012-201362

APPENDICES

Appendix 1

List of AHS Facilities and Non-Alberta Referring Centers of STOL

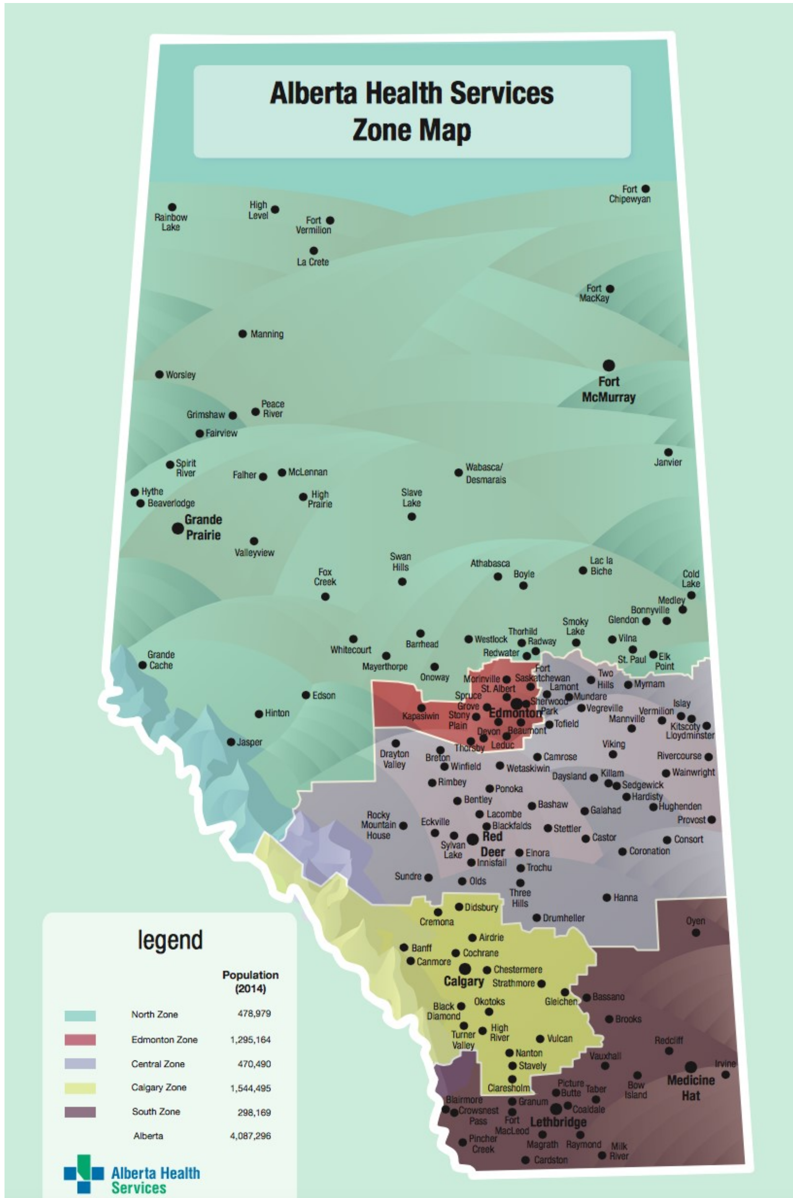
Centre	Name of facility	24/7 Pediatrics	Pediatrics Outreach Clinics	24/7 ED
ATHABASCA	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	Yes
BARRHEAD	ASPEN REGIONAL HEALTH AUTHORITY	No	No	Yes
BEAVERLODGE	PEACE COUNTRY HEALTH	No	No	Yes
BON ACCORD	CAPITAL HEALTH	No	No	No
BONNYVILLE	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	Yes
BOYLE	ASPEN REGIONAL HEALTH AUTHORITY	No	No	Yes
CALGARY - ACH	CALGARY HEALTH REGION	Yes	Yes	Yes
CAMROSE	EAST CENTRAL HEALTH	Yes	Yes	Yes
COLD LAKE	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	Yes
CONSORT	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	No	No	No
CORONATION	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	No	No	Yes
CROSS CANCER	CAPITAL HEALTH	No	No	No
DAYSLAND	EAST CENTRAL HEALTH	No	No	Yes
DEVON	CAPITAL HEALTH	No	No	Yes
DRAYTON VALLEY	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	No	No	Yes
EDSON	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	Yes
ELK POINT	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	Yes
FAIRVIEW	PEACE COUNTRY HEALTH	No	NO	Yes
FORT CHIPEWYAN	NORTHERN LIGHTS HEALTH REGION	No	NO	No
FORT MCMURRAY	NORTHERN LIGHTS HEALTH REGION	Yes	Yes	Yes
FORT SASKATCHEWAN	CAPITAL HEALTH	No	No	No
FORT VERMILLION	NORTHERN LIGHTS HEALTH REGION	No	Yes	No
FOX CREEK	PEACE COUNTRY HEALTH	No	No	Yes
GIBBONS	CAPITAL HEALTH	No	No	No

