Heated and humidified nasal CPAP on neonatal transport

It is widely accepted that neonatal patients who require airway support should receive heated and humidified gases. This can be a challenge when providing short-prong nasal continuous positive airway pressure (CPAP) in the transport environment. This article describes how heated and humidified gases can be provided during transport in this group of patients and describes the results of an audit into its effectiveness.

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Key points

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1. Humidification of ventilated gases is possible to achieve safely and effectively on transport.
2. Patient temperature data demonstrates the benefit of using active humidification with transport CPAP.

The importance of heating and humidifying airway gases administered via a mechanical ventilator has been well established. If inspired gases are not adequately humidified, the respiratory system can be compromised through thickened secretions and damage to cilia and mucus membranes[1].

In the transport setting every effort is made to maintain the standards of intensive care that the baby receives in the nursery. Practices are constantly assessed and reviewed to identify problematic areas. An internal audit in 2010 showed that transferring neonates on continuous positive airway pressure (CPAP) led to a decrease in axilla temperature for some patients[2]. At the time Embrace had no means to actively humidify ventilator gas on transport. The audit showed a trend towards a longer stabilisation time as teams attempted to optimise the temperature before departure by increasing the transport incubator temperature or using a chemical gel mattress. Despite these efforts 43% of babies included in the audit arrived at their destination with an axilla temperature of <36.6°C (**FIGURE 1**). After the 2010 audit, the investigators sought to obtain the necessary equipment to actively humidify ventilator gas during transport and to assess this change in practice.

Current practice

There is a wide variety in practice throughout the UK in terms of humidity and how it can be provided in the transport setting. In a survey carried out by the Peninsula Transport service in 2011, Madar found that 18 out of 21 UK neonatal transport teams were able to provide either actively or passively humidified ventilator gases. Of the ten services utilising the Babypac (Smiths Medical, UK) ventilator, two did not humidify gases, five used only heat

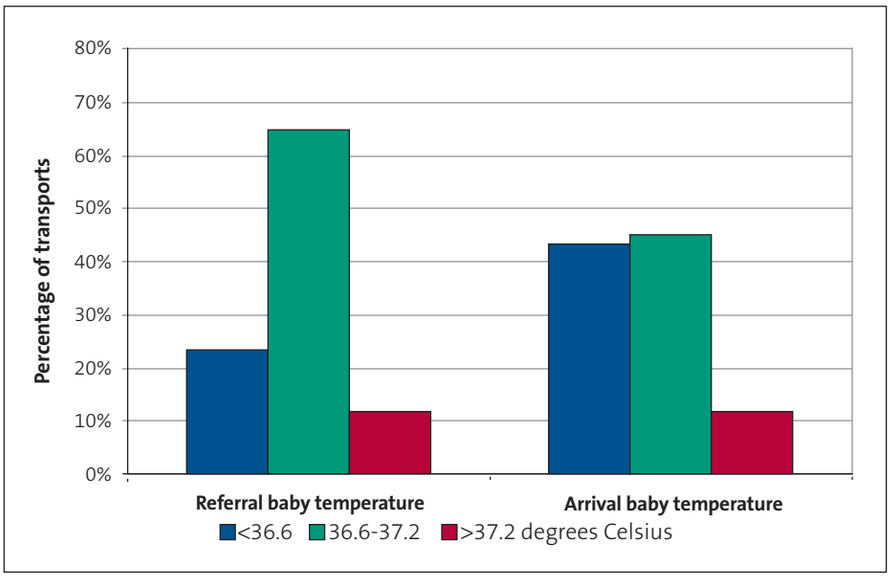

FIGURE 1 Mean axilla temperatures for patients on non-humidified CPAP, 2010 audit.

moisture exchangers (HME) and three also had access to active humidity[3].

Embrace use Babypac ventilators to provide ventilation for neonatal patients. The babies are nursed in Ti-500 incubators (Draeger Medical). Additional warmth, if required, is provided by single-use 'Transwarmer' chemical gel mattresses (CooperSurgical, USA).

For intubated patients a non-humidified circuit (Intersurgical, UK) is used, together with a Humid-Vent Mini (Gibeck/Teleflex, Ireland) HME. An HME is a passive humidification device which traps expired heat and moisture in a membrane. The gas passes back over the membrane on inspiration allowing some of the heat and moisture to be recaptured. HMEs in neonates are not as effective as active humidification, but are considered acceptable for short-term use[4]. A recent Cochrane Review showed that body temperature was significantly decreased when an HME was used compared with heated humidifiers[5].

