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Impact of Weather Conditions on Neonatal Transport in Ontario: A Retrospective Cohort Study

Majed Alruaydi[1], Crystal Cornish[2], Andrea De La Hoz[3], Michael R Miller[4], Soume Bhattacharya[5*]

[1,4,5]Department of Pediatrics, Western University, London, Ontario, Canada
[2,1,3,5]London Health Sciences Centre, London, Ontario, Canada
[3]Lawson Health Research Institute, London, Ontario, Canada
[4,5]Children's Health Research Institute, London, Ontario, Canada

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****Correspondence:***
Soume.Bhattacharya@lhsc.on.ca

Abstract

The successful realization of efficient neonatal transport is central to the regionalization of high-risk perinatal healthcare. Environmental factors such as weather conditions have the potential to impact transport services covering large temperate climatic zones. Our objective was to compare neonatal transport duration and relevant neonatal outcomes during winter versus summer seasons in distinct transport zones. This retrospective cohort study included newborns transported within Southwestern Ontario between January 2014 to December 2022. The serviced clinical network was divided into 4 zones based on geographical location. Transport details, patient baseline demographics, Transport Risk Index of Physiologic Stability V2 (TRIPS-II) scores, and clinically relevant outcomes were recorded. Winter (November-March) versus summer (May-September) parameters were compared within each zone. 960 transports were analyzed; 503 in summer, and 457 in winter. Baseline demographic characteristics were comparable between seasons within zones. In Zone 1, net transport time (minutes) was longer in winter versus summer (p = .019). In Zone 2, transport times were comparable; however, speed (km/min) was slower in winter versus summer (p=0.020). In Zone 3 (the Snow Belt), mean (SD) net transport times were approximately 60 minutes longer in winter versus summer [438.2(93.0) vs. 377.3(104.0), $p < .001$]. In Zone 4, transport times were similar between seasons. TRIPS-II scores, mortality, and major morbidity rates were comparable between seasons across all zones. This large study showed that while neonatal transport services were significantly impacted in the winter, there were no negative effects on post-transport stability, mortality, or major morbidity. Evaluation of this data might inform future service modelling.

Compared to inborn neonates or those born after a maternal transfer, neonates who require acute postnatal transport have demonstrated an increased risk of morbidities such as hypoxemia, glucose abnormalities, intraventricular hemorrhage (IVH) and death [1, 3-5]. Despite increasing evidence regarding the safety of in-utero transfers, in many cases, the ex-utero transfer of at risk and unwell neonatal patients is unavoidable. The effective medical transport of neonates is a critical step in providing timely and appropriate care to these vulnerable patients. With the increasing regionalization of care within the Canadian healthcare system, having dedicated neonatal transport has become essential for improving neonatal survival [1-3].

Each neonatal transport is surrounded by varying levels of risk depending on both clinical and extrinsic factors. These factors can include transport details; for instance, the distance between a referral site and a responding site, transport personnel availability as well as individual risk factors such as a patient's Gestational Age (GA). Additionally, for healthcare settings in geographical locations exposed to variable weather conditions or extremely cold climates, it is possible that changes in weather conditions may affect transport time and subsequently influence patient outcomes. A study from Finland in 2019 demonstrated that a significant amount of air-based medical transport trips were denied or cancelled due to adverse weather conditions in cold climates [6]. In addition, in Florida, a retrospective study conducted in 2021 on children who required transport concluded that weather negatively affected patient body temperature during transport, subsequently causing environmental hyperthermia [7]. Another retrospective study of neonatal transports demonstrated that inter-facility transports lasting longer than one hour were associated with a higher risk of neonatal death compared to transports of shorter duration [8]. Investigating such factors impacting neonatal transport and the successful mobilization of high-risk perinatal care is important for optimizing the transport process, enhancing existing clinical networks, streamlining resource allocation, and improving overall clinical care.