GRANDE CACHE	PEACE COUNTRY HEALTH	No	Yes	Yes
GRANDE PRAIRIE	PEACE COUNTRY HEALTH	Yes	Yes	Yes
GREY NUNS	CAPITAL HEALTH	No	No	Yes
GRIMSHAW	PEACE COUNTRY HEALTH	No	No	Yes
HARDISTY	EAST CENTRAL HEALTH	No	No	Yes
HIGH LEVEL	NORTHERN LIGHTS HEALTH REGION	No	Yes	Yes
HIGH PRAIRIE	PEACE COUNTRY HEALTH	No	Yes	Yes
HINTON	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	No
HOBBEMA	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	No	No	No
JASPER	ASPEN REGIONAL HEALTH AUTHORITY	No	No	Yes
KILLAM	EAST CENTRAL HEALTH	No	No	Yes
LAC LA BICHE	ASPEN REGIONAL HEALTH AUTHORITY	No	No	Yes
LACOMBE	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	No	No	Yes
LAMONT	EAST CENTRAL HEALTH	No	No	No
LEDUC	CAPITAL HEALTH	No	No	Yes
LESSER SLAVE LAKE	PEACE COUNTRY HEALTH	No	No	Yes
LETHBRIDGE	CHINOOK REGIONAL HEALTH AUTHORITY	No	No	Yes
LLOYDMINSTER	EAST CENTRAL HEALTH	No	No	Yes
MAGRATH	CHINOOK REGIONAL HEALTH AUTHORITY	No	No	No
MANNING	PEACE COUNTRY HEALTH	No	No	Yes
MANNVILLE	EAST CENTRAL HEALTH	No	No	No
MAYERTHORPE	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	Yes
MCLENNAN	PEACE COUNTRY HEALTH	No	No	Yes
MISERICORDIA - EDMONTON	CAPITAL HEALTH	No	No	Yes
NORTHEAST COMMUNITY HEALTH CENTER -	CAPITAL HEALTH	No	No	Yes
PEACE RIVER	PEACE COUNTRY HEALTH	No	No	Yes
PONOKA	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	No	No	Yes
PROVOST	EAST CENTRAL HEALTH	No	No	Yes
RAH	CAPITAL HEALTH	No	No	Yes

RED DEER	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	Yes	Yes	Yes
RED EARTH	ASPEN REGIONAL HEALTH AUTHORITY	No	No	No
REDWATER	CAPITAL HEALTH	No	No	Yes
RIMBEY	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	No	No	Yes
ROCKY MT. HOUSE	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	No	No	Yes
ROYAL ALEXANDRA HOSPITAL	CAPITAL HEALTH	No	No	Yes
SLAVE LAKE	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	No
SMOKY LAKE	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	Yes
SPIRIT RIVER	PEACE COUNTRY HEALTH	No	No	No
ST. PAUL	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	Yes
STOLLERY CHILDREN"S HOSPITAL - EDMONTON	CAPITAL HEALTH	Yes	Yes	Yes
STONY PLAIN	CAPITAL HEALTH	No	No	Yes
STURGEON COMMUNITY HOSPITAL - EDMONTON	CAPITAL HEALTH	No	No	Yes
SWAN HILLS	ASPEN REGIONAL HEALTH AUTHORITY	No	No	Yes
TOFIELD	EAST CENTRAL HEALTH	No	No	Yes
TROCHU	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	No	No	Yes
TWO HILLS	EAST CENTRAL HEALTH	No	No	Yes
VALLEYVIEW	PEACE COUNTRY HEALTH	No	Yes	Yes
VEGREVILLE	EAST CENTRAL HEALTH	No	No	Yes
VERMILLION	EAST CENTRAL HEALTH	No	No	Yes
VIKING	EAST CENTRAL HEALTH	No	No	Yes
WABASCA	ASPEN REGIONAL HEALTH AUTHORITY	No	No	Yes
WAINWRIGHT	EAST CENTRAL HEALTH	No	No	Yes
WESTLOCK	ASPEN REGIONAL HEALTH AUTHORITY	No	Yes	Yes
WETASKIWIN	DAVID THOMPSON REGIONAL HEALTH AUTHORITY	No	No	No
WHITECOURT	ASPEN REGIONAL HEALTH AUTHORITY	No	No	Yes