Short-prong nasal CPAP is provided using the BabyFlow system (Draeger Medical, UK). These are short nasal prongs which attach to the ventilator using simple unheated tubing. The Humid-Vent Mini HME is designed to attach to an endotracheal tube and so cannot be used in this circuit.

Equipment

There are a variety of options available to transport services to actively heat and humidify ventilator gases. Some ventilators have an integrated humidification system, eg the Reanimator F-120 (Stephan, Germany). Using new ventilators for the study was not feasible so two potential stand-alone humidifiers were reviewed (**TABLE 1**).

The Neo-pod T (Westmed, UK) is a humidifier specifically designed for the transport environment. The water chamber sits inside the incubator, with an external control panel and power supply. The equipment is light-weight and simple to operate. The ventilator circuits were felt to be too short for use in the study and although the manufacturer can provide longer circuits, they were not available within the audit time frame.

The MR850 (Fisher Paykel, UK) is a humidifier commonly used in nurseries in the region and Embrace staff are familiar and experienced with the product. It is however bulky, relatively heavy and requires a mains power supply. The investigators chose to use this humidifier as they were readily available within the base hospital, and the circuit lengths were appropriate. The dedicated Embrace ambulances have 240v AC inverters so power could be supplied to the humidifiers during the journey.

	Humid-Vent Mini HME	Fisher Paykel MR850 Humidifier	Westmed Neo-pod T Humidifier
Weight (excluding circuit)	4 grams	2,800 grams	200 grams
Power Supply	N/A	AC	DC or AC
Temperature and humidity (manufacturer's data)	Humidity 30mg H_2O/L at a tidal volume of 20mL	Humidity >33mg H_2O/L Chamber 35.5-42°C Airway 35-40°C	No humidity data in product information. Chamber 30-38°C
Additional circuit dead-space	2.4mL	N/A	N/A

TABLE 1 Comparison of equipment for humidity.

The Babypac ventilator is not commonly used with humidified circuits. Work was undertaken with both Fisher Paykel and Smiths Medical to establish that the combination would be safe and effective. The humidifier was positioned below both the ventilator and the patient. The chamber auto-fill line was not used to remove the risk associated with hanging a bag of water. The ventilator was used in constant-flow mode. A calibrated reference-grade pressure monitor was used to quantify the pressure drop across the circuit due to the added flow resistance and this was taken into account clinically.

Variations in humidifier performance related to external factors such as environmental temperature have been described[6]. Despite the use of dual-limb heated circuits, condensation at the expiratory port of the ventilator was noted. The volume of water was dependent on ambient conditions and incubator temperature. The experience of other transport services gave reassurance that this water does not infiltrate the ventilator during routine use.

For added fixation security, Paraid (Birmingham, UK) developed a secure bracket (**FIGURE 2**) to attach onto the transport trolley that meets European incubator transport standards[7].

Completion of the 2011 audit

Transport teams were asked to fill in an audit form for patients transferred in an incubator on short-prong nasal CPAP. Planned, unplanned and time-critical transfers were included. Transfers from an operating theatre or X-ray department were excluded as the procedure or investigation may have impacted the patient's temperature. The data collection ran for a six-and-a-half month period from June 17th to December 31st 2011.

One out of the four Embrace transport incubator trolleys was set up with the Fisher Paykel humidifier. If the humidifier

FIGURE 2 MR850 humidifier in bracket.

trolley was available at the time of referral it was used for the CPAP patient, otherwise another trolley was used and non-humidified CPAP was provided.

Embrace use axilla and abdominal skin temperature measurements as core temperature surrogates for patients who require a level of care consistent with receiving CPAP. The skin temperature is monitored continuously during the journey via the incubator skin probe which is fixed to the skin over the patient's liver with a heat-reflective sticker. An internal audit found a good correlation between skin temperature and axilla temperature[8]. Embrace aspire towards precise temperature control on transport and consider 36.6 to 37.2°C to be an acceptable range of axilla temperatures. These parameters are tighter than some published guidelines[9], but provide a factor of safety and allow for measurement error.

Data were collected on incubator temperature, Transwarmer use, stabilisation time and the total time the patient spent on transport CPAP. Transport teams were asked to indicate if there were any adverse events, including delays related to thermoregulation or equipment.

Results

There were 94 CPAP transports that met the audit inclusion criteria and 64 audit forms were completed (68%). Two patients were excluded; one had missing data and one deteriorated en-route and the team returned to the referral hospital. The remaining 62 transports were analysed and split into humidified and non-humidified groups.