To the best of our knowledge, there is a lack of information regarding the impact of weather on neonatal transport in Canada. Hence, we designed a retrospective study to evaluate the impact of weather conditions on neonatal transport time and neonatal outcomes. Our research question explored whether neonatal transports experience a longer net transport duration in winter versus summer months within pre-specified geographic areas in Ontario experiencing distinct temperate climatic weather patterns. We also sought to explore whether changes in net transport duration in these geographic areas lead to significant changes in neonatal patient outcomes.

Method

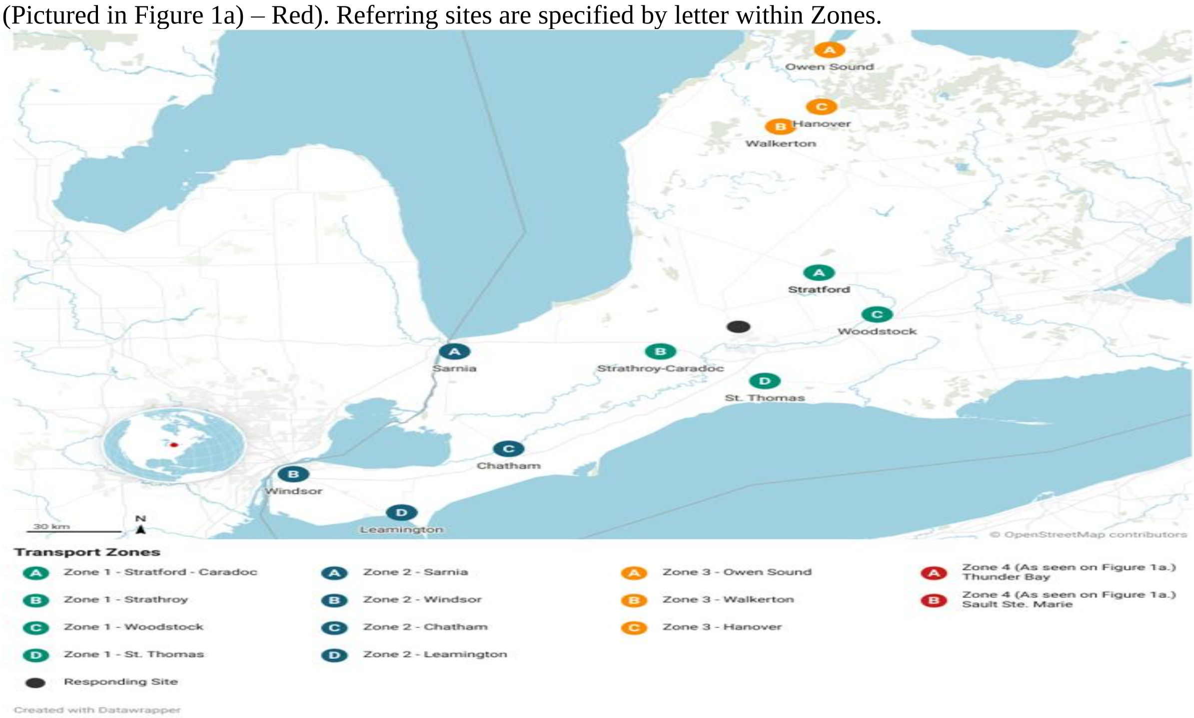
This was a retrospective cohort study conducted out of a tertiary care Neonatal Intensive Care Unit (NICU) in Southwestern Ontario. This regional Level 3 center experiences high annual inborn and out-born admissions rates, and provides a higher level of care to 18 Level 1 and Level 2 NICUs.

To consider the role of geographical distribution and location in influencing specific transport outcomes, we distributed referral centres into 4 geographical zones. Each zone was assigned based on their similar geographical location to ensure similar local weather patterns and road conditions were taken into consideration, as seen in Figure 1a and 1b. Zone 1 included transports from Stratford, Strathroy (also referred to as Strathroy-Caradoc), Woodstock, and St

Thomas. Zone 2 included transports from Sarnia, Windsor, Chatham, and Leamington. Zone 3 (the Snow Belt) included transports from Owen Sound, Walkerton, and Hanover. Zone 4 included transports from Thunder Bay and Sault Ste Marie.