	Province and Territories			
BAKER LAKE, NU	NU	No	Yes	Yes
BRANDON, MB	MB	No	Yes	Yes
DAWSON CREEK, BC	BC	No	Yes	Yes
FORT NELSON, BC	BC	No	Yes	Yes
FORT SMITH, NT	NT	No	No	Yes
FORT ST. JOHN, BC	BC	No	Yes	Yes
HAY RIVER, NT	NT	No	No	Yes
INNUVIK, NT	NT	No	Yes	Yes
REGINA, SK	SK	Yes	Yes	Yes
SASKATOON, SK	SK	Yes	Yes	Yes
TORONTO, ON	ON	Yes	Yes	Yes
WHITEHORSE, YT	YT	Yes	Yes	Yes
YELLOWKNIFE, NT	NT	Yes	Yes	Yes

Alberta Health Services Zone Map



Alberta Health Services: https://www.albertahealthservices.ca/ahs-map-ahs-zones.pdf

Appendix 2

Pediatric Intensive Care Transport Program Questionnaire

The goal of this survey is to increase knowledge about Canadian PICU Transport. We will disseminate our findings through peer review publications and conference presentations in pediatric and critical care fields.

This survey was approved by the Health Research Ethics Board of University of Alberta, Canada, and Northern Alberta Clinical Trial Research Center, in February 2015.

We would like to ask that at least one individual from each site complete the survey below.

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Anna Gunz, MD, Western University, Children's Hospital of Western Ontario, LHSC
Allan DeCaen MD, University of Alberta, Stollery Children's Hospital

July 20, 2015

Hospital/Facility Name ____________________

Survey completed by (name and position/role)

Name____________________ **Position/Role in the transport team**____________________

I. General Inquiries about your PICU

Q1. How many PICU (including Cardiac ICU) beds do you have?

____

Q2. How many full time pediatric intensivists do you have (including cardiac intensivists)?

____

Q3. What level of care does your PICU service?

Medical/Surgical Program	○ Yes	○ No
Cardiac Surgical Program	○ Yes	○ No
ECLS Program	○ Yes	○ No
Solid Organ Transplant Program	○ Yes	○ No

(Please choose all that apply)

II. PICU Transport Team

Q4. Do you have an unit-based transport team that services your hospital currently?

○ YES ○ NO

Q5. Is there a transport service that is NOT affiliated with YOUR hospital that is responsible for bringing patients to your hospital?

○ YES ○ NO

If Yes,

5.1 Please specify (name, organization etc.) ______________________

5.2 Please give a percentage of the transports operated by the service (Best Estimate).

______________ %

Q6. Does your team transport children on ECMO?

O YES O NO

Q7. Which patient populations does the PICU transport team service?

	Within our mandate	Not our mandate but have serviced or will service on case by case basis	Do not service
Premature infants	O	O	O
Neonates (≤28 days old)	O	O	O
Attendance at high risk delivery	O	O	O
Pediatric	O	O	O
Adults (>18 years old)	O	O	O

If there is specific age restriction in pediatric population, please specify.

Lowest age/month ______________ Highest age ______________

Q8. Who is usually on the INITIAL transport call?

