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Incubators in Neonatal Medicine

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Authors' contributions

This work was carried out in collaboration among all authors All authors read and approved the final manuscript.

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ABSTRACT

The incubator for children to improve the survival chances of premature and immature newborns was developed in France as early as 1857. The first device in the United States was built by William Champion Deming at the State Emigrant Hospital on Ward's Island, New York. The first baby placed in it was Edith Eleanor McLean, who weighed 1106 grams at birth on September 7, 1888. The device was heated by 57 liters of water. Precursors to these devices, which mimic the consistent temperature in the womb, were the Ruehl cradle in Moscow in 1835 and the "warm bath" introduced by Credé in Leipzig in 1864. The technology of that time is incomparable to the technology of today's incubators and microbiological incubators.

Keywords: Immature newborns; transport incubators; microbiological incubators; gestation.

1. INTRODUCTION

Roughly every 11th child in Germany is a premature baby, babies born before reaching the 37th week of pregnancy. Many of these children spend their first weeks or months of life in the hospital in an incubator.

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The first incubators were developed in France in the mid-19th century. Since that time, when a lot of warm water flowed through the incubator to warm the bed, the technological advancements have significantly improved. However, then and now, an incubator serves to protect the newborn from germs and creates an environment similar to the mother's womb, where the tiniest babies can survive safely. At first glance, the infant incubator may seem very impersonal and cold to you: the incubator is a transparent box made of plexiglass with or without a cover. The box has openings on the sides through which the baby can be cared for. The incubator provides the tiniest babies with a protective environment. The baby and its vital functions can be monitored at all times. An incubator, colloquially known as a hatchery, and in medical terminology also called a couveuse (French for hatchery), is a medical device that creates and maintains controlled external conditions for various incubation and growth processes [3,8,17,22,67]. Specifically, an incubator generates a microclimate with tightly regulated air humidity and temperature. The couveuse introduced in 1881 by Étienne Stéphane Tarnier (1828–1897) was an incubator for weak newborns [2,3]. Transport incubators are used in inter-hospital transfers, which involve transporting premature and critically ill newborns from one hospital to a more suitable clinic with a specialized department for neonatal care. Transport incubators are designed to meet the specific requirements of incubator transport, ensuring mobility and quick and safe loading. The transport incubator must be capable of heating, enriching the air inside with oxygen, connecting a ventilation bag of appropriate size for the patient, and ensuring cleanliness and hygiene. The first transport incubators were introduced in the mid-1950s by Hermann Hilber in Munich [5,9,11,47]. Intensive care transport incubators are used when the vital functions of premature or newborn infants are at risk. These incubators are equipped with advanced intensive care therapy options, such as suction devices, respirators (ventilators), infusion pumps, and additional monitoring equipment for patient data [5,9,12,24].

2. INCUBATION PROCESS

Incubators create controlled conditions, a closed climate room, in which specific growth processes can occur [1-75]. In addition to the incubators with constant high temperature and humidity used for premature infants, incubators are also referred to as growth chambers in medical laboratories. These microbiological incubators are used for culturing disease-causing organisms or storing blood and human tissue. In this context, the incubator for microbiology itself plays a significant role [23,45,66]. In the neonatal unit, air-conditioned and mobile incubators are used not only for the care of premature and critically ill newborns but also for their transport, and in this form, they are also referred to as transport incubators. Every type of medical incubator creates controlled and optimizable external conditions by adjusting factors such as temperature within the devices to a specific growth or incubation process. With the advancement of technology, incubators have also evolved, and now highly specialized and advanced incubators are available for various applications. An incubator is a closed climate room, ensuring the survival of premature infants. The function of medical incubators is to generate ideal growth conditions and support a growth process. Infant incubators are the most well-known type of incubators. In the context of newborns, transport incubators are also frequently used, allowing for the inter-hospital transfer of premature or critically ill babies. 20 million preterm babies are born worldwide each year, whereas 4 million die in the first months worldwide. 63000 children are born as preterm infants in Germany. 8000 children are born before 30 weeks of gestation and weighting less than 1,500 grams in Germany. The viability limit is 22-24 weeks of pregnancy. Treatment will be performed only in specialized perinatal german centers. Therapy costs for "extreme low birthweight preterm" are 90000 euros per year. In 2021 an incubator that operates without electricity, by Fabian Nest, for Sub-Saharan Africa. Different types of incubators are available, a neonatal incubator, an Open-Box incubator, a Close Box incubator and a double-walled incubator [1-75]. North America dominates the market. 1:10 of newborns are preterm births. This high number of preterms demand for increasing incubator necessity. In general, a transport may be necessary when the baby needs to be transferred from the birthplace to a more specialized hospital that can better meet its needs. Typically, the transport in this scenario is carried out as part of a baby ambulance operation [34,56,66]. The newborn is placed in the baby ambulance within the transport incubator, which allows for both mobility and a safe, hygienic, and quick loading of the baby. Like all infant incubators, transport incubators are heated and enriched with oxygen. Additionally, a manual resuscitator may be connected to the incubator to provide continuous oxygen to critically ill newborns. In addition to conventional transport incubators, intensive care transport incubators are also available, especially for newborns with compromised vital functions. These specialized boxes are equipped with intensive care connections for a suction device or an infusion pump. Monitors for monitoring body functions can also be connected to these types of incubators. Incubator therapy for newborns carries some risks. Babies rely on a relatively constant body temperature, which may not be fully maintained by the incubator treatment. Therefore, the infant's body temperature must be regularly monitored, ideally rectally [20,45,56,57]. Hypothermia, or cooling of the newborn, can occur. On the other hand, hyperthermia, or overheating of the baby, can also occur: as a result of overheating, the baby loses a lot of fluid, potentially leading to electrolyte imbalances. Hyperventilation or tachycardia are also possible. In general, the correct temperature can be set and adjusted on modern devices through skin temperature regulation. However, for extremely premature infants with high fluid loss due to shock or infections, it may be difficult to accurately measure the skin temperature or temperature changes of the young patient. Additionally, oxygen supply in an incubator can pose risks for a newborn. Inadequate oxygen supply due to faulty measuring devices can lead to apnea and ultimately brain damage. In premature infants, overdosing of oxygen can also occur due to measurement errors, potentially damaging the newborn's eyes. Since oxygen increases the risk of fire, personnel must also ensure the elimination of fire hazards in the immediate vicinity of the incubator [31,55,67].