Figure 1a. Large-scale map of referring sites included into the study within the serviced clinical network, classified according to Zone using geographical location. The Responding Site is distinguished using a black circle, Transport Zones are identified by coloured circles (Zone 1 – Green, Zone 2 – Blue, Zone 3 – Yellow, Zone 4 – Red). Referring sites are specified by letter within Zones.

Figure 1b. Focused map of referring sites included into the study within the serviced clinical network, classified according to Zone using geographical location. The Responding Site is distinguished using a black circle, Transport Zones are distinguished by coloured circles (Zone 1 – Green, Zone 2 – Blue, Zone 3 – Yellow, Zone 4 (Pictured in Figure 1a) – Red). Referring sites are specified by letter within Zones.



For this study, all out-born neonates born in pre-defined summer and winter months in the period between January 1st 2014 to December 31st 2022 who needed a higher level of care than could be provided by the centre they were born at, and who were sub-sequentially transported by the local transport team to our center were included. Excluded were babies who passed away before the arrival of the transport team to the referral site, babies who were stabilized and were left to be cared for at the referral site, and babies who became stable during transport and were repatriated to lower levels of care.

Eligible transports were classified into either summer or winter transport groups based on month of transport. The Summer Transport Group consisted of neonatal transports completed between May 1st to September 30th of each study year. The Winter Transport Group consisted of neonatal transports completed between November 1st to March 31st of each study year. Transports completed during April and October were excluded from the study as this was considered part of a ‘washout period’ between seasons.

Data Collection

Pertinent data were extracted from the local transport database. These data included patient demographics, total transportation times, and the specific duration of multiple transport setpoints, such as the time to prepare for departure from the responding site (mobilization time), time to arrive at referral site (response time), and time from arrival at referral to departure from referral site (stabilization time).

Data on Transport Risk Index of Physiologic Stability Version II (TRIPS-II) scores [9] were extracted to evaluate babies’ well-being. Scoring has been validated for evaluating patient status during transport, and for predicting neonatal 7-day and total NICU mortality. Scoring considered patients’ temperature, blood pressure, respiratory status and response to noxious stimuli to assess illness acuity prior to, during, and post-transport.

Patients’ post-transport outcomes, including mortality (within 24 hours of arrival at the responding site) and intraventricular hemorrhage rates (in neonates <32 weeks GA) were extracted from the patients’ electronic records.

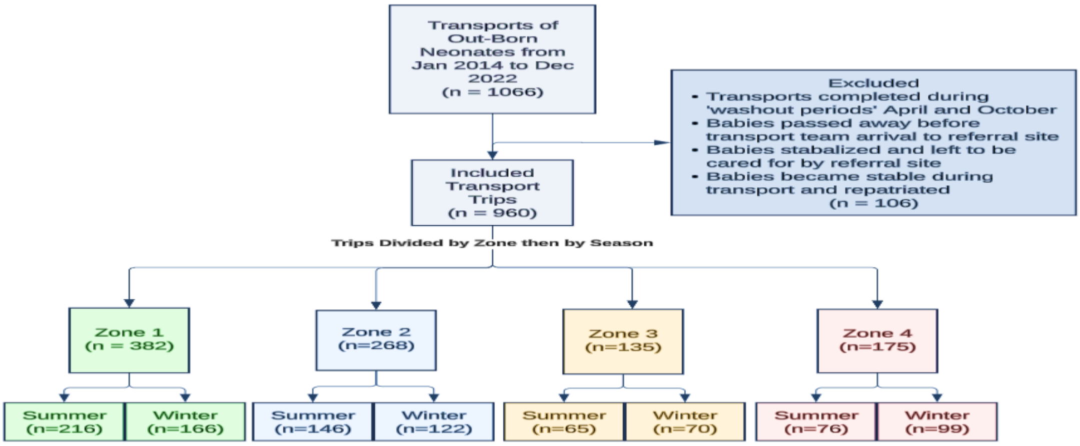
Statistical Analysis

Continuous data were expressed as means ± standard deviations, and intergroup comparisons were conducted using independent t-tests. Categorical data were expressed as frequencies and percentages, and intergroup comparisons were conducted using chi-square tests (or Fisher’s exact tests, as appropriate). Data were analyzed using the statistical software program SPSS version 29 (IBM Corp., Armonk, NY, USA), and $P < 0.05$ was considered statistically significant.

