Review Article

Neonatal transport metrics and quality improvement in a regional transport service

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Abstract: Sick neonates in non-tertiary centers rely on the expert skills of neonatal transport teams (NTTs) and efficient systems to provide safe and timely transport to tertiary centers. Quality metrics to measure and compare performance among transport teams are essential to ensure delivery of high-quality care and efficient use of limited and costly resources. We review the most relevant quality metrics available in neonatal transport and key issues to consider during their utilization. The use of quality metrics for quality improvement is described through the experience of a neonatal transport program based at a quaternary children's hospital in Canada.

Keywords: Transport metrics; quality improvement; neonate

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Introduction

Pediatric critical care transport by specialized teams results in improved outcomes compared with transport by non-specialized teams (1) with decreased unplanned events such as airway-related events, cardiopulmonary arrest, sustained hypotension, and loss of crucial intravenous access; and lower mortality rates (2). Neonatal transports constitute a subgroup of pediatric critical care transports that rely on the expert skills of specialized neonatal transport teams (NTTs) and efficient systems to provide safe and timely transport to tertiary centers. Review of the demographics for NTTs across Canada shows that there are wide variations in the volume of transports, mode of transport and team composition (*Figures 1-3*). In the United States, Karlsen *et al.* reported wide variation in many aspects of neonatal transport including transport training and certification, use of protocols to guide transport care, and quality assurance activities (3).

Whether these variations in the demographics of transport teams lead to differences in performance and outcomes is unclear. For team composition, comparison of transport teams with physicians versus teams without physicians have not shown consistent advantages of one team over the other. Leslie *et al.* showed that although nurse practitioner teams took longer to stabilize infants compared with physician teams, the patient's physiological condition was improved as measured by the changes in temperature and oxygen saturation when the nurse practitioner team was utilized (4). King reported the effect on patient outcomes after change of team composition from nurse-physician team to a nurse only team in neonatal and pediatric transports (5). There were no deaths during transport in both groups, but team response times were significantly shorter for the nurse-only team. A cost analysis has shown that the nurse (RN)/RN model is usually the least costly (6).

Neonatal transport programs require a major investment of financial and human resources for specialized equipment and in the advanced training of personnel. Transport programs have wide variation in processes and practices which are costly to maintain, thus benchmarking of the performance of transport programs is imperative to evaluate the quality of care and identify opportunities

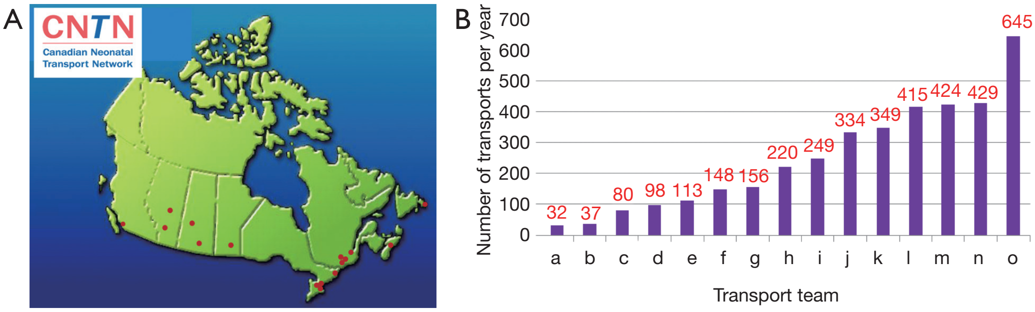

Figure 1 (A) Location of 16 neonatal transport teams in Canada; (B) volume of acute neonatal transports from non-Level III sites for neonatal transport teams in Canada. Source: Canadian Neonatal Transport Network (CNTN) Database 2015.

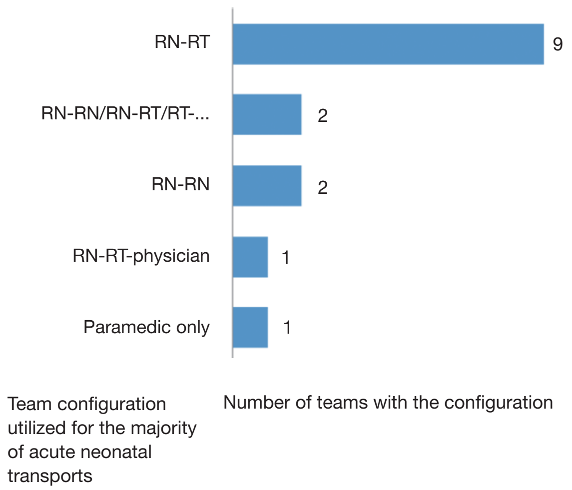

Figure 2 Composition of neonatal transport teams in Canada. RN, registered nurse; RT, respiratory therapist. Source: CNTN Survey Feb 2018.

