A narrative review of thermoregulation techniques used by paediatric theatre staff during intra hospital transfer from paediatric theatres to the Neonatal Intensive Care Unit (NICU)

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A NARRATIVE REVIEW OF THERMOREGULATION TECHNIQUES USED BY PAEDIATRIC THEATRE STAFF DURING INTRA HOSPITAL TRANSFER FROM PAEDIATRIC THEATRES TO THE NEONATAL INTENSIVE CARE UNIT (NICU)

Introduction

Background

Providing warmth and effective thermoregulation is acknowledged as one of the most basic requirements in achieving overall neonatal health and wellbeing (Bailey, 2012). This is especially true within the care of pre-term neonates' who are particularly vulnerable to heat loss, due to their thin immature skin, inability to shiver, low levels of glycogen and inefficient vascular control, which prevents them from achieving effective thermoregulation (Chawla et al, 2011). Furthermore, if not prevented or managed, heat loss and thermal instability in neonates can result in negative outcomes such as neonatal hypothermia.

Neonatal hypothermia is a pathological condition where a neonate's temperature drops below the recommended normal temperature range (Vilinsky and Sheridan, 2014). World Health Organisation (WHO) (1997) guidelines define neonatal hypothermia as an auxiliary temperature lower than 36.5°C and also divide hypothermia into three classifications. These include: mild hypothermia (36.0°C to 36.4°C); moderate (32.0°C to 35.9°C); and severe below (32°C). Whilst perhaps considered dated, the definition of neonatal hypothermia by WHO (1997) continues to guide current practice and is cited in recent research (Dail, 2018).

Although therapeutic hypothermia is used to treat conditions such as Neonatal Hypoxic-Ischaemic Encephalopathy (Smee et al, 2014), the outcomes of controlled hypothermia are very different to accidental hypothermia, with its negative affects widely reported. A seminal RCT first demonstrated the connection between hypothermia and different mortalities and morbidities in neonates (Silverman et al, 1958). Despite recommendations from this trial highlighting the significance of keeping neonates normothermic, the global burden of neonatal hypothermia remains high (Lunze et al, 2013). Importantly Laptook et al, (2007) identified that in pre-term neonates with each degree below 36.5°C to 37.5°C there was an increased 28% chance of mortality. A prospective cohort study by De Almedia et al, (2014) also reported that hypothermia was linked to early neonatal death in preterm infants. Similarly Wilson et al, (2016) showed that admission hypothermia at birth was associated with neonatal deaths in a large European cohort (n=5697) of extremely preterm neonates. However, no association between hypothermia and neonatal morbidity was discovered. Despite this, retrospective studies of low birth weight preterm infants on admission to NICU have shown links to morbidities such as respiratory distress syndrome, haemorrhage, neurological injury, severe Retinopathy of Prematurity (ROP), Necrotising Enterocolitis (NEC), Bronchopulmonary Dysplasia (BDP) and Nosocomial infection in relation with low admission temperature to NICU (Miller et al, 2011; Chang et al, 2015; Lyu et al, 2015).

In response to such research, international and local guidelines are available, which stress the importance of maintaining thermoregulation in neonates

(WHO, 1997; Resuscitation Council, 2015). Despite these guidelines and standards, the global burden of neonatal hypothermia is still reportedly high especially within low income countries and remains a challenge (Lunze et al, 2013). Further evidence within the United Kingdom from the Royal College of Paediatrics and Child Health (2018), National Neonatal Audit Programme stipulates that hypothermia is an area requiring improvement with only 64% of pre term neonates less than 32 weeks achieving an admission temperature of 36.5°C to 37.5°C within one hour of birth.

Rationale

There is significant risk of hypothermia also occurring during the transfer of preterm neonates from NICU to paediatric theatre for surgical procedures, where ambient temperatures are variable (Wang et al, 2015). This is problematic for these neonates, who are particularly vulnerable to heat loss through radiation, conduction, convection and evaporation into the surrounding environment (Chitty and Wyllie, 2013). The instability associated with surgically invasive procedures, together with the effect of anaesthetic on neonates' normal homeostasis, has been shown to increase the clinical chance of hypothermia occurring following surgical transfer of neonates by up to four times compared to other intra hospital transfers (Viera et al, 2011). Additionally surgical factors such as type and length of surgery, degree of neonatal prematurity and weight have been suggested as risks for hypothermia especially during surgery in which a major body cavity is opened (Paul et al, 2018).