Results

Our study analyzed 960 transport runs: 503 in summer and 457 in winter. Figure 2 shows a summary breakdown of transports included in the study.

Figure 2. Summary of charts reviewed, categorized by Zone and categorized by season.



Baseline demographic characteristics, mode of transport, and transport distances are summarized in Table 1. Mean (SD) postnatal age (days) at transport was higher in the winter compared to summer in Zone 1 [6.0(13.6) days vs 2.5(5.4) days, p = .001]. In Zone 2, the winter cohort was found to have a lower mean (SD) birth weight (grams) compared to that of the summer [2483(1016) g vs 2760(966) g, p = .024]. In Zone 3 the pre-transport TRIPS-II score mean (SD) was higher in summer than in winter [11.5(8.8) vs 8.0(9.4), p = .040]. In Zone 4, the birthweight and weight at the time of transfer mean (SD) were higher in the winter cohort [2840(1026) g vs 2499(1091) g, p = .030; 3052(110) g vs 2662(1156) g, p = .023]. All other baseline demographic characteristics were comparable between the two seasons in all zones.

Table 1. Baseline demographic and clinical characteristics in the four predefined transport zones

	Zone 1			Zone 2			Zone 3			Zone 4		
Variable	Summer Transport (n= 216)	Winter Transport (n=166)	P Value	Summer Transport (n= 146)	Winter Transport (n= 122)	P Value	Summer Transport (n= 65)	Winter Transport (n= 70)	P Value	Summer Transport (n= 76)	Winter Transport (n= 99)	P Value
Gestation-al age in weeks, M (SD)	36.8 (3.6)	36.4 (3.9)	0.255	35.9 (4.5)	35.0 (4.7)	0.118	36.5 (3.9)	36.4 (3.6)	0.897	34.7 (5.1)	35.6 (4.5)	0.238
Postnatal age in days, M (SD)	**2.5 (5.4)**	**6.0 (13.6)***	**<0.001**	6.6 (14.2)	10.5 (19.0)	0.059	5.5 (13.5)	9.8 (17.6)	0.116	10.4 (17.9)	13.1 (19.3)	0.341
Sex, n (%)												
Male	136(62.7)	100 (58.5)	0.734	87 (59.2)	80 (64.5)	0.691	43 (66.2)	36 (49.3)	0.970	37 (47.4)	53 (52.5)	0.504
Female	80 (36.9)	70 (40.9)		59 (40.1)	43 (34.7)		21 (32.3)	36 (49.3)		41 (52.6)	48 (47.5)	
Birth weight in grams, M (SD)	2970 (885)	2976 (927)	0.944	**2760 (966)**	**2483 (1016)***	**0.024**	2944 (937)	2839 (817)	0.497	**2499 (1091)**	**2840 (1026)***	**0.035**
Weight at transfer in grams, M (SD)	2980 (877)	3098 (958)	0.208	2873 (1135)	2667 (1102)	0.133	3032 (1116)	3185 (1432)	0.489	**2662 (1156)**	**3052 (1102)***	**0.023**
Pre-transport TRIPS-II Score, M (SD)	8.8 (9.0)	9.4 (10.2)	0.544	13.5 (12.7)	10.8 (10.9)	0.088	**11.5 (8.8)**	**8.0 (9.4)***	**0.040**	12.4 (11.2)	12.7 (11.6)	0.877
Distance in km per trip in km, M (SD)	51.3 (10.9)	51.9 (12.2)	0.314	142.7 (36.3)	144.9 (36.5)	0.612	186.8 (27.6)	189.0 (26.8)	0.634	1179.5 (253.4)	1212.0 (241.0)	0.383
Mode of transport, n (%)												
Land	217 (100%)	171 (100%)	N/A	145 (98.6%)	122 (98.4%)	1.000	40 (61.5%)	58 (79.5%)	0.025	0 (0%)	3 (3%)	0.258
Air	0 (0%)	0 (0%)		2 (1.4%)	2 (1.6%)		25 (38.5%)	15 (20.5%)		78 (100%)	98 (97%)	

