THERMO-MANAGEMENT IN NEONATAL CARE: FUTURE NEEDS

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Abstract: Pre-term babies are not able to efficiently maintain normothermia due to limited capacities of their regulation system dealing with changing environmental conditions. Typically immature neonates are very often hypothermic being associated with negative impact on survival rate. Thermal management of neonates can be difficult across the continuum of care in and outside hospitals due to conflicting targets in optimal thermal management versus patient care. This paper summarizes current clinical needs, state-of-art methods and future directions towards improved thermal management for these fragile patients.

Keywords: neonatal intensive care, thermal management, clinical unmet needs, future developments

Introduction

Thermal management of immature neonates can be truly challenging in daily clinical practice covering a broad range of sometimes conflicting requirements in keeping a patient at optimal core temperature versus needs of easy and fast patient access for therapeutic interventions and necessary patient care. Besides avoiding cold and heat stress, thermal management includes also rapid and safe warming as well as therapeutic cooling complemented by an optimal humidity management. The section “Methods in Patient Monitoring” of the German Biomedical Society conducted an invited workshop on thermal management in NICU. Experts from clinics, universities and industry discussed unmet clinical needs, trends in neonatal care as well as options for improvements and open points summarized in this paper.

Thermal Management: Definition and Current Practice

Prematurely born infants show a reduced ability to react appropriately to environmental changes in temperature due to immature developed thermal regulation mechanisms [1,2]. Thermal management in neonatal care means providing optimal microclimates for an infant in relation to its gestational age, weight and specific pathologies for all clinical situations [3,4]. This covers care at different acuity levels including emergency care, intra- and inter-facility transport, surgery as well as during diagnostic and treatment procedures (e.g. during Magnetic Resonance Imaging). It should be emphasized that an optimal climate needs to take into account optimal humidity levels as well. Neonates loose significantly more heat via their skin and by respiration than adults [5]. Therapeutic cooling is used in patients with asphyxia.

Ideally, methods should support easy access to the neonate, allow continuous physiologic monitoring not being affected by thermal management procedures and ensure maximum patent safety and comfort. Several warming methods are available based on different physical principles such as convection heating, warming mattresses and radiation.

Most often used are incubators. Closed incubators offer well-defined temperature and humidity conditions, however compromised by less easy access to the patient for the medical staff and parents. Open incubators offer better patient access, but not well-defined humidity levels which results in an increased water loss. Hybrid systems combine the advantages of both approaches. These integrated systems allow automated servo-controlled but also manually controlled thermo-management.

Warming by mattresses is an active warming method. However, heat transfer from the mattress is less effective and ill-defined. Radiators provide effective warming using infrared radiation. Spectral bands are divided in three categories (IR-A, IR-B & IR-C), each having different absorption properties in human tissue. IR-A can potentially cause burns or eye damages [6]. Warming with radiators is often used in labour and delivery rooms for resuscitation and when intensive access to patients is needed, and they exposed for a longer time without covering.

In emergency care use of polyethylene foils have found broad acceptance isolating the patient’s skin from the environment to reduce evaporative heat loss. During paediatric surgeries the room temperature is typically elevated up to 32 °C, which is rather uncomfortable for the medical staff. Besides those non-invasive techniques also invasive techniques with warmed or cooled infusions are applied.

Clinical Problems / Recommendations in Research Needs

Weak clinical evidence

Due to the progress in medical and technical aspects, nowadays, preterm infants have a larger chance of survival with gestational ages even less than 24 weeks. However, most clinical studies in epidemiology and therapy recommendations are relatively old, not necessarily appropriate for this extended patient population. It has been found that documentation of body temperatures has
often less priority e.g. during emergency treatment of life-threatening situations. Additionally, challenges are posed by small patient numbers and large diversity of patient populations.

What is the optimal target measure?
Still an issue for any thermo-management scenario is the definition of the optimal variable (core body temperature, difference of core / peripheral temperatures, FiO2, etc.) to be targeted and its value dependent on the specific patient situation (gestational age, pathologies, weight, etc.)

Improved Temperature measurements
Oesophageal and rectal probes are mainly used for measurement of core body temperature (CBT). Rectal probes can deviate by up to 2°C from core body temperature and it has been also shown that core body temperature varies between different regions of the neonate’s body (lung, liver, kidneys) [7].

Adhesive temperature probes measure skin temperature, they can fall off or cause skin lesions. Space left on the baby’s body to attach these sensors is often limited. Additionally, these simple sensors provide temperature measurements for the specific location only. More sophisticated probes based on zero-heat flux or passive heat flow methods have been developed and might be more suitable to infer CBT, but they are not commercially available. Another aspect is the integration of several sensors to reduce cable clutter. Ultimately, contactless temperature measurements are preferred, which provide spatially resolved temperature maps discriminating CBT and peripheral temperatures easily. Here, thermography is a promising technology being investigated for surface temperature maps e.g. in Kangaroo care. With this method even contactless monitoring of respiration rate is possible in addition inferred from temperature changes at the nostrils [8]. However, absolute temperature measurements are not feasible currently due to the unknown emissivity of the skin. Also, thermography is limited when the neonate is covered by blankets.

Servo-controlled thermal management
Automated systems with servo-controllers provide significant improvements in patient outcomes [9]. However, these complex systems are often not used in servo-control-mode because, for instance, caregivers are concerned that an incubator cools a febrile patient and may delay the recognition of early sepsis. Involvement of medical staff in early stages of system development and better education in opportunities and limitations of these technologies could lead to improved clinical acceptance rates.

Obviously, temperature probes for these systems need to be robust against measurement artefacts and should automatically detect dislocations.

Neonates show already a circadian rhythm [10]. Servo-controlled thermal management might suppress this rhythm, which requires further investigations.

Automated temperature controller can cause significant temperature changes e.g. after the incubator was closed. Guidelines on limits of maximal temperature variations are recommended based on improved clinical evidence. Similarly, therapeutic hypothermia needs to be supported by more clinical research as well.

Algorithms for early detection of Sepsis
It has been shown in [11] that an impending sepsis can be detected by integrating information from CBT and peripheral measurements. So far, no automated algorithm outperforms sepsis detection by nurses. New signal processing techniques might help to improve detection.

Conclusion
Efficient thermal management in neonatal care is crucial for optimal patient outcome. Significant changes in patient population, treatment options and technical opportunities have been observed opening an interesting and relevant field for future research.

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Bibliography