Studies also identify these problems within clinical practice. Morehouse et al, (2014) demonstrated that 58% of previously normothermic neonates returned to NICU following surgery were hypothermic. Comparatively Bastug et al, (2016) highlight hypothermia as a frequent problem (27.1%) in neonates post transfer following surgery, with more severe cases linking to an extended length of time out of NICU and also the premature neonate's weight.

From the literature available relating to theatre transfer, there is more precise reporting of hypothermia as a clinical complication during adult transfers (Bambi et al, 2015). Although a prospective study of newborn neonates (n=62) by Paul et al, (2018) does indicate that of the neonates returned to NICU 52% were normathermic compared to 90% prior to intra hospital transfer to theatre. The author's conclusions identify a lack of thermal care guidelines applicable to intra hospital transfer beyond NICU to the operating theatre. Additionally, while there are thermoregulation guidelines available within some local paediatric areas (Great Ormond Street Hospital (GOSH), 2017). A lack of specific intra-hospital standard care guidelines relating towards maintaining normothermia of neonates during intra hospital transfer to and from paediatric theatre for surgical procedures is evident. Within theatres, many health care professional groups are responsible for hypothermia prevention. Thus, in the absence of standardised guidelines, wide variations of practice can exist (Gustafsson et al, 2017). Therefore, this review aims to explore thermoregulation practices used by paediatric theatre staff to prevent neonatal hypothermia post-transfer and provide recommendations for improvements.

Methods

A search of the literature was undertaken, incorporating analysis of international and local policy documents and government publications regarding neonatal thermoregulation. Electronic databases were accessed including The British Nursing Index, EBSCO, Ovid, Wiley and Science Direct. Key phrases included a combination of neonatal*: 'Thermoregulation', 'Transfers', 'Hypothermia',' Warming techniques' , 'Temperature Monitoring' and 'evidence-based practice', which were further enhanced with the use of Boolean terms such as 'and' and 'or'. Additionally 'not' 'therapeutic hypothermia' was used to ensure relevant literature relating to unintentional hypothermia was accessed. The searches limits were set to include only full text, English language and peer reviewed articles. To ensure the most recent evidence time limits were set to include literature published only within 2011-2019.

Results

Diagnosis of Hypothermia

Methods of diagnosis which are described in the literature include electronic, infrared, tympanic and skin thermometers (Smith et al, 2013). According to Smith, (2014) suitable body sites for assessing temperature measurement in neonates include axilla, tympanic, forehead, abdomen, oesophagus and bladder. Axilla temperature measurement is recommended by WHO, (1997). Usually measured intermittently, research studies have used intermittent axillary temperature as a comparison with different methods of temperature measurement and report its usefulness and accuracy (Robertson-Smith et al,

2015). In spite of guidelines recommending axillary temperature measurement as a robust method and being common practice within neonatal care, it can also be intrusive with some research showing neonatal discomfort (Sim et al, 2016). As a solution Smith et al, (2013) suggests that constant skin temperature monitoring on neonates' abdomens with self-adhesive probes and intermittent axilla temperature measurement ensures more accuracy.

Furthermore, continuous sensor monitoring is recommended in neonatal transfers from delivery room to NICU to enable early prevention, diagnosis of hypothermia, and subsequent management (Chitty and Wyllie, 2013). Despite this evidence, recent studies which specifically focus on the most appropriate method of temperature monitoring during neonatal transfers following neonatal surgery are lacking. While Schafer et al, (2014) highlighted the positive aspects of continual temperature sensors they also reported the need for care to be taken to prevent skin break down under adhesive electrodes, recommending that probes be changed frequently. Skin break down under probes is also confirmed in other research literature (Lund, 2014). Consequently skin care should be considered with their use due to neonates' delicate skin structures.

Perioperative considerations

Pre warming the operating theatre prior to neonatal surgery is key to ensuring an optimal environmental temperature to prevent inadvertent hypothermia (Torossian, 2008). GOSH (2017) thermoregulation guidelines recommend an environmental room temperature of <26°C. Challenges however in maintaining this environmental temperature are noted, with such temperatures not being

comfortable for surgeons and operating staff wearing surgical clothes (Tander et al, 2005).

