A NEW TRANSPORT INCUBATOR FOR PRIMARY CARE OF LOW BIRTH WEIGHT BABIES

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ABSTRACT

A new portable, cheap and indigenous incubator made of polystyrene has been devised for delivery of primary health care services to the newborn babies in the community. Twenty six babies with a mean weight of 1726 g (range 1388-1981g) and gestational age of 35.3 weeks (range 34-38 wks) were continuously evaluated for 2 hours observation period, in naked and clothed conditions. Rectal, abdominal skin, foot, ambient air and nursery temperatures were recorded. The baseline core temperature of the babies was 36.58 (±0.21) °C; after incubator care it was recorded s 36.80 (±0.10) °C in naked infants. The baseline core temperature of the clothed babies was 36.63 (±0.21) while it was 37.01 (±0.18) after 2 hours of incubator care. An ambient air temperature of 33-34°C in the incubator (thermoneutral temperature range for these babies being 31.0-33.8°C) was achieved within 30-60 minutes of incubator stay (nursery temperature being 28±0.6°C). No evidence of carbon dioxide narcosis, hypoxia, acidosis, or adverse thermoregulatory behavior was observed. One baby had hypoglycemia (blood sugar <35 mg/dl) and another had sweating. There is a scope for providing additional facilities like administration of oxygen, phototherapy, X-rays through the incubator without disturbing the baby.

Key words: *Low birth weight, Primary care, Incubator care, Thermoregulation.*

One of the most important aspects of neonatal care is the realization of the simple fact that small babies need to be kept warm. Various methods have been described to maintain a baby's temperature but the incubator seems to be one of the simple and safest ways. Effective thermoregulation is an important determinant of increased survival and enhanced growth of small babies.

The transportation of neonates is a specialized task. A need has been felt for a safe, cheap and effective transport of low birth weight babies in developing countries. Most of the developing countries cannot afford the high cost of incubators; and do not have the necessary trained personnel to use them(1). This study was undertaken with the objective of devising a cheap and indigenous portable baby incubator for transport of babies for effective delivery of primary health care services to neonates. We also studied its technical feasibility, efficiency and safety.

Material and Methods

After extensive review of the insulating properties of materials, expanded polystyrene was chosen as the most suitable material for fabrication of the incubator. It has a low thermal conductivity, low water absorption, is rigid and light weight. It is physiologically harmless, has neutral pH and is resistant to bacteria(2). It can be moulded so that there are no sharp edges

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and is resistant to acid and alcohol. The lid has been made of moulded acrylic sheet for ease of observation and aesthetic appearance. Two holes were made in the lid for effective ventilation (*Fig. 1*). The final dimensions of the incubator are as given in *Table I*.

Twenty six babies who were on human milk or a commercially prepared formula were studied. The babies did not have any immediate neonatal complications and were not on intravenous fluid. They were clinically stable, healthy and were not receiving oxygen or phototherapy.

To confirm the thermal insulation capabilities of the designed incubator, initial few observations were made after placing a hot water bottle inside the incubator. The temperature of the water could be maintained between 34-31°C upto 4 hours.

The clinical tests were conducted in our Neonatal Intensive Care Unit between April to August 1990. Informed consent of the mother was obtained in all cases.

TABLE I–*Dimensions of Incubator*

Outer dimensions		Mattress	
Height	36 cm	Lengh	56 cm
Length	61 cm	Breadth	29 cm
Breadth	36 cm	Thickness	3 cm
Thickness			
Polystyrene	4 cm		
Lid	5 cm		
Weight	2030 g		
Lid	1150 g		
Box (polystyrene)	640 g		
Mattress	240 g		
Ventilatory holes (open)	3.6 cm (diameter) × 2 number Area ($1Ir^2$): 20.2 sq. cm.		