Note. Abbreviations: TRIPS-II Score = Transport Risk Index of Physiologic Stability Version II Score. *p < .05

Table 2 summarizes the results of the comparative analysis of transport details, transport net duration, transport speed, post-transport TRIPS-II scores, and mortality and IVH rates (in neonates <32 weeks GA). In Zone 1, the average distance traversed was 52 km; mean (SD) net transport time (minutes) was longer in winter versus summer [215.8(65.0) min vs 200.7(57.0) min, p = .019]. In Zone 2, the average distance traversed was 144 km and transport times were similar, but speed (km/min) mean (SD) was slower in winter versus summer [.58(0.10) km/min vs. .63(0.20) km/min, p = .020]. In Zone 3, the Snow Belt, the average distance traversed was 188 km; net transport time mean (SD) was longer in winter versus summer [438.2(93.0) min vs. 377.3(104.0) min, p < .001]. Lastly, in Zone 4, average distance traversed was 1195.75 km; transport times mean (SD) were similar between winter and summer seasons [747.0(253.0) min vs. 712.6(212.0) min, p = .331]. Mortality rates and IVH rates in neonates <32 weeks were similar between seasons across all zones. Post transport TRIPS-II scores were comparable in Zones 1, 2, and 4. In Zone 3, post-transport TRIPS-II score was lower in winter versus summer [6.6 (10.6) vs. 11.5 (10.5), p = .012]; however, after accounting for the difference in the pre-TRIPS-II score between seasons in Zone 3, the post TRIPS-II score difference was no longer significant (p = .301).

Table 2. Comparative analysis of transport times and post transport outcomes in summer and winter in the predefined transport zones.

	Zone 1			Zone 2			Zone 3			Zone 4		
Variable	Summer Transport (n= 216)	Winter Transport (n=166)	P Value	Summer Transport (n= 146)	Winter Transport (n= 122)	P Value	Summer Transport (n= 65)	Winter Transport (n= 70)	P Value	Summer Transport (n= 76)	Winter Transport (n= 99)	P Value
Mobilization Time in min, M (SD)	45.8 (38.9)	52.1 (46.7)	0.150	73.6 (109.7)	77.5 (121.5)	0.778	64.2 (49.6)	76.6 (51.0)	0.152	214 (186.5)	228.4 (226.6)	0.650
Response Time in min, M (SD)	**100.8 (55.8)**	**112.8 (60.3) ***	**0.004**	179.8 (123.1)	317.5 (1438.0)	0.250	**197.8 (67.7)**	**252.8 (137.1) ***	**0.004**	463.6 (222.0)	490.6 (254.8)	0.460
Stabilization time in min, M (SD)	68.5 (32.5)	73.2 (33.6)	0.168	85.1 (46.8)	87.8 (45.6)	0.627	86.1 (46.8)	87.8 (40.9)	0.820	113.0 (86.2)	118.1 (62.3)	0.647
Total Transport Travel Time in min, M (SD)	132.2 (48.5)	142.1 (56.3)	0.062	247.6 (129.1)	270.1 (139.2)	0.171	**295.1 (96.7)**	**350.4 (91.0) ***	**<0.001**	591.7 (213.4)	618.1 (257.3)	0.465
Travel speed in km/min, M (SD)	**0.4 (0.1)**	**0.3 (0.1) ***	**0.027**	**0.63 (0.2)**	**0.58 (0.1) ***	**0.020**	**0.69 (0.2)**	**0.57 (0.1) ***	**<0.001**	2.39 (2.9)	2.42 (2.9)	0.935
Net transport time in min, M (SD)	**200.75 (57)**	**215.8 (65)***	**0.019**	334.8 (137)	357 (143)	0.192	**377.3 (104)**	**438.2 (93) ***	**<0.001**	712.60 (212)	747 (253)	0.331
Post Transport TRIPS-II Score, M (SD)	8.0 (10.0)	9.4 (11.1)	0.225	13.5 (13.1)	11.8 (12.6)	0.318	**11.5 (10.5)**	**6.6 (10.6) ***	**0.012**	11.9 (11.47)	12.5 (11.5)	0.758
Overall mortality, n (%)	4 (1.9%)	5 (3.1%)	0.509	11 (8.4%)	7 (6.7%)	0.806	1 (1.7%)	2 (3.1%)	1.000	3 (4.2%)	7 (8.3%)	0.343
Mortality during transport or 1st 24 hours, n (%) ^	2 (50%)	2 (40%)	1.000	2 (18.2%)	0 (0%)	0.497	0 (0%)	0 (0%)	N/A	1 (33.3%)	1 (14.3%)	1.000
IVH in <32 weeks, n (%)[#]	4 (22.2%)	5 (26.3%)	1.000	9 (47.4%)	10 (38.5%)	0.761	2 (22.2%)	3 (37.5%)	0.620	4 (20.0%)	8 (47.1%)	0.157