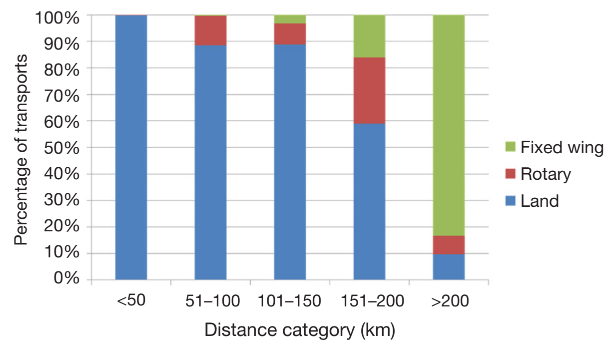

Figure 3 Mode of transport for first leg of transport by distance category. Source: CNTN 2015.

for improvement. The care delivered in the transport environment is distinct from the neonatal intensive care unit (NICU), and significantly affected by technical and logistical issues such as equipment, NTT availability, and travel distance. Thus, it is essential to factor in these technical and logistical issues during the interpretation of transport quality indicators.

The American Academy of Pediatrics (AAP) Section on Transport Medicine, Canadian Paediatric Society, and transport experts in the UK have strongly recommended the development of benchmarking and standards for transport performance (7-9). However, quality metrics for neonatal/pediatric transport are only recently being developed (10) and where indicators exist; there is no consensus on the reference standards to use to evaluate the performance of transport programs (11).

Previous reports of quality metrics in pediatrics have included both neonatal and pediatric transports; but the neonatal population has unique considerations from that of older pediatric patients. Focusing on neonatal transports, this review aims to outline the important quality metrics that can be used for benchmarking, and important factors to consider when utilizing these metrics. To demonstrate the use of these metrics for quality improvement, the experience of the neonatal transport program based at a quaternary children's hospital, the Hospital for Sick Children in Toronto, Canada will be described.

Quality metrics for neonatal transport

The Canadian Neonatal Transport Network (CNTN) was founded in June 2013 and is based at the Hospital for Sick Children. The primary goal of the CNTN was to develop a national neonatal transport database to allow benchmarking and improve quality of care and outcomes. The CNTN includes all of the 16 NTTs in Canada who conduct approximately 5,000 neonatal interfacility transports annually and enter data on their transports into a common database.

Quality metrics for the CNTN were defined shortly after the inception of the CNTN during the development of the CNTN database. The potential list of metrics was generated following a review of the literature and metrics proposed by other neonatal/pediatric transport groups (7,11,12). A face to face meeting with the medical director and/or manager representative(s) from all 16 neonatal teams occurred in Oct 2013 to develop standardized quality metrics. The final list of metrics was determined by national consensus utilizing the nominal group technique (13).

The Institute of Medicine's domains of quality (14) were utilized to categorize the indicators as these domains were deemed highly relevant for evaluation of transport programs. The six domains and representative metrics in neonatal transport adopted by the CNTN are compared with those utilized by other programs in *Table 1*. Review of this table demonstrates that many of the metrics are consistent across the different programs which validate their importance and acceptance.

Expanding the scope of work by NTTs to our obstetrical communities

Maternal transfer to an appropriate facility, is one of four high-evidence based practices during the perinatal management of neonates born at <32 weeks gestational age (GA) shown to reduce mortality by 18% without an increase in severe morbidity (16). Canadian national guidelines recommend that deliveries at <32 weeks GA occur in a high-risk perinatal center (17). This recommendation is based on improved outcomes for infants born at high-risk obstetrical sites compared with those born at non-high-risk obstetrical sites and transported to tertiary neonatal units after delivery (18). Despite these recommendations, 28% of deliveries of infants of GA <29 weeks in Canada occur in a non-perinatal (outborn) centre (19) and outborn deliveries in Canada remain one of the highest internationally compared with rates of 15% in Australia (20) and 16% in the United States (21). Perinatal centres and transport programs can have an important role in effecting a decrease in outborn deliveries. An obstetric indicator, number of deliveries at GA <32 weeks in non-tertiary centers is among the CNTN quality indicators. Inclusion of this metric highlights the importance of promoting and advocating for maternal transfers for preterm deliveries in order to improve outcomes. This is in the quality domain of equity to ensure that mothers in all regions can have access to the appropriate level of care for best neonatal outcomes. In addition, modifiable obstetrical interventions which have been shown to improve neonatal outcomes such as administration of antenatal steroids, magnesium sulfate and delayed cord clamping for preterm deliveries is important to promote in non-tertiary centers (16,22,23).