There were similar demographics in both groups, although the non-humidity group had a slightly lower gestational age at time of transfer (**TABLE 2**).

FIGURE 3 compares incubator temperatures on the arrival of the transport team at the patient's cot-side in the referring hospital, the transport incubator set-temperature on departure from the referring unit and the incubator set-temperature on arrival at the destination unit. Ten of the total number of patients (16%) were nursed under radiant warmers at the referring hospital and did not count towards the initial mean values. Initial incubator and patient temperatures at the referring hospitals were similar for both groups, as were stabilisation time and total time on transport CPAP (**TABLE 2**).

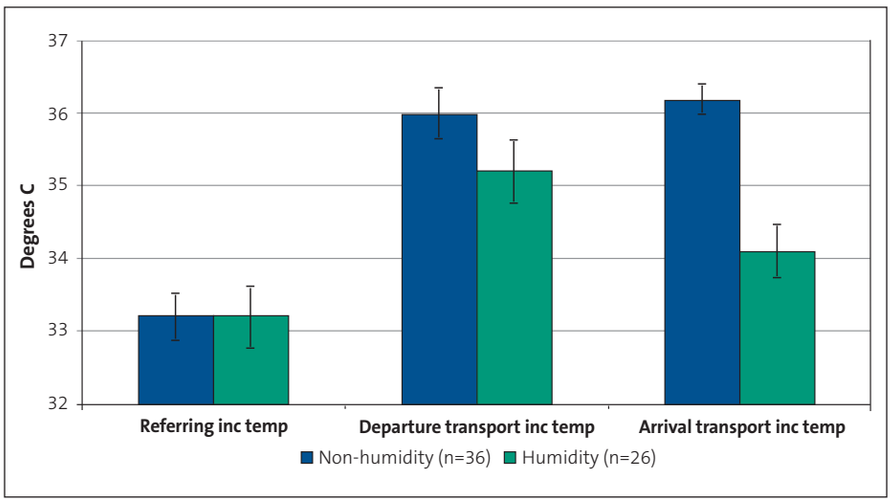

FIGURE 3 Mean incubator temperatures for patients transported on CPAP, mean values +/- standard error of the mean.

Most temperature-related interventions, issues and delays occurred in the non-humidified group (**TABLE 3**). When analysed in detail the interventions were almost entirely related to patients <1300 grams or <31 weeks' corrected gestation. There was no clear correlation with age or gestation at birth.

FIGURES 4 and **5** show axilla temperatures measured at either end of the transport episode: the arrival of the transport team at the patient's cot-side in the referring hospital, and at handover of the patient at the destination hospital. **FIGURE 4** illustrates an improvement in temperature control since the original audit (**FIGURE 1**), even without humidified CPAP. However the addition of humidification almost eradicated hypothermia in patients transported on CPAP; only 11% had skin temperatures that fell below 36.6°C at any point during the journey (**TABLE 3**), and no patient arrived at the destination with an axilla temperature below 36.6°C (**FIGURE 5**).

FIGURE 3 shows that without humidity, transport incubator temperatures on arrival were on average around 3°C higher than unit incubator temperatures (33°C). With humidity they were around 1°C higher. The incubator temperature for patients who received humidity was significantly reduced during the journey in response to the patient's skin temperature (Student's T-Test p=0.03).

	Non-humidity (n=36)	Humidity (n=26)
Gestation, mean completed weeks	28 (24-40)	28 (24-40)
Corrected gestation, mean completed weeks	31 (26-40)	32 (27-44)
Age, mean days	17 (1-52)	28 (1-58)
Weight at transport, mean grams	1360 (730-3550)	1350 (630-3600)
Stabilisation time, mean minutes	79 (34-215)	73 (30-175)
Time on transport CPAP, mean minutes	103 (43-185)	117 (55-215)

TABLE 2 Demographics and times for stabilisation and transport, range in brackets.

Discussion

Since the disappointing results of the original audit there has been a greater emphasis on achieving appropriate temperature control within the service and transport teams usually set a higher transport incubator temperature for patients receiving CPAP in expectation of temperature-related challenges. However **FIGURE 5** shows that 23% of patients in the humidified group arrived with an axilla temperature of greater than 37.2°C and the downwards trend of transport incubator temperatures in this group suggests that they were initially set too high for the patient. With the introduction of humidified CPAP and in the light of the audit results, initial transport incubator temperature settings need to be reconsidered. The investigators acknowledge that there is a group of mature infants for whom temperature control is difficult because they are only

	Non-humidity (n=36)	Humidity (n=26)
Transwarmer use	36%	8%
Skin temperature dropping below 36.6°C at any point during the journey, even transiently	42%	11%
Temperature control-related delays to transport	14%	0%

TABLE 3 A comparison of three markers of temperature control improvement.