Babies were placed inside the incubator after a feed and when they were normothermic with an initial abdominal skin temperature (T_{ab}) between xiphoid and umbilicus) of atleast 36.5°C. A diaper was tied. Rectal temperature T_r was recorded at 2 cm depth and peripheral temperature (T_F)

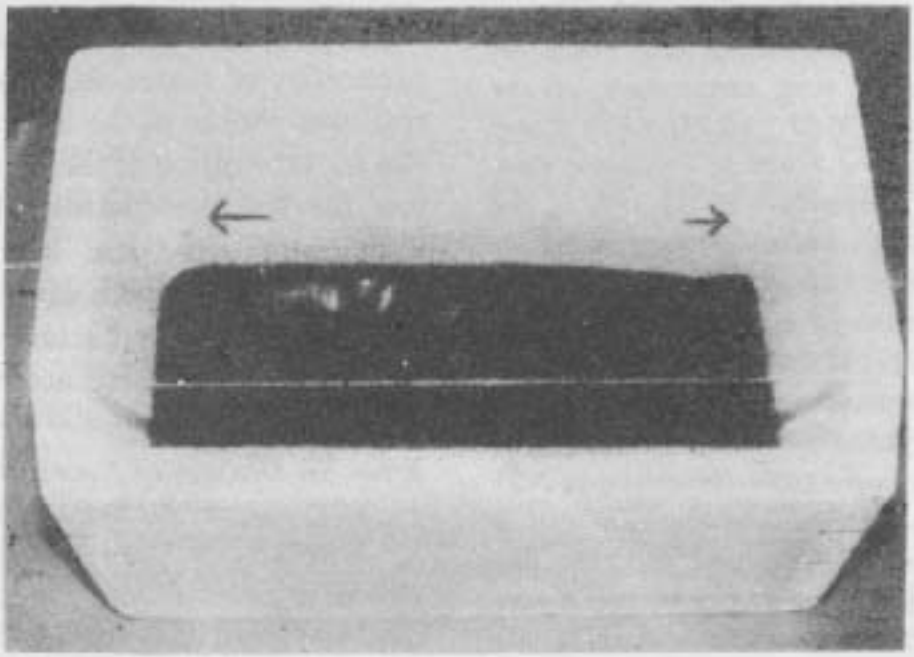

Fig. 1. The transport incubator consisting of the polystyrene box and acrylic lid. Two ventilatory holes (← →)are seen.

with the thermistor probe held between the great toe and second toe of the right foot. Ambient air temperature (T_{am}) was recorded 10 cm above the mattress (*Fig. 2.*). Nursery temperature (T_n) was maintained between 28±0.6°C. All temperatures were recorded for one minute with a continuous read out electronic thermometer (Medical systems) with an accuracy of ± 0.1°C. The accuracy of the thermometer was cross checked with a standard mercury thermometer certified by Bureau of Indian Standards (IS 3055, 1977). To obviate error between thermometers we used a single electronic thermometer for all the observations. The probe was cleaned with spirit and lubricated with sterile jelly prior to rectal insertion.

The terminology used in this text is as per standard definitions of ambient temperature, behavioral temperature regulation, thermoneutral zone, heat loss(3).

Babies were monitored for apnea, continuous heart rate and respiratory rate using a system V monitor (Air shields). Hemoglobin oxygen saturation (SaO_2) was measured by a pulse oximeter (Ohmeda Biox 3700) with a flexible neonatal probe attached to the left foot. Arterialized capillary samples for blood gas analysis were carried out within 15 minutes of collection on AVL 995 automatic blood gas system (Switzerland). Whole blood sugar was monitored using dextrostix and glucometer (Ames). Hypoglycemia was defined as blood sugar of less than 40 mg/dl, irrespective of gestation.

The general behavior, activity, color and excessive crying were recorded. Babies who were quiet or asleep were tested to a blink response with a beam of light or clapping of hands.

Each baby was continuously observed over a period of 4-8 hours by one of us. Initially babies were studied naked for ease of observation and once the confidence was established they were studied with clothes on. The following observations were made