- O Non-Clinical administrative personnel
- O Pediatric Intensivist
- O Pediatric Emergency Physician
- O PICU fellow
- O RN in transport team
- O Non-specified RN
- O Others

(Please check all that apply)

If non-clinical administrative personnel selected, please specify details: ______________________

If other selected, please specify details: ______________________

Q9. For the acute care transport of a child, please indicate the team composition used and the approximate percentage of transports each team composite is utilized (Best Estimate).

- ○ RN; one only ________%
- ○ RT; one only ________%
- ○ Paramedic only ________%
- ○ RN - RN ________%
- ○ RN - RT ________%
- ○ RN - paramedic ________%
- ○ RN - physician ________%
- ○ RN - RT - Physician ________%
- ○ Other ________%

Total 100 %

Q10. Number of personnel (FTE) whose primary responsibility is transport (they may fulfill other workforce needs when not scheduled for transport)?"

MDs dedicated to transport Number (FTE & individuals) ________________

RNs dedicated to transport Number (FTE & individuals) ________________

RTs dedicated to transport - Number (FTE & individuals) ________________

Paramedics dedicated to transport - Number (FTE & individuals) ________________

III. Activity of the Transport Team

11. What is the number of transports carried out by your transport program per year?

____

11.1 Of these transports, what is the total NUMBER of PEDIATRIC transports? (Best estimate)

____

11.2 Of the pediatric transports, what is the percentage with admission to the PICU? (Best estimate)

________________%

11.3 Of the PEDIATRIC transports, please indicate the proportion of each type of transport that these comprise (Best Estimate).

- Community Hospital to your center (Tertiary-care Hospital) ________%
- Tertiary-care Hospital to Tertiary- or Quaternary-care Hospital ________%
- Repatriation to center with a lower level of care ________%
- Other ________%

Total 100 %

Q12. What proportions of transports does the transport team perform the following procedures (Best Estimate)?

- Invasive Mechanical Ventilation ________%
- Non-invasive Mechanical Ventilation ________%
- High Flow Nasal Cannula ________%
- Arterial Line placement ________%
- Central Line Placement ________%
- ECMO ________%

Q13. Which modes of ground transport are utilized by your program?

- ○ Ground - local EMS
- ○ Ground - private transport service
- ○ Ground - dedicated to TT

(Please check all that apply.)

Q14. Which modes of air transport are utilized by your program?

- ○ Rotor (not dedicated to Transport Team (TT))
- ○ Rotor (dedicated to TT)
- ○ Fixed wing propeller (not dedicated to TT)
- ○ Fixed wing propeller (dedicated to TT)
- ○ Fixed wing jet (not dedicated to TT)
- ○ Fixed wing jet (dedicated to TT)

(Please check all that apply.)

Q15. Please provide proportion of each transport mode.

- Ground ________%
- Rotor ________%
- Fixed Wing jet/propeller ________%

Total 100 %

Q16. For air transport, how far is the take-off/landing platform for fixed wing/jet/propeller planes from your home site?

- ○ It is on-site
- ○ Within 15 min distance (Off-site)
- ○ 15-30 min distance (Off- site)
- ○ >30min distance (Off- site)

(Please check one that apply)

16.1 How far is the take-off/landing platform for rotor aircraft from your home site (aka helipad)?

- O It is on-site
- O Within 15 min distance (Off-site)
- O 15-30 min distance (Off- site)
- O >30min distance (Off- site)

(Please check one that apply)

Q17. Does your transport service have target times for transports?

Mobilization Time (Dispatch to leave home site)

O Yes O No O Unknown

If yes, please give the value in minutes, ______________ minutes

Stabilization Time (Arrival at referral site to departure from referral site)

O Yes O No O Unknown

If yes, please give the value in minutes, ______________ minutes

Q18. How long is your average transport, from dispatch to arrival at receiving facility?

Please give value in minutes. ______________ minutes

Q19. What is the distance from home site to the farthest referral site in your catchment area (Best Estimate)?

Please give value in kilometers. ______________ kilometers

Q20. Who has the responsibility to decide the mode of transport and team composition?

