Management in health
XXV/3/2021; pp. 18-22

INFRARED THERMOGRAPHY – A NEW APPROACH FOR TEMPERATURE MONITORING IN NEONATES

Vlad DIMA[1], Ioana ANGELESCU[1], Andreea VIDRU[1], Georgeta GRECU[1], Mihaela DEMETRIAN[1], Andreea Avramescu-CALOMFIRESCU[1], Adriana Sarah NICA[2,3], Adrian TOMA[4,5]

[1] "Filantropia" Clinical Hospital, Bucharest, Romania
[2] Clinic III, National Institute of Recovery, Physical Medicine and Balneology, Bucharest, Romania
[3] "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania
[4] Medlife Memorial Hospital, Bucharest, Romania
[5] "Titu Maiorescu" University, Bucharest, Romania

INTRODUCTION. Infrared thermography is an alternative for measuring the body temperature of the neonates without touching or disturbing them. This technique can replace the conventional means of measuring the body temperature. It works by measuring the thermal radiation of the body's surface .

OBJECTIVE. Promoting this noninvasive method of measuring body temperature. This method eliminates the discomfort caused by the sticking of electrodes on the skin and eliminates possible burns or necrosis caused by them.

MATERIALS AND METHODS. We used an infrared digital camera for measuring the body temperature of 45 neonates in the first hour of life. We compared the values obtained by different types of temperature monitoring devices.

RESULTS. The arms, the ties and the buttocks tend to change their temperature according to the room's temperature. The skin on the abdomen and chest has a more stable temperature that doesn't modify easy despite the room temperature. The temperature values obtained through IR thermography are similar to the ones obtained through temperature measurement with skin sensors or axillary temperature measurement.

CONCLUSIONS. The infrared digital cameras are easy to use, precise and can measure very rapidly the neonates' body temperature without touching them, in perfect consistency with the minimal stimulation protocol .

Keywords: body temperature, newborn, infrared thermography, minimal stimulation

INTRODUCTION

Measuring body temperature is a vital parameter in monitoring newborns. Occurrence of fever in these fragile patients is a reliable indicator of an underlying infectious pathology or an eating disorder.

Newborns possess certain anatomical features that make them vulnerable to temperature changes in the surrounding environment. These features are: reduced amount of subcutaneous fat, thin epidermis, large body surface area in proportion to body mass, blood vessels located near the skin surface. Newborns tend to lose heat 4 times faster than adults [1].

Thermal instability of newborns is worth discussing especially in the first 5 days of life [2]. For this reason it is essential for the newborn to be placed in conditions that will ensure thermal neutrality [3].

After birth, the temperature of a newborn will rapidly drop, requiring activation of metabolic thermogenesis (lipolysis of brown fat). This thermogenesis will resume for several hours. It is substantial to mention that thermogenesis will take place only in the conditions of adequate tissue oxygenation, a hypoxic newborn being unable to produce enough heat to self-adapt thermally [4].

According to the WHO, normal body temperature values range between 36.5 and 37.5 degrees Celsius. Although the AAP mentions that multiple cases of pediatric febrile episodes don't require treatment (AAP, 2006), it should not be ignored that, in infants under 90 days of age, fever must be recognized and urgently investigated, as their condition can promptly deteriorate [5].

Temperature can be measured by the means of mercury thermometers, electronic thermometers, skin temperature sensors and more recently, using infrared cameras. Taking into account that there exist concerns referring to transmission of possible infections through the medium of reusable thermometers, it is sensible to use non-invasive methods that do not involve contact with the skin or mucous membranes of newborns [6]. In a newborn, temperature values are measured with mercury or electronic axillary thermometers due to safety, hygiene and simplicity reasons. There are not enough arguments to encourage intrarectal temperature measurement [7]. A meta-analysis conducted in the year 2000 on 3,201 participants (20 studies) demonstrated that the mean difference in rectal and axillary values is 0.17 degrees Celsius (-0, 15-0.50 degrees C) in newborns and 0.92 degrees Celsius (-0.15-1.98 degrees C) in children and young adults [8].

In a neonatal intensive care unit, the gold standard for temperature measurement is by the incubator electronic sensors. They are attached to skin using adhesive tape which in premature babies can produce skin ulcerations upon removal. Consequently, it is necessary to implement technologies based on remote measurement of body temperature [9].