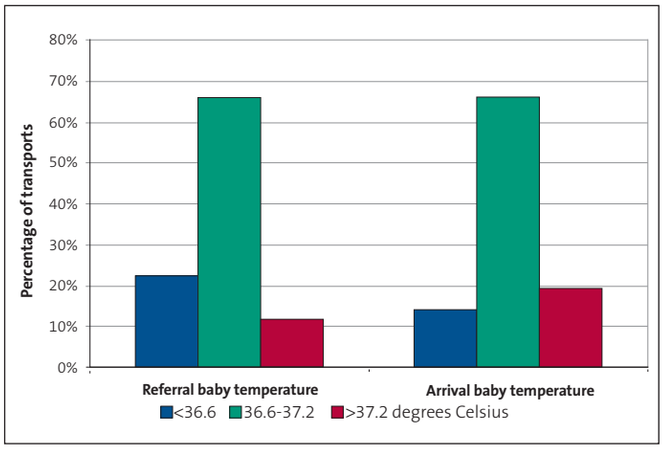

FIGURE 4 Mean axilla temperatures for patients on non-humidified CPAP, 2011 audit.

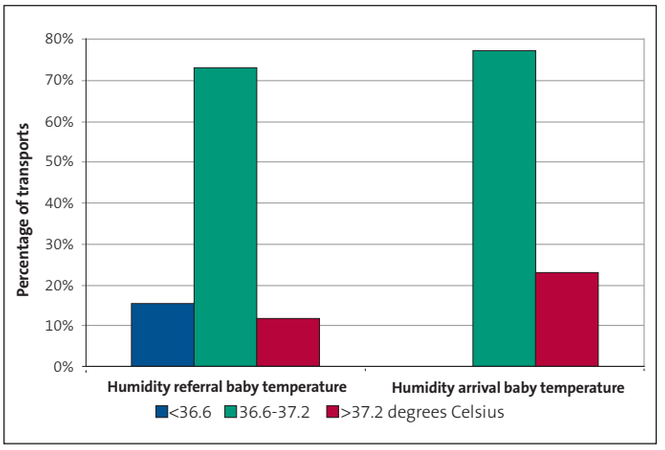

FIGURE 5 Mean axilla temperatures for patients on humidified CPAP, 2011 audit.

being nursed in an incubator due to the needs of the transfer process[10].

There were several limitations associated with this project. The small sample size and lack of randomisation may have reduced the quality of the results, although probably not the general conclusions. The recording of temperature-related interventions has now been made mandatory in the Embrace transport paperwork, and compliance will be audited.

Safety was of primary importance throughout the project. There were no adverse incidents related to the equipment. The weight of the humidifier was offset by the removal of two syringe pumps from the incubator trolley. Staff found the humidification set-up easy to use, and the introduction of extra equipment did not impact on stabilisation times.

Adding new equipment to a transport service has a potential financial impact in terms of consumable use. Humidifier compatible ventilator circuits are more expensive than comparable non-heated versions, but this additional cost was offset by a dramatic reduction in Transwarmer mattress usage. Without considering the initial capital equipment costs, the practice change was cost-neutral.

Conclusions

Babies on humidified CPAP had better temperature control during transport with no temperature-related stabilisation delays. Fewer Transwarmer mattresses were needed in this group yet there were no instances of babies arriving at the referral unit with sub-optimal temperatures. There were subjective reports of increased patient comfort and improved tolerance of CPAP. The patient temperature data, together with the unseen protection given to delicate airways, demonstrates the benefit of using humidification during CPAP with neonates during transport.

The results of this study showed that a greater number of babies in the humidified group became too warm (axilla temperature >37.2°C) compared with the non-humidified group. Episodes of hyperthermia may be detrimental to the neonate and should be avoided[11]. It is anticipated that improved experience and confidence may reduce the incidence of environmental hyperthermia.

Extending the quality of care provided in the intensive care nursery to the transport setting would suggest that humidifiers should also be used for ventilated patients as well as all infants who receive CPAP. The use of active humidification for intubated patients will be developed and there will be audit of this practice to compare it with passive humidification using an HME.

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Declarations of interest

None

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