	Mode of transport:	Team Composition:
Fixed (Pre-specified)	O	O
Non-Clinical administrative personnel	O	O
Pediatric Intensivist	O	O
Pediatric Emergency Care Physician	O	O
PICU fellow	O	O
RN in transport team	O	O
Non-specified RN	O	O

EMS transport coordinator	○	○
Others	○	○

(Please choose one that apply)

IV. PICU Transport Database

Q21. Are your transport calls recorded? ○ YES ○ NO

Q22. Do you have a transport specific database? ○ YES ○ NO

If Yes,

22.1 How is the database recorded?
○ Paper-based
○ Computer-based

Please specify the computer program (e.g. FileMaker, ACCESS) ______________________

22.2 Who does the data input?
○ Dedicated personnel
e.g. research assistant, research RN etc.
○ RN or RT on transport team
○ Physician
○ Others ______________________

22.3 Does the database link to the hospital electronic Medical record? ○ YES ○ NO

22.4 What year was the database launched? ______________________

22.5 What kind of data is recorded in the database?

	Yes	NO
Patients Demographics (ID, Name etc.)	○	○
Information of referral site (Name, Postal Code etc.)	○	○
Details of transport times/dates of transport	○	○
Vital Signs during transport	○	○
Blood Work result (Blood gas etc.)	○	○

Q23. Is there a way to flag critical incidents that occur on transport ○ YES ○ NO

If Yes, please specify ____

Q24. Do you have an established continuing education(CE) program for the transport team providers?

○ YES ○ NO

Q25. Do you have an established Quality Assurance (QA) program? ○ YES ○ NO

If Yes, please explain

25.1 How are charts identified for review (e.g. random, flagged, all charts, etc.)?

____

25.2 Do the results of your QA process influence your CE content?

____

Q26. Please provide any further comments relevant to this survey or pediatric transport below.

Thank you for completing the survey and submitting your valuable comments.

Appendix 3

Pediatric Severity Scoring Systems

Pediatric mortality scores

Several studies were conducted in the 1990s to assess the utility of scores designed to predict mortality of hospitalized children, such as Pediatric Index of Mortality (*PIM*) and Pediatric Risk of Mortality (*PRISM*) in predicting the transport needs of critically ill or injured children, mostly with poor performances [50, 101]. In recent years, new scores such as Pediatric Index of Mortality 3 (*PIM3*) and *PRISMIII* have been used to measure the severity of illness in critically ill or injured children in PICU settings [49, 90]. However the complexity of these mortality scores can be detrimental for the use in the transport settings; they require assessment items such as details of blood work results and diagnosis, which would not be readily available to the caregivers at referral centers [38, 102].

Pediatric Risk of Mortality [93]

Variables	Age Restrictions and Ranges		Score
Systolic Blood Pressure (mmHg)	Infants	Children	
	130 -160	150- 200	2
	55 - 65	65 - 75	
	>160	>200	6
	40- 54	50- 64	
	<40	<50	7
Diastolic Blood Pressure (mmHg)	All ages		6
	>110		
HR (beat/min)	Infants	Children	
	>160	>150	4
	<90	<80	
Respiratory Rate (Breath/min)	Infants	Children	
	61 - 90	51 - 70	1
	>90	>70	5
	Apnea	Apnea	
PaO2/FIO2	All ages		
	200 - 300		2
	<200		3
PaCO2 (torr)	All ages		
	51 - 65		1
	>65		5
Glasgow Coma Score	All ages		
	<8		6
Pupillary Reactions	All ages		
	Unequal or Dilated		4
	Fixed and Dilated		10
PT/PTT	All ages		
	1.5 x control		2
Total Bilirubin (mg/dL)	> 1month		
	>3.5		6
Potassium (mEq/L)	All ages		
	3.0 - 3.5		1
	6.5 - 7.5		
	<3.0		5
	>7.5		
Calcium (mg/dL)	All ages		
	7.0 - 8.0		2
	12.0 - 15.0		
	<7.0		6
	>15.0		
Glucose (mg/dL)	All ages		
	40 -60		4

	250 - 400	
	<40	8
	>400	
Bicarbonate (mEq/L)	All ages	
	<16	3
	>32	

Pediatric Early Warning Score (PEWS)