Note. Abbreviations: TRIPS-II Score = Transport Risk Index of Physiologic Stability Score; IVH=Intraventricular Hemorrhage, NICU = Neonatal Intensive Care Unit. Definition of times: Mobilization Time (from call to leaving the door of responding hospital), Response Time (from leaving the door to reaching to destination center), Stabilization Time (from arrival at referral to leaving referral), Total Travel Time (mobilization, response, and return minus the stabilization) Net Transport Time (entire time to complete the transport)
*p < .05; ^ denominator is NICU deaths; [#] denominator in neonates <32 weeks.

Discussion

Our study compared neonatal transport durations and patient outcomes experienced throughout the summer and winter seasons to explore the impacts of adverse weather conditions on the successful regionalization of neonatal transport in Ontario, Canada. We analyzed 960 neonatal transport runs in 4 distinct geographical zones in our catchment area. For each transport run, details exploring the time spent on mobilization of teams, travel times (to and from referral sites) and stabilization times were considered. We found that in two out of the four zones we described (Zone 1 and Zone 3), transport times were significantly longer in winter than in summer. One of these zones (Zone 3) is located in the Canadian Snow Belt surrounding the Great Lakes, and is known to face significant adverse driving conditions during the winter. In this zone, we observed that net transport time was longer by approximately 61 minutes in winter than in summer – influenced by a longer time needed to reach the destination, as well as a slower travel speed. The transport times in Zone 1 were also longer in winter than summer by approximately 15 minutes which, though statistically significant, is unlikely to be clinically significant. Zone 1 is also geographically located closest to our centre. The transport times in Zone 2 were also longer in winter than summer by 22 minutes but this difference was not statistically significant. Finally, in Zone 4 – which involved air travel and is the farthest geographically from our area – we saw winter transport durations were longer in the winter than in the summer by 35 minutes but the difference was again not statistically significant. As expected we did not detect a difference in stabilization time in any zones.

To examine clinical outcomes, we explored post-transport TRIPS-II score as well as mortality during or within 24 hours of transport, and intraventricular hemorrhage rates in neonates less than 32 weeks gestational age. TRIPS-II scoring is a tool utilized to describe the level of illness acuity of transported neonates at different timepoints including prior to, during and post-transport. The TRIPS-II score has been validated for a seven-day mortality rate at NICU admission after high-risk transport, as well as for predicting total NICU mortality [9]. A higher score is associated with a higher risk of mortality. A high score that increases during transport is associated with the greatest mortality rate. In our cohort, we did not find a significant increase in post-transport TRIPS-II score in any zone. In Zone 3, the post-transport TRIPS-II score was lower in winter versus summer at the bivariate level. However, the pre-transport TRIPS-II score in this zone was also found to be lower in winter versus summer. When accounting for this discrepancy during analysis, the difference in post-TRIPS-II score was no longer significant. Mortality rates were low in the entire cohort and similar in all zones and all seasons.