NTTs have a key leadership role in their region among the non-tertiary sites. Tracking of preterm deliveries <32 weeks at non-tertiary sites with feedback to their non-tertiary sites to promote maternal transfers may be one of the most impactful interventions to improve neonatal outcomes. The New South Wales region of Australia has been successful in the reduction of non-tertiary deliveries where statewide coordinated strategies including a perinatal telephone advice line to optimize in utero transfers were effective in reducing non-tertiary hospital births at GA <29 weeks from 19.7% to 14.9% (20). In the greater Cincinnati area, perinatal outreach education to providers at non-specialty perinatal centers promoted maternal transfer at <32 weeks to decrease outborn deliveries from 25% to 11.8% between 1995–1997 *vs.* 2003–2007 (21).

Methodological considerations for benchmarking

Standardize definitions, especially transport times

Karlsen demonstrated the importance of standardized definitions in her report of a survey of American transport teams, as she found that data quality was hindered by inconsistency in the definitions of the variables and indicators collected; and data quality was insufficient to allow benchmarking for comparisons across programs (3).

The nomenclature and descriptors for key transport time metrics that are used by different transport services (11,15,24) are summarized in *Table 2*. Transport times which are the mainstay of measurement for the quality domains of timeliness and efficiency are bogged down by inconsistencies in their definitions in publications and reports (25). The duration of time for care provided by the transport team at the referral site has been labelled variably as scene time (10) and stabilization time (11). The duration of time for the transport team to depart from their home site has been labelled as response time (26) or more commonly, mobilization time (12,15). There are commonalities in the choice of metrics and definitions

Table 1 Institute of Medicine's Six Domains of Quality and comparison of metrics in neonatal transport from different regions and programs

Quality domain*	CNTN	GAMUT	Ohio	CATS	NTG
Safety: *avoiding harm to patients from the care that is intended to help them*	• Dislodgement of therapeutic devices • Crew injury • Patient injury • Medication errors • Medical equipment failure	• Dislodgement of therapeutic devices • Crew injury • Patient injury • Medication errors • Medical equipment failure • Verification of tracheal tube placement • Waveform capnography for ventilated patients • Serious reportable events	• Dislodgement of therapeutic devices • Crew injury • Adverse drug events • Medical equipment failure • Verification of tracheal tube placement • Continuous end-tidal CO_2 monitoring • IV infiltration • Use of lights & sirens • Appropriate patient restraint during transport	• Dislodgement of therapeutic devices (endotracheal tube, IV devices) • Occluded endotracheal tube • Medical equipment failure (loss of monitoring, ventilator malfunction, exhaustion of oxygen supply) • Ambulance accident rate	
Effective: *providing services based on scientific knowledge to all who could benefit and refraining from providing services to those not likely to benefit (avoiding underuse and misuse, respectively)*	• Hypothermia (temperature <36.0 ℃, any time during transport) • First attempt intubation success • First attempt peripheral intravenous insertion success • Endotracheal tube malposition • Cardiac arrest • Hypotension requiring treatment during transit • Clinical deterioration requiring return to referral unit or vehicle stoppage • Unplanned transfer to higher level of care within 24 h of transport • Urgent intervention upon arrival at destination • CO_2 <30 mmHg • Hypoglycemia <2.6 mmol/L persistent despite intervention	• Hypothermia (temperature <36.5 ℃ axillary at destination site) • First attempt successful tracheal tube placement • Rapid sequence intubation • CPR during transport • Hypoxia during transport (saturation below 90%)	• Hypothermia • Intubation success rate • Premedication prior to intubation • Patient arrest during transport • Hypotension during transport • Floor to ICU transfer within 4 h	• Core temperature <34.0 ℃ • Respiratory arrest • Cardiac arrest • Hypoglycemia <2.5 mmol/L) • Systolic hypotension (infant <55 mmHg) • Unplanned re-transfers • Interventions after ICU admission	• Hypocarbia <4 kPa (30 mmHg) • Hypercarbia >7 kPa (52.5 mmHg) and pH <7.20
Patient-centered: *providing care that is respectful of and responsive to individual patient preferences, needs, and values and ensuring that patient values guide all clinical decisions*	• Parent on transport	• Reliable pain assessments	• Family on transport • Pain assessment & management	• Patient satisfaction	• Parent on transport

Table 1 (*continued*)

Table 1 *(continued)*

Quality domain*	CNTN	GAMUT	Ohio	CATS	NTG
Timely: *reducing waits and sometimes harmful delays for both those who receive and those who give care*	• Dispatch time • Land vehicle response time to home base • Mobilization time • Response time • Age when target temperature of 34.0 ℃ reached for therapeutic hypothermia • Percent in target range within 6 h for therapeutic hypothermia	• Mobilization time	• Dispatch time • Scene time (equivalent to stabilization time for CNTN) • Total transport time	• Acceptance time (equivalent to dispatch time for CNTN) • Mobilization time • Response time • Stabilization time • Total transport time	• Despatch time (time from referral to mobilisation from team base) • Response time • Stabilization time • Age when target temperature 34 ℃ reached for therapeutic hypothermia • Percent in target range within 6 hours for therapeutic hypothermia
Efficient: *avoiding waste, including waste of equipment, supplies, ideas, and energy*	• Stabilization time • Total transport time	• Use of standardized patient care handoff	• Standardized patient handoff	• Faulty initial triage (72 h window) • Number waiting >8 h for transport team • Number transferred out of region • Team refusals	• Team refusals (transfer by another service for your catchment area)
Equitable: *providing care that does not vary in quality because of personal characteristics such as gender, ethnicity, geographic location, and socioeconomic status*	• Maternal transfer to high-risk perinatal center for deliveries at <32 weeks gestational age		• Above metrics stratified by sex, race/ethnicity, age, religious preference, insurance status, rural/urban/suburban, and by referral hospital		