PEWS was originally proposed as a system to reduce the occurrence of suboptimal ward care and identify children at risk of critically ill conditions [103-105]. Duncan *et al*., who created the first scoring system of *PEWS*, identified 20 clinical and physiologic parameters to score. To date, several variations of *PEWS* have been designed for applicability in different clinical settings including transport; all of them are called *PEWS* [37, 87, 103, 106-109]. Petrillo-Albarano *et al*., for example, launched a modified version of *PEWS* called Transport-PEWS (*TPEWS*) to help assess a child's condition and to predict the final destination in transport settings. However, it has not been widely used in current practice due to the lack of validation studies as well as its complexity with more than 20 assessment items [37].

Transport Pediatric Early Warning Score (TPEWS) [37]

	3	2	1	0
Airway/breathing (3 [or a 2 with heliox] require respiratory therapist; exception: helicopter transport or medical control approval)	Unstable OR artificial airway RR >25 above normal RR 5 below normal with retractions and/or >50 % FIO2 requirement not including nebs PCO2>55 acutely with pH <7.35 (not intubated) BiPAP acutely Heliox via ETT/BiPAP ECMO iNO	RR >20 above normal Using accessory muscles 40%-49% FIO2 not including neb >=3 LPM O2 or >1 LPM O2 for infant Continuous neb or 3 intermittent nebs in 1 h Heliox by mask PCO2 >50 acutely with pH <7.35(not intubated)	RR >10 above normal 24%-40% FIO2 not including neb =<2 LPM O2 or <1 LPM O2 for infant PCO2 actually >45 (not intubated) Intermittent nebs	No adjuncts No O2 requirement RR WNL for age No retractions
Circulation (3 require RN)	Gray CRT >=5s HR >=30 above normal with a temperature of <38C° Bradycardia Requiring >40 mL/kg volume replacement Requiring pressors or emergent blood products	CRT 4 s or HR >=20 above normal with temperature of <38C° Systolic BP less than normal lower parameters of 70±2 x age in years >2 y old MAP>90	Pale CRT 3 s HR >=10 above normal with a temperature of <38C° Systolic BP less than normal upper parameters of 90±2 (age in years) >2 y old	Pink, CRT 1-2s HR WNL BP WNL
Disability (GCS =<10 acutely needs respiratory therapist unless approved by medical control)	Lethargic, confused Reduced pain response GCS=<10 acutely Medically paralyzed and sedated	Irritable or agitated but not consolable GCS =<12 acutely	Sleeping, Irritable but consolable	Playing Appropriate

Bedside-Pediatric Early Warning System (BPEWS)

BPEWS score is a simplified version of the original *PEWS* thatlimits the assessment items to seven clinically fundamental elements (i.e., heart rate, systolic blood pressure, capillary refilling time, respiratory rate, respiratory effort (Y/N), oxygen saturation, and oxygen amount given) with which to score. This was expected to promote its clinical application as well as to make the measurement reliability better, considering that it can be utilized by a variety of health care providers including non-pediatric specialized personnel [87 108 109]. Since the *BPEWS* score was created to prevent unexpected cardiopulmonary arrest in children on pediatric wards, evidence has shown that it can also differentiate children who need an urgent admission to a PICU from those who do not, with high sensitivity and specificity. *BPEWS* has been the most widely applied and evaluated *PEWS* in current pediatric practice, nonetheless, it requires modifications to be used in the transport settings where invasive interventions (e.g., endotracheal intubation, vasopressor infusion, or chest tube placement) may need to be performed before a triage call.