Pre warming equipment prior to the neonate's arrival in theatre is also advantageous and is particularly important when transferring neonates from their incubator onto the operating table which if not adequately warmed can induce cold stress upon neonates (Loersch, et al 2011). Forced air warming device blankets which cover the operating table are predominately used within theatre settings which do not interfere with the surgical field (Buisson et al, 2004). A multi centre observational study by Witt et al, (2013) demonstrated sufficient prevention of perioperative hypothermia of neonates and infants up to 10kg with use of pre warmed forced air devices. Qureshi (2012) also emphasises the importance of pre warming of fluids used during surgery, surgical skin preparations and also warming intravenous fluids as simple methods to prevent hypothermia occurring. In addition pre warming blankets and hats is also a simple yet important consideration for the transfer back to NICU which can help limit heat loss (Fastman et al, 2014).

Transfer thermoregulation techniques

Within NICU neonates are cared for in incubators or radiant warmer beds (Loersch et al, 2011). Incubators are designed to reduce heat losses by radiation, convection, conduction and evaporation (Turnbull and Petty, 2012). Whilst radiant warmers provide heat from a combination of conduction and radiation allowing direct access to neonates (GOSH, 2017), it is generally

accepted that incubators are most commonly used for NICU transfer. Yet a study by Meyer and Bold (2007) of preterm neonates did not show clear benefit of incubators over radiant warmers during transfer from delivery unit to NICU within preterm neonates wrapped in occlusive plastic. However such thermal care options are not always available within theatre and can be impractical (Paul et al, 2018). To mitigate this issue, thermoregulation guidelines recommend that where possible neonates are transported within their own thermal environment during intra hospital transfer (GOSH, 2017). Conversely from an anaesthetists perspective patient transfer within a closed incubator raises important safety concerns surrounding immediate access to the patient and most critically their airway (Schroeck et al, 2016).

Whilst Resuscitation Guidelines (2015) for neonatal life support provide clear recommendations for transfer techniques for pre term neonates less than 32 weeks gestation including warmed humidified gases, a thermal mattress alone or a combination of increased room temperature with plastic wrapping of head and body with thermal mattress. There is however a lack of thermal guidelines to prevent hypothermia specifically for intra hospital transfers of preterm neonates following surgery.

Plastic coverings over neonates' torso and extremities are a recognised and low cost method of thermoregulation thought to reduce conductive and evaporative heat loss (Freer and Lyon, 2012). For transfer of low birth weight neonates from the delivery room to NICU a Randomised Controlled Trial (RCT) conducted by Hu et al (2018), confirmed that the use of plastic bags during

transportation reduced the rate of moderate hypothermia in the intervention group by 24.1%. Within peri operative care the use of plastic wraps are less reported. Yet a study by Tourneux, et al (2017) examined occlusive polythene bags for improving thermal management of preterm neonates born before 32 weeks during surgery, only small improvements were noted, including the thermal benefits the bags provided in decreasing evaporative heat losses. Although the benefits of plastic coverings in preterm infants are recognised within NICU guidelines and delivery room guidelines at birth there are no specific guidelines for their use within surgical intra hospital transfer.

In addition to plastic coverings thermal mattresses are recommended in guidelines to provide effective thermoregulation to neonates during resuscitation and stabilisation at birth (Resuscitation Council, 2015). Within neonatal intra hospital transfer of neonates, gel filled mattresses that produce heat when a disk within the mattress is snapped causing the gel to crystallise, safely and effectively can improve body temperature of the hypothermic neonate during transfer (Liu et al, 2018). Despite these mattresses being common practice, a prospective cohort study by McCarthy and O'Donnell, (2011) found that neonates still presented with hypothermia despite being on gel filled mattresses. Mathew et al (2013) compared the use of gel filled mattresses to plastic coverings with results concluding that both methods were equally effective in preventing hypothermia.