R.P. Clark and J.K. Stothers already used infrared color thermography to monitor newborns skin temperature distribution in as early as 1980.

The utilization of infrared thermography is based on the principle that all bodies with a temperature above absolute zero release electromagnetic radiation, known as infrared radiation or thermal radiation (wavelength of 0.75-1000 lm).

Human skin has a constant emissivity of 0.98 ± 0.01 for a wavelength of 2-14 lm (4.13). This emissivity does not depend on the color of the skin. Furthermore, emissivity is not affected even if the skin is burned. Cosmetics applied to the skin can modify its emissivity [10].

The first infrared emission detector was built during World War II. Little by little, these infrared detectors were accustomed to medicinal purposes covering a variety of pathologies.

Figure 1. Neonates distribution by delivery mode

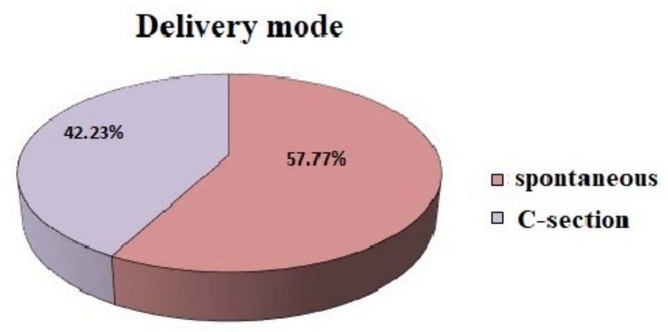


Figure 2. Neonates distribution by gender

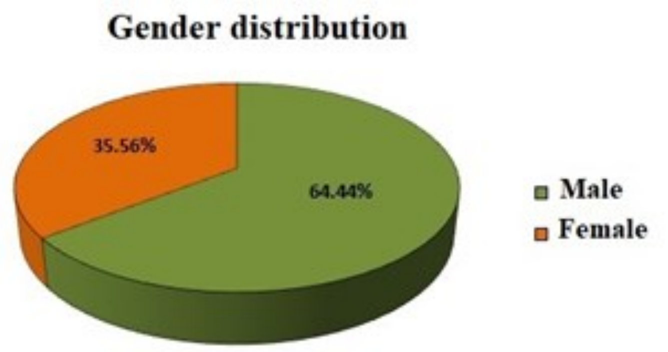


Figure 3. Infrared thermal scanner – FLIR THERMA-CAM B4

Jung et al. [11] and Ammer et Ring [12] pointed out the fields of medicine in which infrared thermography was used: diabetic neuropathy, vascular disorders, breast cancer detection, thermoregulation studies, fever screening, neurological imaging (thermoencephaloscopy), dentistry, dermatology, muscle pain, rheumatology, ophthalmology, liver metastases detection, intestinal ischemia, kidney transplantation, cardiology, gynecology, cryotherapy, neonatology and pediatrics, forensic medicine.

The relevance of IR thermography is limited by the depth of its penetration, IR radiation not being emitted by skin layers beyond 5 mm deep, therefore being ineffective in examining tissues in depth or organs. Granted that a large number of physiological or pathological changes trigger alterations in the dermis through the capillary network, IR thermography proves to be an effective tool in assessing patients. Rapid progression of technology in this field makes us consider this method of patient examination, especially since there are scientific papers that prove the importance of applying IR thermography [13].

Since the 1980s IR thermography has proven to be useful in neonatology while studying the physiology of thermoregulation in newborns and investigating necrotizing enterocolitis in preterm infants [14].

In 2020, Lorato et al. published an article that demonstrated that infrared thermography with multiple camera can be used for evaluating the respiratory motion of the infants, avoiding skin damage generated by sensors for chest impedance [15].

Given that no direct skin contact is necessary, IR thermography can be used to optimize thermal conditions in delivery rooms and NICU. Incubators that can monitor temperature of newborns by IR thermography can also be constructed.

MATERIAL AND METHODS

In the Filantropia Clinical Hospital from Bucharest, Romania, we completed a clinical study in which we monitored body temperature of newborns at the end of the first hour of their life. Temperature measuring was performed for a group of 45 healthy full-term infants, at the Filantropia Clinical Hospital from Bucharest, in the time period of May – June 2013.