Bedside Pediatric Early Warning System (BPEWS) score [87]

		Component Sub-score			
Component	**Age Group**	**0**	**1**	**2**	**4**
Heart rate, bpm	<3 months 3 to <12 months 1 to 4 years 5 to <12 years ≥12 years	>110 and <150 >100 and <150 >90 and <120 >70 and <110 >60 and <100	≥150 or ≤110 ≥150 or ≤100 ≥120 or ≤90 ≥110 or ≤70 ≥100 or ≤60	≥180 or ≤90 ≥170 or ≤80 ≥150 or ≤70 ≥130 or ≤60 ≥120 or ≤50	≥190 or ≤80 ≥180 or ≤70 ≥170 or ≤60 ≥150 or ≤50 ≥140 or ≤40
Systolic Blood Pressure, mmHg	<3 months 3 to <12 months 1 to 4 years 5 to <12 years ≥12 years	>60 and <80 >80 and <100 >90 and <110 >90 and <120 >100 and <130	≥ 80 or ≤60 ≥100 or ≤80 ≥110 or ≤90 ≥120 or ≤90 ≥130 or ≤100	≥100 or ≤50 ≥120 or ≤70 ≥125 or ≤75 ≥140 or ≤80 ≥150 or ≤85	≥130 or ≤45 ≥150 or ≤60 ≥160 or ≤65 ≥170 or ≤70 ≥190 or ≤75
Capillary Refill, second		<3			≥3
Respiratory rate, bpm	<3 months 3 to <12 months 1 to 4 years 5 to <12 years ≥12 years	>29 and <61 >24 or <51 >19 or <41 >19 or <31 >11 or <17	≥61 or ≤29 ≥51 or ≤24 ≥41 or ≤19 ≥31 or ≤19 ≥17 or ≤11	≥81 or ≤19 ≥71 or ≤19 ≥61 or ≤15 ≥41 or ≤14 ≥23 or ≤10	≥91 or ≤15 ≥81 or ≤15 ≥71 or ≤12 ≥51 or ≤10 ≥30 or ≤9
Respiratory Effort		Normal	Mild increase	Moderate increase	Severe increase/any apnea
Oxygen saturation, %		>94	91–94	≤90	
Oxygen therapy		Room air		Any: <4 L/min or <50%	≥4 L/min or ≥50%

Transport Risk Assessment in Pediatric (TRAP)

TRAP score was built by Kandil *et al*. to help determine appropriate dispositions of transported pediatric patients [36]. They adopted four pre-transport predictors of in-hospital mortality previously identified by Orr *et al*. (i.e., systolic blood pressure, respiratory rate, oxygen requirement, and altered mental status), and added four extra variables derived from other scoring tools and expert opinion at their institution (i.e., pulse, temperature, capillary refilling time, and heart rate) [43]. *TRAP* score has an advantage in its simplicity compared to *TPEWS*; it can be scored quickly by any members of the transport team or caregivers at referral centres. A feasibility study of *TRAP* has found that it has good applicability and an association of *TRAP* with increased odds of admission to the PICU.

Transport Risk Assessment in Pediatrics (TRAP) Score [36]

		2	1	0		2	1	0
<12month old	**Heart Rate; bpm**	<90 or >180	90-109 or 150-180	110-150	Systolic Blood Pressure; mmHg	<60 or >110	60-69 or 90-110	70-89
1-12year old		<65 or >140	65-79 or 116-140	80 -115		<75 or >130	75-89 or 116-130	90-115
>12year old		<50 or >120	50-59 or 101-120	60-100		<85 or >150	85-101 or 131-150	100-130
	Respiratory Status	apnea, gasping, intubated	RR>=50, SpO2<90	RR<50, SpO2>=90	FIO_2	>=50% or >=4LPM	<50% or <4LPM	Room Air
	Capillary Refilling Time; seconds	>3 seconds	2-3 seconds or fluid bolus given	<2 seconds	Pulses	Absent	Faint or bounding	Normal
	Glasgow Coma Scale	<7	7-11	12-15	Temperature	<35 or >40	35-35.9 or 38.1-40	36-38

Canadian Pediatric Triage and Acuity Scale (CPTAS)

