Predictors of Unfavorable Thermal Outcome During Newborn Emergency Retrievals

Beatrice Skiöld, MD, PhD,[1,2] Michael Stewart, MD,[1,2] and Christiane Theda, MD, PhD[1-4]

Abstract

Objective: Maintenance of normal body temperature is a challenge during transports. We aimed to identify predisposing factors for unfavorable thermal outcome during emergency retrievals of neonates.

Methods: Demographic data and clinical variables for transports performed over a 2-year period were extracted from the Newborn Emergency Transport Service (Victoria, Australia) database. Arrival temperatures outside normothermia (36.5°-37.5°C) were defined as an unfavorable outcome.

Results: Normothermia on arrival at the receiving hospital was achieved in 78% of 1,261 transports. The strongest predictor of unfavorable thermal outcome was an abnormal temperature at the start of the retrieval (odds ratio [OR] = 8.04; 95% confidence interval [CI], 5.91-10.95; $P < .001$) followed by very low weight on transport (< 1,500 g; OR = 2.49; 95% CI, 1.63-3.80; $P < .001$) and respiratory support (OR = 1.81; 95% CI, 1.29-2.54; $P = .001$). Medications (eg, inotropes and sedation/muscle relaxation) or central/peripheral venous/arterial lines were not significant predictors of outcome when temperature at retrieval start, weight at transport, and respiratory support were adjusted as cofactors. Mode of transport (road, fixed wing, or rotary wing aircraft) and outside temperature were not associated with thermal outcome.

Conclusion: Abnormal temperature at the start of the retrieval, very low transport weight, and respiratory support were strong predictors of unfavorable thermal outcome during neonatal emergency transports.

Maintenance of normal body temperature is fundamental for the well-being of the newborn and a cornerstone of neonatal care.[1] Hypothermia may delay the transition from fetal to neonatal circulation[2] and has been related to serious morbidity[3-6] and mortality.[6,7] Hyperthermia is less common in the neonatal period but may also have detrimental effects.[8,9]

Thermal homeostasis is determined by the neonate's ability to balance heat production and heat loss.[10] There are 4 main mechanisms of heat loss: evaporation (eg, skin and airway moisture evaporation), conduction (eg, through skin to surface contact), convection (eg, blood flow redistribution and diffusion off the skin to moving air), and radiation (radiant energy from the body surface). The predominant mode of heat production in the neonate is nonshivering thermogenesis through brown fat lipolysis, which requires oxygen and an energy source provided through adequately circulating blood. The balance can easily be disrupted, and this may lead to a vicious circle in which a compromised neonate gradually gets cold, aggravating the underlying condition and leading to greater challenges to achieve a normal body temperature.[11] In clinical practice, awareness of these mechanisms is essential when assisting the neonate to maintain normal body temperature.[12]

Temperature control in newborns has been studied extensively during the first hours of life,[11] but large-scale reports on how temperature is regulated and maintained thereafter are scarce. Neonates requiring transportation to another hospital are known to be at risk because maintenance of normal body temperature is often a challenge during transfers. On review, surprisingly few recent publications address temperature homeostasis on transport.[12-14] The primary objective of this study was to identify predisposing factors for unfavorable thermal outcome during emergency retrievals of neonates.

Methods

The Newborn Emergency Transport Service (NETS) is a statewide neonatal intensive care retrieval service in Victoria, Australia. NETS serves a population of 5.6 million and covers an area of 227,000 km^2. Approximately 1,100 primary emergency transports are performed every year (ie, about 3 per

1. Newborn Emergency Transport Service, Royal Children's Hospital, Melbourne, Victoria, Australia

2. Royal Women's Hospital, Melbourne, Victoria, Australia

3. Murdoch Childrens Research Institute, Melbourne, Victoria, Australia

4. University of Melbourne, Parkville, Victoria, Australia

Address for correspondence:
Christiane Theda, MD, PhD, Royal Women's Hospital, Neonatal Services, 20 Flemington Road, Parkville, VIC 3052, Australia,
Christiane.Theda@thewomens.org.au

Acknowledgments
The authors thank the NETS nursing and medical team for the efforts to maintain our database. We would like to give special thanks to Jane Piriatinski for assistance with the data retrieval.

One of the authors (BS) was supported by The Swedish Society of Medicine, Sällskapet Barnavård, and The Swedish Brain Foundation.

1067-991X/$36.00

http://dx.doi.org/10.1016/j.amj.2014.10.012

day, both from rural Victoria and within metropolitan Melbourne). For all transfers, demographic variables, clinical parameters, and medical/nursing management are documented and prospectively entered into the NETS database.

For the present study, the NETS database was reviewed for primary emergency transfers (defined as a transfer because of a condition requiring urgent retrieval under medical supervision) performed between July 1, 2007, and June 30, 2009. All infants with recorded temperatures at stabilization and on arrival at the receiving hospital were eligible for analysis, excluding patients treated with therapeutic cooling. In total, 1,261 transported neonates were included in the present review.