Newborns involved in this research received Apgar 9 and 10 at 1 and 5 minutes. They all had normal weight at term. Premature babies or newborns with medical conditions diagnosed antepartum or immediately after birth were not included.

Regarding the delivery type, both newborns from spontaneous and cesarean section were randomly selected (57.77% vs. 42.23% – figure 1).

Gender distribution of newborns was also aleatory, the majority represented by male babies (64.44% – figure 2).

Temperature measurements were taken after the first bath and skin cleansing, at about 50 minutes of life. The newborns were placed in open incubators. Because our goal was to quantify the temperature with a thermography camera (FLIR – forward looking infrared), we avoided placing the newborns in closed plexiglass incubators, as this material reflects the entire infrared spectrum. We compared temperature measurements obtained by the sensors in the open incubators (placed on the abdomen) for 23 nn. and electronic thermometers placed in the axillae for 22 nn., with the maximum temperature indicated by the thermograph in the abdomen.

We used the FLIR THERMACAM B4 thermograph (Figure 3). This device has high accuracy in measuring infrared emission, especially the temperature, its thermal sensitivity being of 0.08 degrees Celsius. This temperature detection precision is maintained over

Management in health
XXV/3/2021; pp. 18-22

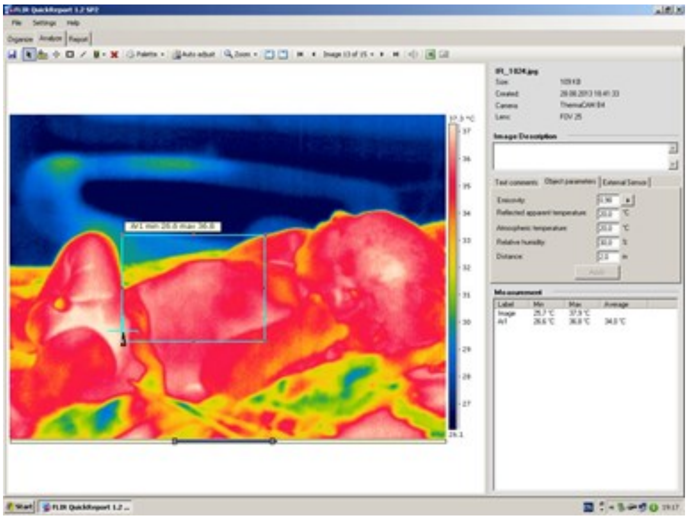
the range of -20 to +55 degrees Celsius in ambient temperature. (according to the manufacturer's technical description). This device was used because it was the only one we could find at that time and this one belonged to the 3rd Clinic of the National Institute of Recovery, Physical Medicine and Balneology, Bucharest.

With reference to the ambient temperature of newborns at the time of measurement and the thermal indicator showing 26 degrees Celsius, we consider that the accuracy of the device was not affected.

The reference temperature for thermography was established to be the upper abdomen and chest temperature, because these zones are considered to be the most thermally stable ones.

The software used for interpreting the infrared images was provided by the manufacturer of the thermal scanner – FLIR Quick Report 1.2 SP2 (Figure 4).

Figure 4. Thermal imaging analyzing software



RESULTS

The study determined that immediately after birth the temperature is relatively even over the entire body surface (figure 5). As expected, the peripheral areas are the ones that lose heat the easiest.

The thermographic images depict green-blue coloration for the colder areas and reddish coloration for the warmer areas. In order to correctly interpret the images obtained by thermography, it is important to carefully visualize and analyze the temperature and color scale (figure 6). In figure 6 one can best observe the contrast between the blue color of colder areas (the surrounding environment with a temperature of approximately 26 degrees Celsius) and the red color of the warmest areas of the body (chest and abdomen – approximately 36.8 degrees Celsius).

Skin temperature evens out immediately after bathing. This can be witnessed by comparing the image obtained before bathing (figure 7) and the image obtained after bathing (figure 8). The uniformity of temperature distribution is a result not only of bathing, but also of the open incubator where heat is regulated according to the skin temperature of a newborn.