*, from Institute of Medicine (14). CNTN: Canadian Neonatal Transport Network; GAMUT: Ground and air medical quality transport; from a total of 27 metrics in GAMUT, only 17 of these which are relevant for neonates are included (12); Ohio: Ohio Neonatal/Pediatric Transport Quality Collaborative, only neonatal metrics included (10); Note that considerable overlap exists between the GAMUT and Ohio metrics as the development of GAMUT was led by leaders of the Ohio Collaborative; CATS, Children's Acute Transport Service, London, UK (11); UK NTG: Neonatal Transport Group (15).

Table 2 Definition of transport times used for quality metrics

Terminology	Descriptors for the same time interval			
	CNTN	CATS	NTG	NETS
Dispatch time (CNTN); Acceptance time (CATS); Decision time (NTG); Tasking time (NETS)	Referral made *to* dispatch	Referral *to* referral accepted	Referral *to* referral accepted	Call *to* decision to task
Mobilization time (CNTN, CATS, NETS); Activation time (NTG)	Dispatch *to* leave home base	Referral accepted *to* leave home base	Decision *to* mobilisation from home base	Team activation *to* depart from home base
Response time	Referral made *to* arrive at referral	Referral made *to* arrive at referral	Referral *to* arrival in referring unit	Call *to* first look
Stabilization time	Arrival at referral *to* depart from referral	Arrival at referral *to* depart from referral	Time in referring unit	First look *to* ready to depart
Total transport time (CNTN, CATS); Total mission time (NTG, NETS)	Dispatch *to* return to home base	Referral accepted *to* arrive at home base	Referral *to* return to home base *or* start of next transfer if back to back	Call *to* return to home base

CNTN: Canadian Neonatal Transport Network; CATS: Children's Acute Transport Service, London, UK (11); NTG: UK Neonatal Transport Group (15); NETS: Newborn and Paediatric Emergency Transport Service Sydney (24).

among the teams, but future reports and publications should strive to align nomenclature and descriptors with those summarized in *Table 2*.

Once the definitions of transport times have been standardized, the next challenge is in the determination of reference standards for benchmarking as large variations have been reported (4,24,27-31). The Infant Transport Team of British Columbia published their standards for transport times, with 'response' times of 15 min for transport requests of very unstable patients by land and 1 hour by air (26). However, their definition of 'response' time was in fact mobilization time as defined by other transport systems (see *Table 2*). Moreover, these recommended standards have not been tested for validity and generalizability.

The optimal stabilization time is not known and it is recognized that shorter stabilization times which are targeted in the adult population (32), do not result in better outcomes for neonates (2,33). Neonatal patients have longer stabilization times compared with pediatric patients (median stabilization time of 80 *vs.* 45 min) (31); and neonates with a higher severity of illness (defined as ventilated and on inotropes) have longer stabilization times compared with non-ventilated neonates (median stabilization time 125 *vs.* 63 min) (31).

Rather than minimization of stabilization times, a major goal is to expedite (I) the arrival of the NTT at the referral site (response time) so that the infant can benefit from their advanced skills; and (II) the arrival of the infant at the destination hospital for definitive care (34). However, from an evaluation of performance perspective, these times must be corrected for distance, weather and available modes of transport, as these factors are beyond the control of transport teams (24).

Benchmarks for transport times can be determined by service standards, e.g., land vehicle response time of 15 min by paramedic services for critical transports; or expert consensus. However, benchmarks can be derived by data using the regional performance such as national medians and interquartile ranges for continuous variables and odds ratios with 95% confidence intervals for proportions. The Ground and Air Medical qUality Transport (GAMUT) QI collaborative uses the Achievable Benchmarks of Care (ABC) method (35) to determine reference standards. The ABC method establishes the performance level consistently being attained by the best participants that account for at least 10% of the overall population. A major advantage of this method is that it allows the comparison of performance between groups of varying sizes.