3. STABILITY OF THE INCUBATOR

Stability of the incubator plays an important role in interhospital transfer of the babies, the transport from station to station [34,44]. A battery provides this mobility status. A CO-Sensor, carbon monoxide sensor, measures regularly the CO-concentration in the incubator. Temperature constancy is very important for the baby. Integrated scales for weight measurement and constant oxygen supply with a sufficient oxygen saturation percentage is of upmost necessity. There is an infection risk in warm and humid conditions [23,66,67,70]. Humidification control is also very important. Transepidermal water loss inversely correlates with gestational age at birth (TEWL) [4,7,9,13]. Recent studies have focused on noise reduction in the incubator ("neurodevelopmental dungeon"). Ther have been noises from the oxygen airflow, from the micro-humidification systems, from a loud environment. Permanent hearing impairments in preterm infants are recently described. Moreover a delayed language acquisition was found. Therefore stability of a closed climate chamber is crucial. The incubator has a resonance frequency of 100 Hz. External noises sound tonal, booming, and muffled inside the incubator, initiating reflex status and sleep behavior changes. Due to the oxygen amount, a fire risk is known in contact with flammable materials on the incubator. Factors influencing the market of incubator production include the prevalence of preterm births, low birth weight, a growing research community, Covid-19 in pregnant women, maternal age and a market growth until 2028. High costs with a missing coverage in developing countries is challenging. The possibility of X-ray application in the incubator is appreciated in different newborn diseases. Artificial Intelligence with a Fuzzy controller (FUZZY LOGIC CONTROL) plays a more and more important role with monitoring of actual and target values, corrections to desired values immediately and moreover an incubator parameter control for controlling multiple input and output variables with highly variable parameters [34,74,75]. Phototherapy with LED lights/sensors and light-emitting diodes and light-dependent resistors are obligatory features of an incubator of younger age. Heating enrolls 36-38 degrees, whereas the heater converts electrical energy into thermal energy [3,7,8,22].

4. CONCLUSION

The future will add new technology like artifial intelligence (AI) into the incubator system to control all parameters and all changes in parameters timely as close as possible [76-79]. A fully operational incubator with precise control over temperature, humidity, and airflow was designed and evaluated in a project [79]. Alongside the incubator development, a heuristic simulation was developed to fine-tune and test the Mamdani fuzzy logic controller [79]. The controller was subsequently implemented in the incubator prototype [79,80]. Premature birth is a global issue, with thermoregulation posing a significant challenge for premature infants who are often placed in incubators for convective heating [81]. Current methods of control involve sensing either the incubator air temperature or the infant's skin temperature for heat regulation [81]. However, using only one of these parameters can result in fluctuations in either the air or skin temperature. A further study aimed to investigate the feasibility of incorporating both the incubator air temperature and the infant's skin temperature in a fuzzy logic control system for heating regulation [81]. The control system was tested using a mathematical model of the infant-incubator system, confirming that traditional control methods can lead to temperature fluctuations or slow rise times in core temperature [81]. The fuzzy logic control demonstrated a smoother and more effective regulation with the desired rise time [81,82]. Another papers present the application of adaptive fuzzy sliding mode control (AFSMC) for a respiratory system to assist the patients facing difficulty in breathing [83]. Compared to neonatal care, this adaptive sliding mode control (AFSMC) could play an important role in controlling parameters of newborn in an incubator [83,84].

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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