Figure 5. Temperature distribution after birth

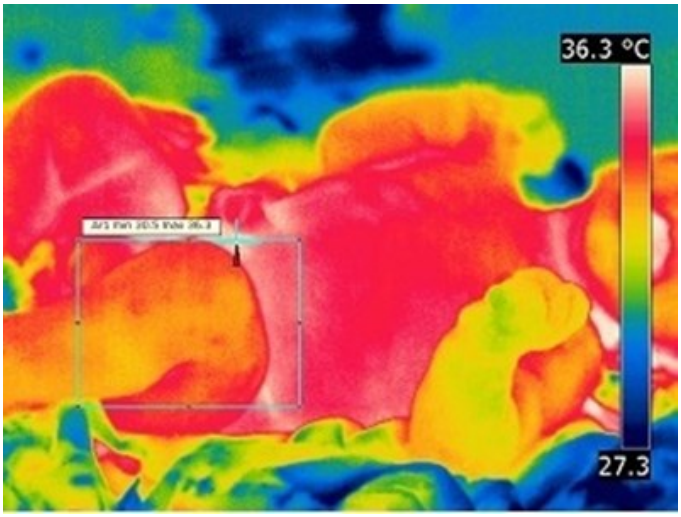


Figure 6. Color spectrum depending on the temperature (from blue to red)

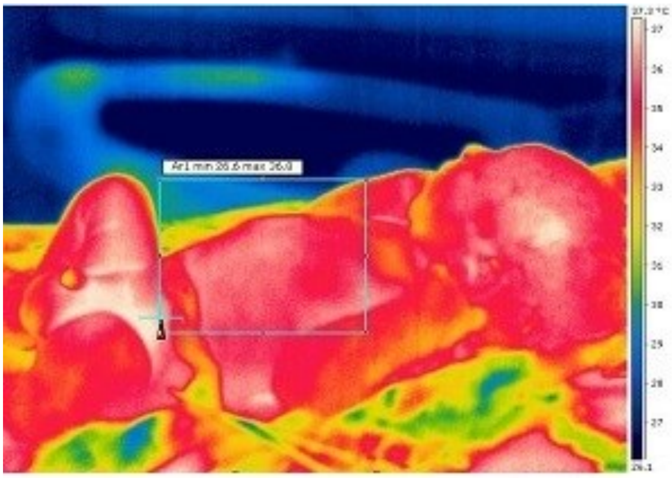


Figure 7. Temperature distribution before bathing

In the first group in which temperature measurements were obtained by the electronic skin sensor was compared with the temperature measurements obtained by the

Figure 8. Temperature distribution after bathing

Figure 11. Comparison between temperature mean values cutaneous sensor vs thermometer vs. FLIR B4

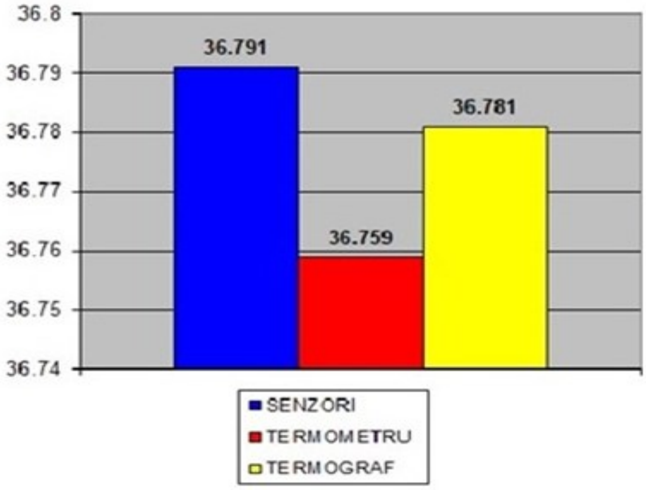


Figure 9. Temperature comparison FLIR B4 vs. cutaneous sensor (23 neonates)