Reporting of low frequency events

Some of the teams in Canada have low transport volumes, or some of the indicators involve a small number of cases

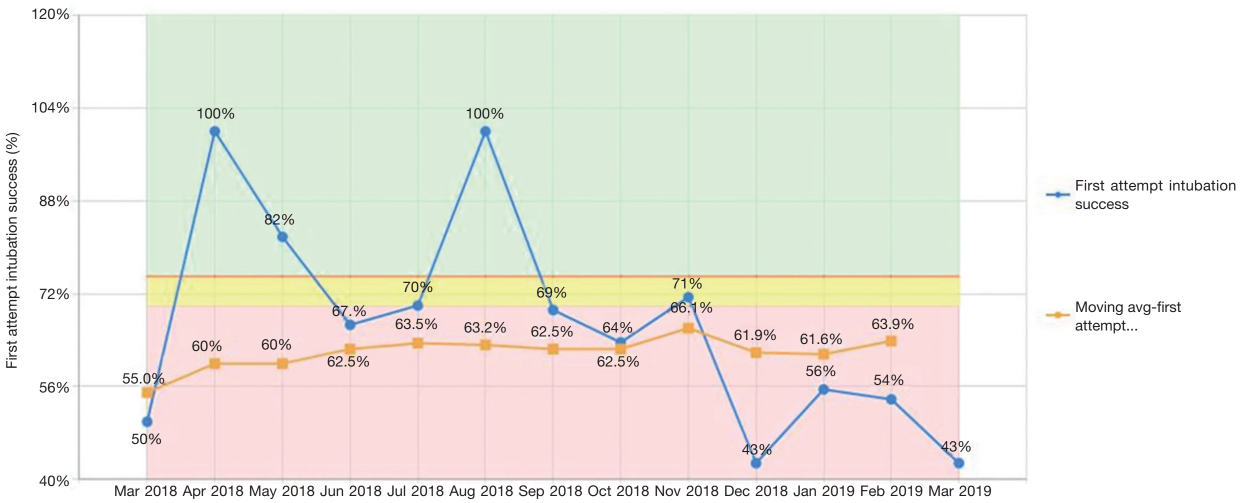

Figure 4 Plotting low frequency events to demonstrate changes in rates over time utilizing hypothetical data. Blue line demonstrates monthly rates and shows major fluctuations due to small sample sizes. Orange line is the 12-month moving average and is a clearer representation of changes over time.

even for high volume teams. An example of a low frequency event is endotracheal intubation which has decreased in neonatology due to the preference for non-invasive ventilation as the primary mode of respiratory support even for extremely premature infants. For infrequent events, monthly rates may have major fluctuations even with small changes in the number of events, and true trends may be difficult to visualize. A clearer report of the changes in rates over time can be visualized using the moving average. See *Figure 4* for rates for first attempt intubation shown by month and by 12-month moving average using hypothetical data. This example demonstrates how the format of data reports can have a major influence on the utility of the data. In addition, any comparative analysis of indicators should adjust for the volume of service for low frequency events.

Ensure comparison of similar populations

The populations being analyzed need to be clearly defined as different populations can have major differences in outcomes. For example, we need to distinguish between interfacility transports compared with on-scene transports; between transports to a higher level of care compared with lateral or return transfers; between neonates that are admitted to tertiary sites compared to non-tertiary sites; and between neonates that are only admitted to intensive care units compared to all units. For this latter comparator, the neonatology literature demonstrated that mortality rates can be significantly underreported if only patients surviving to NICU admission are included compared to all deliveries which include a significant proportion of delivery room deaths (36).

Another inconsistency in the populations analyzed is in the definition of a neonate, which has not been well standardized across reports. For example, GAMUT utilizes age <29 days (12), whereas CNTN utilizes corrected GA up to 44 weeks for preterm infants.

In order to ensure standardization of definitions and study populations for benchmarking, a robust method would be to collect raw data from the multiple comparator sites utilizing a common database, and these data sent to a central site where the analyst can standardize definitions and populations. The ability to utilize one common database for all Canadian NTTs is one of the strengths of the CNTN database; whereas limitations of other databases that rely on entry of aggregate data by individual sites (12,15), is that definitions or populations maybe subjectively determined and thus less standardized, even if the numerators and denominators are objectively defined.

Customized selection of quality metrics

Many of the transport metrics are relevant for transports for all populations. However, the benchmarks for some, such as stabilization time will require adjustment based on age group as neonatal transports have been shown to have

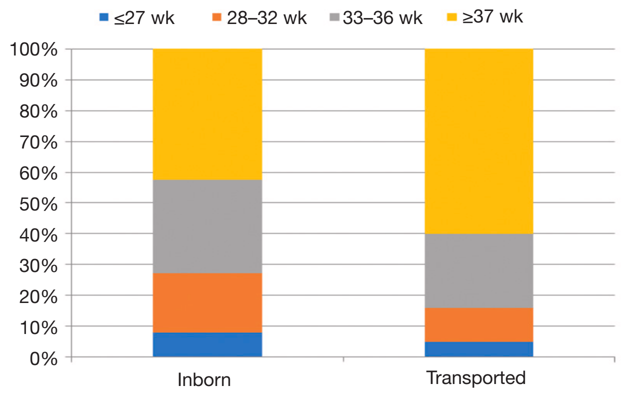

Figure 5 Neonates born in perinatal centers versus infants transported to NICUs. Source: Canadian Neonatal Network data (inborn) http://www.canadianneonatalnetwork.org/Portal/LinkClick.aspx?fileticket=9K3crPtfgQs%3d&tabid=39; and CNTN data 2015 (transported).