An effective neonatal transport system is critically dependent on resources such as specially trained personnel and specialised transport equipment and vehicles. The transport process also involves many stages including the mobilization of a transport team, dispatch on either air or road, stabilization, and finally, return travel. Outside the need for personnel and infrastructure, extrinsic factors such as adverse weather conditions that disrupt travel could become significant extrinsic barriers in executing a safe and optimal transfer. In a country such as Canada, which experiences a wide range of climate conditions, winter months carry the risk of significant adverse weather conditions such as snow storms, blizzards, and freezing rain that can interrupt air and road transportation. In regions of the country experiencing temperate climactic weather conditions, these unfavourable, and often dangerous, transport conditions can occur on a fairly regular basis in the winter and are often described as causes for transport delay [10]. This is true in other countries with similar weather patterns as well. A study from northern Finland reported that 36% of their helicopter emergency medical missions were cancelled due to icy weather conditions [6]. This, in turn, led to delays in definitive treatment in 37% of adult patients in their cohort. The authors also reported that the estimated time that would have been saved if helicopter transport could have been successfully dispatched would have been about 60 minutes [6].

The neonatal population is highly vulnerable and susceptible to complications such as hypothermia, hypoglycemia, respiratory deterioration and hemodynamic instability, and subsequently mortality and brain injury [1, 3-7]. Longer transport duration could have a detrimental impact on neonates due to significant delay in obtaining higher level neonatal care [3]. It is considered that neonates transported for longer durations have a higher risk of significant adverse outcomes, with Pai et al. reporting that transport teams that took more than 60 minutes to arrive at a responding centre were associated with an increased risk of clinical deterioration [5]. In our cohort, we found that despite longer transport times in winter in some zones, transported neonates did not experience an increased risk of adverse health outcomes. In the most climatically affected zone (Zone 3), the net transport duration in winter was longer by approximately one hour, which would seemingly present a clinically significant difference; however, no increased rate of complications was demonstrated. Our data present a reassuring trend that has the potential to alleviate parental anxiety and reassure health care providers in referring centers. However, we should be cautious about extrapolating these findings to all neonates. Many aspects of clinical care in neonates who are born extremely preterm or asphyxiated are time sensitive and, therefore, these subsets may continue to be more vulnerable to an adverse outcome of longer transport times. Our findings suggest that the potential risk of longer transport times should be recognized by the health care teams when laying down plans for medical care. However, it should be recognized that a lengthened transport time does not inherently lead to increased adverse health outcomes. Furthermore, contingency plans should be provided ahead of time in subsets of patients whose medical treatment are particularly time sensitive. At the organizational level, our findings may have the potential to inform resource management and infrastructure development such as ensuring that helicopters providing transport services have adequate ice protection service or alternate air transport modes are available in case of road closures to facilitate time sensitive transports.

Interestingly in our cohort, while most of the air transports were completed in Zone 4, there was no significant difference in transport duration found in this area between summer and winter. While we did not collect the data on the number of transport missions cancelled, any delay or rescheduling was captured in the mobilization time, which was not significantly different. In Zone 3 – found within the Snow Belt – the amount of air transport was higher in summer (38.5%) than in winter (20.5%). A further subgroup analysis in Zone 3 based on the mode of transport showed no significant association between post-TRIPS-II score and mode of transport in summer compared to winter.

We acknowledge that our study has some limitations due to its single centre retrospective design. Potential confounders that might impact transport times such as competing transport requests and personnel availability, availability of dedicated vehicles was not accounted for. Additionally, there was missing data regarding some parameters that may introduce some bias. However, our study is the first of its kind to explore the effect of weather on neonatal transport in Canada and has a robust sample size that strengthens its validity. Future studies that further explore the effect of weather-related delay in specific subsets of neonates with extreme prematurity and perinatal asphyxia would help inform practices regarding the specific transport of these high-risk patients.

Conclusion

This large study showed that within two of the four predefined geographic zones, the time needed to complete neonatal transport was significantly longer during winter, but without any negative impact on post-transport stability, mortality, or major morbidity. Evaluation of these data might inform future service modelling.

Declarations

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Disclosure Statement

No potential conflict of interest was reported by the authors.

Ethics Approval

Institutional ethics approval was obtained by the Western University Research Ethics Board (WREM 122171) for conduct of the study.

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