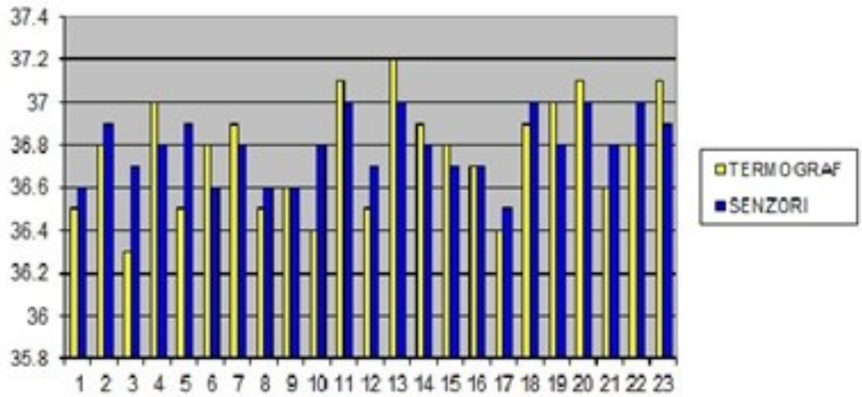
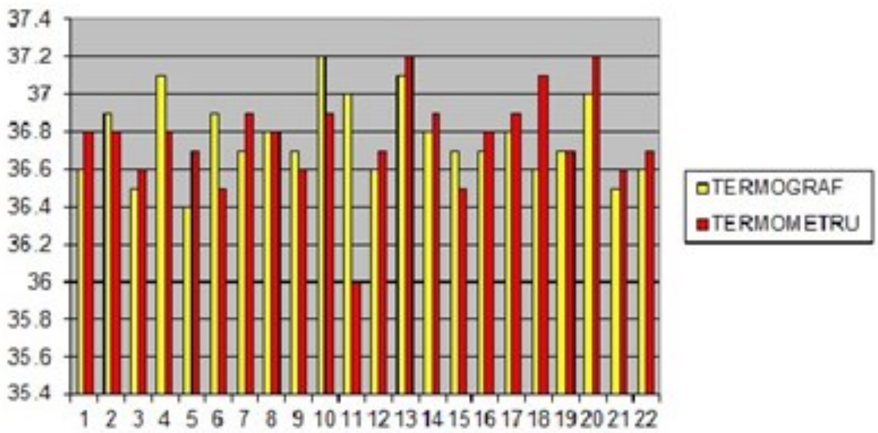


Figure 10. Temperature comparison FLIR B4 vs. thermometer (22 neonates)



thermograph, average values of 36.79 and 36.75 degrees Celsius were recorded (figure 9).

In the second group, in which the temperature findings were acquired with the axillary thermometer and compared with the temperature findings acquired with the thermograph, average values of 36.75 and 36.76 degrees Celsius were registered (figure 10).

Mean values obtained by measuring temperature using the 3 methods (skin sensor, electronic thermometer and thermograph) were very similar (36.791, 36.759 and 36.781) **(**figure 11). For this reason, it is evident that usage of thermography as a method of measuring temperature is an alternative that must be taken into account, especially since it does not involve any risk for the newborns.

DISCUSSIONS

During this study, the infrared thermograph proved to be a reliable tool for noninvasive temperature monitoring. Given the fact that our aim is to be as gentle as possible with the neonates, a new, noninvasive tool for routine evaluation could be an asset for each neonatology department.

In 2012, Abbas et al. conducted a study on 12 preterm babies in different scenarios (convective neonatal incubator, kangaroo mother care, open radiant warmer) and they concluded that IR thermography can be used as a standard temperature monitoring technique for the neonate [14]. As opposed to their methods, we used IR thermography for measuring temperature in a group of 45 full term neonates, but in a single type of environment in their first our of life. Even if we used different types of neonatal patients and different types of scenarios, the benefits of using IR thermography were obvious in both of studies.

In 2013, when this study was conducted, it was a national premiere for the use of thermography in Neonatology.

Management in health
XXV/3/2021; pp. 18-22

The study was presented at the National Conference on Neonatology in Murighiol in 2013 [16] and later at the 18th Congress of the Polish Association of Thermology, in Zakopane, in 2014 [17], where it was highly regarded. Thermography was subsequently used in Romania in other studies to evaluate the respiration of the newborn [18].

CONCLUSIONS

Considering the intention of minimizing stimulation of infants in neonatology departments, applying infrared thermography to measure temperature of newborns appears to be a feasible solution.

A thermograph is a convenient device that provides instantaneous temperature values at the moment of measurement. Comparing a thermograph with electronic temperature sensors and electronic thermometers we established that this tool reveals high-precision data while measuring skin temperature.