Table 3 Most responsible problem in neonatal transports in order of frequency

Most responsible problem	n
Respiratory GA >27 weeks	1,101
Prematurity	841
Hypoxic ischemic encephalopathy or seizures	678
Cardiac	473
Surgical	302
Hypoglycemia	163
Sepsis	149
Hyperbilirubinemia	96

Source: CNTN data 2015.

much longer stabilization times compared with pediatric transports (31).

GAMUT services transports of all ages and has proposed 27 quality metrics among which 17 were relevant for neonates (12). This highlights the importance of customization of quality metrics based on the age of the population, and that neonate-specific metrics should be further delineated.

One of the conditions that are more common among neonates who are transported is hypoxic ischemic encephalopathy (HIE). For neonates with HIE who are eligible for therapeutic hypothermia (TH), NTTs have a vital role in the timely initiation of TH within 6 hours of birth in order to improve outcomes (37). This has been recognized by NTTs and timely initiation of TH has been included as a quality indicator by the CNTN and Neonatal Transport Group (see *Table 1*).

There are several neonatal conditions with best practice standards that can be utilized to set benchmarks for the neonatal transported population. The care of preterm infants during the "Golden Hour" after delivery can be optimized to minimize their risk of intraventricular hemorrhage (IVH), especially since the risk of IVH is greater in neonates born in non-tertiary centers compared with those born in tertiary centers (18). Prevention of hypocarbia or hypercarbia, and avoidance of excessive fluid boluses are two important practices to target as metrics for NTTs which can decrease the risk of IVH (38). Another potential neonatal quality metric is to minimize stabilization and NICU admission times to be shorter than the typical times for neonates who have time sensitive conditions such as duct dependent cardiac lesions or surgical emergencies due to bilious vomiting or intestinal perforation.

Risk adjustment of metrics for severity of illness—an ongoing challenge

Neonates transported to NICUs differ from neonates born in perinatal centers in demographic characteristics such as GA as shown in *Figure 5* and most responsible problem as shown in *Table 3*. Due to the wide heterogeneity in conditions and varying severity of illness among neonatal transports, an objective and reliable tool to measure severity of illness is required to allow risk adjustment for comparison of outcomes. However, this has been difficult to achieve and a major gap exists in this area.

Due to the heterogeneity of conditions, a physiology based score based on objective parameters prior to NTT interventions would be most pertinent. The most commonly utilized measure of severity of illness in neonatal transport has been the transport risk index of physiologic stability (TRIPS) score (39). The TRIPS score was developed with the purpose to assess changes in patient status as a result of the transport process, and a worsening in the TRIPS score has been associated with increased mortality. Higher TRIPS scores have been associated with an increase in 7-day mortality and severe IVH risk.

The individual components of the TRIPS score represent physiologic parameters: temperature, blood pressure, respiratory status and response to noxious stimuli. Changes in these components can be a proxy for improvement or deterioration in clinical status. The change in TRIPS score may have face validity as a measure of quality of care. While these parameters may be modifiable with clinical interventions in some cases; in other cases, the changes in TRIPS scores may not necessarily be due to quality of care but rather due to non-preventable clinical deterioration. To account for changes in the severity of illness scores such as the TRIPS score due to factors beyond quality of care, a group from California are utilizing the Quality Change Point 10th percentile from their network to evaluate the quality of care provided by the transport team (40). For the TRIPS score, the narrow spectrum of values utilized to derive the score require further review to consider different blood pressure parameters for varying GAs.

There are other severity of illness measures that are not included in the TRIPS score, such as level of respiratory support, fractional inspired concentration of oxygen, and hemodynamic support; that have been utilized individually or in combination with other factors as measures of severity of illness among transported patients (31,41-44). These additional parameters require further study through comparison with TRIPS scores and association with outcomes but do have potential utility due to ease of use.

The mortality index for neonatal transportation (MINT) score has been shown to correlate with mortality and was proposed as a measure of severity of illness which can assist with effective triage at the time of the first telephone contact by the referring hospital with the transport team (42). This early determination of severity of illness can help decide which infants may benefit from the presence of a physician or a more timely response. However, its use has not been widely adopted due to the large number of transports with missing data for 2 of the score's 7 main components (paO_2 and pH) which require the availability of an arterial blood gas measurement.

It is also important to recognize that some of the metrics should take into account patient demographics that increase baseline risk such as GA for hypothermia, intubation success rates, and PIV insertion success rates; and distance as an important determinant of risk for hypothermia and time to target temperature for TH.