Normothermia was defined as an axillary and/or rectal temperature between 36.5° and 37.5°C. The desirable thermal outcome was normothermia on arrival to the receiving unit irrespective of initial temperature. Inversely, unfavorable thermal outcome was defined as any neonate being hypothermic (< 36.5°C) or hyperthermic (> 37.5°C) at the end of the transfer.

The following variables were investigated for associations with unfavorable thermal outcome: weight and gestation at birth and at transfer, sex, plurality, severity of illness, mode of transport (road/fixed wing/rotary wing), and outside average monthly temperature (as per data published by the Bureau of Meteorology Government of Australia, www.bom.gov.au). Weight at birth and at transport were stratified into 3 groups: very low, < 1,500 g; low, 1,500 to 2,500 g; and normal, > 2,500 g. Severity of illness was investigated by exploring the following clinical parameters: respiratory support (mechanical ventilation or continuous positive airway pressure [CPAP]); chest drains; umbilical venous/arterial catheters; peripheral arterial catheters; and pharmacological treatment with inotropes, antibiotics, sedatives, analgesics, muscle relaxants, and anticonvulsants.

Statistical analysis was performed with PASW Statistics software 21.0 (SPSS Inc, Chicago, IL). In univariate analyses, the Student *t*-test was used for continuous variables and the Pearson chi-square test was used for categoric data. The Spearman rank coefficient was used to assess the correlations between temperatures before and after retrieval. The relative strength of associations was evaluated according to the following guidelines proposed by Portney[15]: Spearman rho of 0.25 to 0.50 represents an association of fair strength, 0.5 to 0.75 represents an association of moderate strength, and values above 0.75 reflect very good associations. Logistic regression was used to investigate the contribution of the previously mentioned variables regarding thermal outcome. A *P* value less than .05 was chosen as the cutoff level for significance.

Results

The study sample consisted of 1,261 infants; 480 (38%) were female, 776 (62%) were male (sex data missing for 5 infants), 1,148 (91%) were singletons, and 112 (9%) were twins (plurality not reported for one infant). Other baseline demographic variables and clinical parameters are shown in Table 1. The main primary reasons for transport listed were respiratory illness (27%), prematurity (15%), and neurologic (11%) or abdominal (11%) conditions; all other primary specified reasons (cardiac, infection, metabolic, hematologic, chromosomal disorders, and administrative/bed status) were less than 10%. In 12% of transports, a specific diagnosis was not listed. Road ambulance was used for 77% of transports, fixed wing aircraft for 19%, and rotary wing/helicopter for 4%.

Before transport, 25% of infants were hypothermic (< 36.5°C), 69% were normothermic (36.5°-37.5°C), and 6% were hyperthermic (> 37.5°C). Normothermia on arrival to the receiving unit, irrespective of the initial temperature, was achieved in 78% of all infants, whereas 16% were hypothermic and 6% were hyperthermic (Fig. 1a). If temperature was abnormal before the retrieval, it was likely to be abnormal at the end of the transfer (Spearman rho = 0.61, $P < .001$).

An unfavorable thermal outcome (ie, neonates being hypothermic or hyperthermic at the end of the transfer) was more common in infants with very low birth weight, very low transfer weight, low gestational age at birth, and low corrected gestational age at transport ($P < .001$ for all); 36% of very low transfer weight babies were hypothermic at arrival (Fig. 1b). An unfavorable thermal outcome was also more common in infants on respiratory support (mechanical ventilation and CPAP); infants having umbilical catheters or peripheral arterial lines; and infants having received and/or receiving antibiotics, inotropes, analgesia, short-acting muscle relaxation (Pearson chi-square, $P < .001$ for all) and sedation (Pearson chi-square, $P = .025$).

In univariate analyses, sex, plurality, chest drains, use of anticonvulsants or long-acting muscle relaxation, outside average temperature during the month of transfer, duration of trip, and mode of transport were not significantly associated with body temperature on arrival at the receiving hospital.

Logistic regression was used to investigate the contribution of the clinical variables with regard to outcome and for the correction of possible covariances. The strongest predictor of unfavorable thermal outcome was an abnormal temperature at the start of the retrieval (odds ratio [OR] = 8.04; 95% confidence interval [CI], 5.91-10.95 [$P < .001$]) followed by very low transfer weight (< 1,500 g; OR = 2.49; 95% CI, 1.63-3.80; $P < .001$) and respiratory support (OR = 1.81; 95% CI, 1.29-2.54; $P = .001$). Other investigated variables did not contribute to an adverse thermal outcome when temperature at the start of the retrieval, weight on transport, and respiratory support were taken into account.

A review of temperature gradients of individual patients showed that in 207 transports (16.4%) the patient temperature remained stable, in 644 transports (51.1%) patients arrived warmer, and in 410 transports (32.5%) patients arrived colder (Fig. 2a). Of the 36 patients who gained more than 1°C (Fig. 2b), the vast majority (32/36) were hypother-