Combination approaches of gel filled mattresses and plastic coverings have been studied recently within a Cochrane review by Mccall et al, (2018) which

highlights the risk of inadvertent hyperthermia when using combinations of interventions. Further evidence highlights the clinical complications hyperthermia presents to neonatal health (Trays and Banerjee, 2014). Additionally guidelines by Sweet et al, (2019) include a recommendation of caution when using gel filled mattresses and plastic covering together within delivery room stabilisation due to associated hyperthermia. Although not focused specifically on this combination of warming methods, the study by Schroeck et al, (2016), underscored the importance of careful temperature monitoring during transfer to prevent such hyperthermia during neonatal transfer following surgery in neonates warmed perioperatively by forced air warming methods. Despite research surrounding thermoregulation techniques relating to admission temperature to NICU following delivery being available, there appears to be a specific lack of focus on methods of preventing heat loss during intra hospital surgical transfer of neonates following surgery where neonates can be at their most vulnerable.

Ensuring Evidence Based Practice

This lack of focus within research and guideline's regarding intra hospital transfer of neonates following surgical procedures can impact on ensuring evidence based practice. Evidence based practice is a priority in ensuring neonatal health (WHO, 2017). Thereby, guidelines within this area should be implemented which are evidence-based and standardised to decrease practice variation and provide optimal outcomes for all neonates (Knobel, 2014). A cohort study by DeMauro et al, (2013) demonstrates an increase in admission temperature subsequent to such formalised guideline implementation.

Furthermore, the study emphasised the importance of multidisciplinary involvement and continuous education in sustaining these improvements and introducing thermoregulation guidelines.

Additionally it could be suggested that any lack of guideline standardisation within neonatal surgical intra hospital transfer, can contribute to clinical practice, which is guided by theatre staff preference. Such practice variations are problematic not just for thermoregulation care, but also in the diagnosis, treatment and management of hypothermia. Fanaroff and Fanaroff (2016) stresses that guidelines should be followed in order to guarantee evidence based multidisciplinary team practice rather than practice guided by individual clinicians' judgements.

Education

Education is an important aspect of ensuring that those caring for neonates apply the latest clear evidence regarding thermoregulatory care within clinical practice (Altun and Karakoc, 2012). Despite this, evidence highlights a lack of knowledge within thermoregulatory care of neonates. For example, a quasi experimental study by Purnamasari et al, (2017) discovered nurse's knowledge about the prevention of heat loss regarding newborn thermoregulation was inadequate pre intervention. However, significant improvement in knowledge was identified following implementation of education interventions such as lectures, discussion, videos and supervision during practice. Importantly within neonatal intra-hospital transfer, education was a key consideration for a Quality Improvement (QI) project by Engorn et al (2016) which focused on a transfer

protocol, checklist, transport education and ongoing temperature monitoring. These improvements delivered more successful education which significantly improved hypothermia rates.

Despite such education, barriers to implementing new guidelines are possible and difficulties are highlighted in relation to implementing new guidelines within operating departments, in particular, due to the variety and large number of health care professionals working within them (Munday, et al, 2013). Therefore it is important that practice change guidelines are applied that are clear, specific and standardised within surgical neonatal intra hospital transfer.

Discussion

This narrative review has emphasised the importance of maintaining neonatal normothermia and avoiding inadvertent hypothermia during surgical procedures and subsequent intra hospital transfer to prevent morbidity and mortality amongst neonates. Research highlighted clearly supported that accurate temperature monitoring is imperative to diagnose and treat hypothermia. In particular pre warming the theatre environment and equipment prior to surgery was an important area of thermoregulatory care within perioperative preparation shown in this review. Despite clear recommendations being available within delivery room and neonatal resuscitation guidelines regarding techniques to prevent preterm neonatal hypothermia during intra hospital transfer, a lack of sufficient guidelines and research literature that specifically focuses on preventing neonatal hypothermia following intra hospital transfer from paediatric theatre to and from NICU has been identified. This is also echoed within other

specific research evidence relating to neonatal intra hospital transfer (Paul et al, 2018). Additionally in order to promote evidence based practice this review has highlighted the importance of preventing individual staff preference from determining thermoregulation techniques used during transfer. Further QI projects within this area would be of great benefit in improving thermoregulatory care within clinical practice.

Overall these findings from the literature warrant a call for further specific research surrounding thermoregulation care of intra hospital transfer of neonates following surgical procedures. Limitations to be considered within this review include its narrative approach to studying the literature and also significantly non-English research was not accessed.

Conclusion

This narrative review highlights a lack of specific research and guidelines pertaining to neonatal thermoregulation during intra hospital transfer between theatres and NICU following neonatal surgery. Hopefully findings from this review will help drive more research into thermoregulation practice along with specific standardised guidelines.

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