Utilization of quality metrics

A major purpose of transport databases is to generate reports which can be used by teams to drive quality improvement. Benchmarking of performance can guide how to target funding and educational efforts. Several regions and programs are currently utilizing these metrics for benchmarking and quality improvement.

The Pediatric Intensive Care Audit Network (45) and United Kingdom Neonatal Transport Group (15) have been utilizing their databases to compare activity and severity of illness, which has provided support for service development and procurement of new equipment.

Internationally, more than 350 transport programs including adult, pediatric and neonatal populations submit their summary data to the Ground and Air Medical qUality Transport (GAMUT) database (12). The GAMUT database provides a basis for transport teams to track, report and analyze their team activity and compare them with other teams world-wide. Use of timely comparator reports such as those generated by GAMUT can promote review of local data, and increase dialogue and sharing of practices with other programs.

Within Canada, the CNTN database collects granular data from all 16 NTTs in Canada onto a customized common database which provides a rich source of data for reporting and benchmarking. A site reporting application is available to all NTTs to generate local data reports in real time. This application is being utilized at SickKids to generate reports which are used to conduct daily reviews of runs that have occurred in the previous 24 hours with front line clinicians. A focus of the review is to audit the accuracy and completeness of data collection, and review metrics to compare with local program and national benchmarks. The metrics reviewed during these run reviews are summarized in *Figure 6*. This regular audit and feedback process enhances front line NTT engagement through a better understanding of how the data are used to improve processes and outcomes. At SickKids, data are collected prospectively in real time by front line transport team members and entered onto the CNTN database as part of their routine documentation at the end of their transport run. This direct involvement in data entry with the audit process during run reviews rather than having non-clinical data abstractors enter the data retrospectively, promotes data accuracy and completeness. The CNTN quality metrics are being utilized by the HSC NTT medical directors and managers on a monthly basis to track team performance, identify areas for improvement, and evaluate changes in outcomes over time after implementation of interventions.

Within the CNTN, the tracking of data has provided an impetus for the sharing of best practices. CNTN conducts regular web conferences with all 16 NTTs in Canada, Transport Run Indicators

Team configuration	Was it appropriate? Should a physician have attended?	**Delay in mobilization time (>30 min)**
Mode of transport	Was most efficient mode chosen? Check response time	awaiting EMS
Delay in dispatch or reaction time	awaiting blood products	awaiting lift assist
arranging transportation	awaiting equipment	**Delay in stabilization time**
team unavailable	awaiting fellow	waiting for paperwork; xray; bed
triaging calls	awaiting bed	patient acuity; procedures
awaiting more information	other; specify	trainee education
Clinical: physiologic	Temp <36.0; <35.0	bradycardia with non-physiologic HR <100
pneumothorax	need for intubation	cardiac arrest
unexpected desaturation	resp arrest requiring resus	MBP <GA and clinical signs
resp arrest during transport		glucose <2.6 under ACTS care
clin deter req return to referral	clin deterioration requiring vehicle stoppage	unable to transfer due to clinical instability
Clinical complications		
difficult IV access	number of attempts for PIV	number of attempts for ABG
dislodged ETT	malpositioned ETT	number of attempts for ETT
dislodged UAC, UVC, PAL	iatrogenic injury to patient	medication error
For GA <32 wks	FiO_2 >30%	seizures, decreased tone
at 1 hour: for Golden Hour Apgar	pCO_2 <40	pCO_2 >60
	MAP <GA	decreased perfusion
HIE	time to passive cooling	time to active cooling
	time to target temp 34.0	eligible and not cooled
		reason not cooled
iNO commenced at what time	**OI at iNO initiation**	
Post transport clinical deterioration		
urgent intervention within 1 h of handover to receiving hospital: e.g. increased resp support, iNO, CPR		
patient died within 24 hours of transport		
unplanned transfer to higher level of care within 24 hours of transport		
Equipment complication		
supplies not available	defective supplies	not enough equipment (IV pump), supplies depleted
vehicle malfunction	no electrical power available	
amb/air equipment incompatible	amb mechanical: need to change vehicles	
ventilator malfunction	loss of compressed gas	no additional compressed gas available
loss of power	incubator heater failure	IV pump failure
System complication	helicopter not available	fixed wing not available
delay >30 min for bed with Criticall	delay >30 min departure waiting for bed	
weather	traffic congestion	vehicle crash
arrive at wrong destination	injury to patient	injury to team member

Figure 6 Metrics reviewed during daily run reviews at SickKids.

where the quality metrics are reviewed. After review of the metrics, the topics of highest relevance and importance are chosen by CNTN members for further discussion. Transport teams that have previously worked in silos are able to utilize these comparisons to identify areas of strength and share best practices; and identify areas in need for improvement to help focus quality improvement efforts. During a recent CNTN web conference, we focused on TH in transport where we presented data on national variations in the time to target temperature after initiation of TH (see *Figure* 7). We shared national practices including the recent implementation of the cooling blanket in transport by 2 teams, management of cases with mild encephalopathy, and guidelines for anticonvulsant therapy. During another web conference, intubation success rates were compared nationally which led to the sharing of practices for training in endotracheal intubation.