By using a thermograph, appearance of dermatitis and skin lesions generated by the plaster when fixing electronic temperature sensors are avoided, as well as the risk of transmitting infections from one patient to another through reusable thermometers is reduced and minimum stimulation protocol specific to neonatal intensive care units is successfully complied with. Moreover, time required to measure temperature of newborns in a neonatology department decreases significantly while using a thermograph compared to other methods.

The advantage of obtaining digital images with the infrared thermal profile of a newborn is the fact that these images can be stored and subsequently studied in order to perform extensive investigations of infrared thermography.

A thermograph in a neonatology department can replace thermometers, shorten temperature measurement time, decrease the rate of transmission of infections through reusable thermometers and reduce the incidence of dermatitis and skin lesions caused by the adhesive of the skin sensors. In conclusion, a thermograph is an easy to use, accurate and cost-effective device worth invested in for a neonatology department.

References

1. Ladewig PW, London ML, Olds SB. Maternal-newborn nursing care: The nurse, the family, and the community: 9th Edition. Menlo Park, CA: Addison Wesley Longman Inc. 2017.
2. Nagy E. Gender-related differences in rectal temperature in human neonates. Early Hum Dev. 2001 Aug;64(1):37-43.
3. Smith LS. Temperature monitoring in newborns: A comparison of thermometry and measurement sites Journal of Neonatal Nursing 2004;10(5).
4. Asakura H. Fetal and neonatal thermoregulation. J Nippon Med Sch. 2004 Dec;71(6):360-70.
5. Craig JV, Lancaster GA, Williamson PR, Smyth RL. Temperature measured at the axilla compared with rectum in children and young people: systematic review. BMJ. 2000 Apr 29;320(7243):1174-8.
6. Sganga A, Wallace R, Kiehl E, Irving T, Witter L. A comparison of four methods of normal newborn temperature measurement. MCN Am J Matern Child Nurs. 2000 Mar-Apr;25(2):76-9.
7. WHO Safe motherhood - Thermal control of the newborn: a practical guide - WHO/FHE/MSM/93.2 – 1994.
8. Craig JV, Lancaster GA, Williamson PR, Smyth RL. Temperature measured at the axilla compared with rectum in children and young people: systematic review. BMJ. 2000 Apr 29;320(7243):1174-8.
9. Abbas AK, Heimann K, Jergus K, Orlikowsky T, Leonhardt S. Neonatal non-contact respiratory monitoring based on real-time infrared thermography. Biomed Eng Online. 2011 Oct 20;10:93.
10. Lahiri BB, Bagavathiappan S, Jayakumar T, Philip J. Medical applications of infrared thermography: A review. Infrared Phys Technol. 2012 Jul;55(4):221-235.
11. Jung A, Zuber J, Ring F. A Case Book of Infrared Imaging in Clinical Medicine. Warszawa: MedPress, 2003.
12. Ammer K, Ring EFJ. The Thermal Image in Medicine and Biology. Vienna: Uhlen Verlag, 1995.
13. Infrared Thermal Mapping, Analysis and Interpretation in Biomedicine - SELVAN, Arul and CHILDS, Charmaine. Infrared Thermal Mapping, Analysis and Interpretation in Biomedicine. In: NG, Eddie YK and ETEHADTAVAKOL, Mahnaz, (eds.) Application of Infrared to Biomedical Sciences. Springer, 2017:377-394.
14. Abbas AK, Heimann K, Blazek V, Thorsten Orlikowsky , Neonatal infrared thermography imaging: Analysis of heat flux during different clinical scenarios - Steffen Leonhardt - Infrared Physics & Technology2012;55:538-548.
15. Lorato I, Stuijk S, Meftah M, Kommers D, Andriessen P, van Pul C, de Haan G. Multi-camera infrared thermography for infant respiration monitoring. Biomed Opt Express. 2020 Aug 3;11(9):4848-4861.
16. Patologie respiratorie neonatală – volum de rezumate ISBN 978-973-632-779-7 A XVI-A Conferința Națională de Neonatologie, Murighiol, România.
17. Proceedings of the 18th Congress of the Polish Association of Thermology - Zakopane, Poland, April 4th – 6th, 2014 Volume: Thermology international 2014;24(2):53-67.
18. Luca C, Andriţoi D, Corciovă C. The use of thermographic techniques and analysis of thermal images to monitor the respiratory rate of premature new-borns. Case Studies in Thermal Engineering. 2021;25:100926.