CPTAS was introduced to assist healthcare workers with pediatric patient triage in an emergency department setting. It adopts a 5-level (Level 1 being resuscitation to Level 5 being non-urgent) triage tool, using clinical signs and symptoms assessed by healthcare providers to determine the urgency level of pediatric patients presenting to emergency departments [91]. The five physiological items (i.e., consciousness level/behaviors, respiratory rate, the level of respiratory distress, heart rate, peripheral perfusion) are utilized to assess patients' levels of acuity. It is not an ordinal scoring system. Patients are classified in the highest acuity level when at least one of the items for that level is met. For instance, even if patients have values in a normal range in four items, they will be categorized in a higher acuity level when the fifth item indicates a higher acuity level. It has been well validated to identify pediatric patients in need of immediate assistance as well as safely identify less urgent patients who can wait, to optimize the use of limited health care resources [110-114]. In a certain adult medical transport program, i.e., Ornge in Ontario[47], the adult version of the triage acuity scale (Canadian Triage and Acuity Scale; *CTAS*) has been adopted to determine the timing of their transports. However, the decision criteria have not been based on sufficient scientific evidence. Further, the pediatric version (*CPTAS*) has not been evaluated if it can help decision-making process in transport.

Canadian Pediatric Triage Assessment Scale [91]

Level	Time to Care	LOC*	Respiratory Rate	Respiratory Status	Heart Rate	CRT**
1 (Resuscitation)	Immediate	Unresponsive	<-2SD or >+2SD	Severe distress	<-2SD or >+2SD	Cardiac arrest, Shock, Cyanosis
2 (Emergent)	<15 minutes	Lethargic, altered LOC*	< -SD or >+SD	Moderate	< -SD or >+SD	CRT>4sec
3 (Urgent)	<30 minutes	Atypical behavior	Outside of NR#	Mild	Outside of NR#	CRT>2sec
4 (less urgent)	<60 minutes	Consolable, history of atypical behavior	Normal for age	Normal	Normal for age	Normal
5 (non-urgent)	<120 minutes	No recent history of change on behavior/vital sign	Normal for age	Normal	Normal for age	Normal

LOC*: Length of Stay, CRT**: Capillary refilling time, NR#: Normal range

<u>**Ornge Triage Acuity Scale for Transport**</u>

OTAS Level	Time to receiving	Description
Level I (Resuscitation)	<4 hours	Conditions that are threats to life or limb (or imminent risk of deterioration) requiring immediate aggressive interventions that cannot be delivered at the sending hospital or nursing station; patients requiring immediate intervention at the receiving facility. E.g. Declared Life or Limb; acute STEMI, acute multisystem trauma, acute vascular emergency requiring immediate surgical intervention- type A dissection; premature labour. Level I calls are automatically approved for duty outs and overtime. The fastest available and appropriate response will be dispatched.
Level II (Emergent)	<6 hours	Conditions that are a potential threat to life, limb or function requiring rapid medical interventions. These patients have a serious illness or injury and have the potential for further deterioration. They need prompt treatment to stabilize developing problems and treat acute conditions. These may be patients with relatively stable conditions that overwhelm a local hospital/nursing stations ability to care for them i.e. intubated patient in a setting without a ventilator or acute conditions such as ACS or non-STEMI with ongoing chest pain; septic patient with early end organ failure in rural hospital requiring tertiary level care.
Level III (Urgent)	<12 hours	Conditions that could potentially progress to a serious problem requiring emergency intervention. These patients are stable but their diagnosis or presenting problem suggests a potentially more serious process. These may be patients that are undifferentiated without a clear diagnosis but are stable currently but there is a concern for possible deterioration beyond the capabilities of the sending facility. Other examples include- stable non-STEMI without CP going for PCI; ventilated/septic patient in community hospital requiring tertiary level care; SOB patient with stable VS going to R/O PE from rural hospital
Level IV (less urgent)	<24 hours	Acute conditions that are treated appropriately and stabilized at sending facility going for consultation at a higher level of care. The potential seriousness of their problem based on their presenting problem or diagnosis is not as acute. The need for potential acute intervention is minimal. Examples include; closed fractures requiring orthopedic assessment (with no risk from delay in possible surgical reduction); stable abdominal pain going for assessment (with low risk of surgical cause); This group would include repatriation of patients currently holding a tertiary care ICU bed that require repatriation to open the bed for future acutely ill patient.
Level V (non-urgent)	<48 hours	Non urgent, next day booked transports. Conditions that may be acute but non-urgent as well as conditions which may be part of a chronic problem. The investigation or interventions for some of these illnesses or injuries could be delayed. These are minor complaints that do not pose any immediate risk to the patient.

Obtained via personal correspondence with director of Ornge, Ontario (July 2016)