Regional databases can be adopted by administrative advisory bodies to measure resource allocation and evaluate practices. Many of the CNTN indicators have been adopted by the Ontario Provincial Council for Maternal and Child Health as quality indicators to allow tracking of quality of care and resource utilization at a provincial level. These indicators are being utilized to monitor changes after implementation of quality improvement initiatives, for service accountability, and strategic planning and system monitoring. For example, review of metrics on land vehicle response times for transport teams identified a major discrepancy among teams in Ontario. This data provided strong support for a proposal submitted to our ministry for dedicated land ambulances for each of the teams in Ontario (46).

Summary and future directions

The need for benchmarking in neonatal transport is universally accepted. The recommended quality metrics for neonatal transport are consistent across reports and utilize the framework for domains of quality by the Institute of Medicine. The systems indicators can be utilized by all age

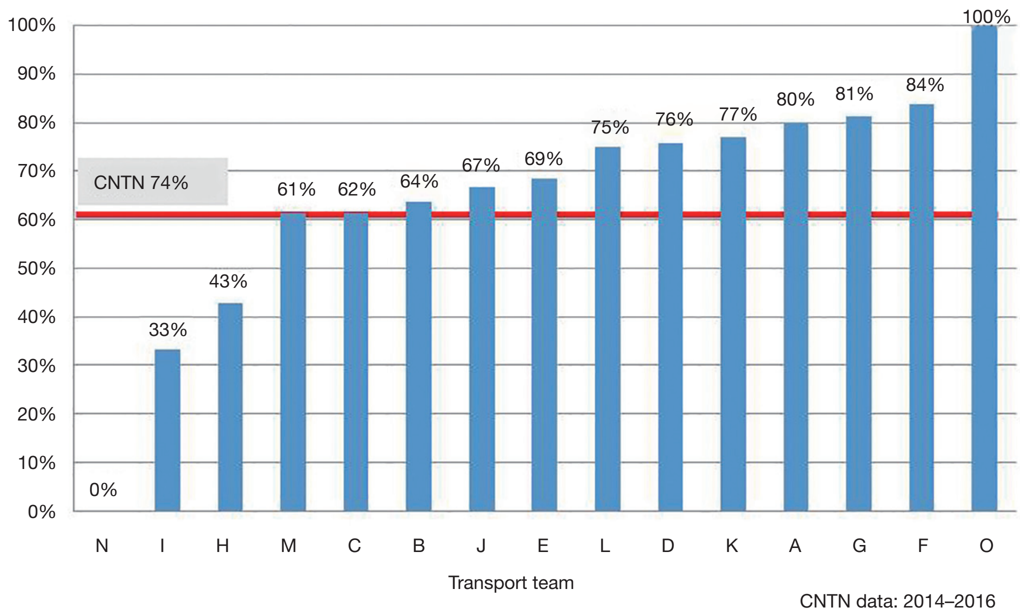

Figure 7 Variation among transport teams in the proportion of cases of therapeutic hypothermia where target temperature of 34.0 ℃ reached at ≤6 hours age.

groups; whereas clinical indicators require customization for the neonatal population. Metrics tracked by NTTs should include preterm deliveries in non-tertiary centers in their regions, as NTTs have a key leadership role to promote maternal transfers including audit and feedback to non-tertiary obstetrical sites.

There is a need for centralized data collection or utilization of common databases to allow standardation of definitions and populations across regions and internationally. While specific regions have centralized databases, improved harmonization of definitions, populations and indicators across regions is required to broaden the net for collaboration. The barriers to this collaboration include limited resources to enter data and funding to hire analysts for real time data management.

To support valid comparisons for benchmarking, further work is required to determine reference standards for benchmarking regionally and internationally; and the development of easy to apply risk adjustment scores to assist with triaging and comparison of outcomes. Metrics for specific conditions commonly managed in neonatal transport such as that currently utilized for timely initiation of TH in HIE require further derivation and implementation.

Significant progress has been made in the development of databases and quality metrics in neonatal transport. In order to achieve the maximal return from these efforts, the data must be utilized to generate meaningful reports to drive and evaluate improvement. The focus of future work should be to develop real time benchmarking reports that are easy to access by all teams and are visually impactful; followed by incentives to ensure that transport programs are continually reviewing their metrics; then the provision of a venue to ensure regular dialogue with other teams. These initiatives will set the momentum to engage teams in continuous quality improvement where current best practices are shared, and new interventions can be formulated and implemented.

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Footnote

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