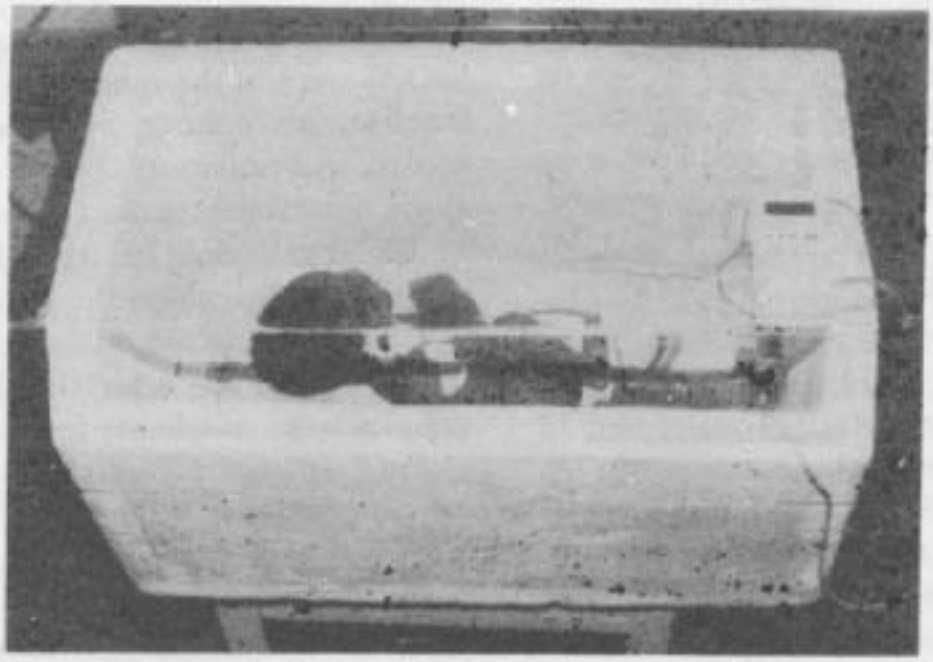

Fig. 2. The transport incubator in use with the baby (the attached monitoring devices are not seen). The thermometer displays the ambient air temperature continuously.

before and after 2-hour incubator care, *i.e.*, rectal, abdominal skin, toe temperatures, blood gas analysis and blood sugar. Ambient air temperature was recorded continuously during the observation period.

Relative humidity (RH) was calculated by placing a Mason's hygrometer inside the incubator for 2 hours along with the baby. Standard hygrometeric tables were used to read the RH(%).

The feasibility of providing other facilities to the babies in the incubator such as oxygen administration, phototherapy, *X*-ray investigations were evaluated. FiO_2 inside the empty incubator was measured with a FiO_2 monitor (Oxygen Monitor DMA) with a 1 L/min and 3 L/min oxygen flow.

The incubator was sterilized with a swab soaked in 2% alkaline glutaraldehyde (Cidex, Johnson and Johnson) and was left to dry for 4 hours. Prior to re-use, the incubator was resterilized with rectified spirit (70% alcohol). The smell of these antiseptics was removed by keeping the opened incubator before a fan for 3-5 minutes. The lid was cleaned with soap and water. Incubator cultures were taken after its use on blood agar plates.

Statistical analysis was carried out using 2 way analysis of variance test for comparing temperatures and paired 't' test for blood gas analysis.

Results

Twenty six neonates (14 males and 12 females) with a mean birth weight of 1726 g (range 1388-1981 g) and mean gestational age 35.3 (range 34-38) were evaluated. Twenty were appropriate for dates while 6 small for dates were included in the study. Of the 26 babies studied, 10 were studied for two observations, 10 for three and 6 for four continuous observations of 2 hour duration. Thirteen babies were studied naked and 13 were studied clothed. The weight, gestation and initial mean temperature of clothed and naked babies were comparable.

The mean rectal temperature (T_r) measured was higher in clothed (36.63°C) as compared to naked (36.58°C) babies and the same is true of foot temperature (T_f). The difference of central and peripheral temperature was within the range of 1.7°C. The ambient temperature (T_{am}) of 33-34°C inside the incubator was obtained in 30-60 minutes by localized warm convection currents of exhaled air. It was higher (maximum of 35.0°C) in clothed as opposed to naked babies (*Table II*). One non septic baby 38 weeks gestation developed sweating and his rectal temperature rose to 37.4°C.

Babies were comfortable in the incubator during the observation period. They sometimes cried due to hunger, boredom, and on voiding urine or stools. On gentle rocking the incubator, they were pacified with ease.

Stable heart rate, respiratory rate and SaO_2% were in the range of ±10% of the baseline, no episode of apnea was recorded. All values of blood sugar were above normal except one (<35 mg/dl).

Blood gas values before and after incubator stay were within the normal physiological range and the differences were insignificant. The arterialized capillary samples were unreliable for true estimate of PaO_2 (partial pressure of oxygen) but our observations on the paired samples in individual babies did not show any appreciable change during stay in the incubator.

With an oxygen flow of 1 and 3 L/min, an FiO_2 of 40% was achieved in 2 minutes, and 1½ minutes; 60% in 7 minutes and 4 minutes and 80% in 20 minutes and 15

TABLE II—*Temperature (°C) Difference Between Naked and Clothed Babies Before and 2 Hours After Incubator*

Temperature	Naked babies (n = 13)		Clothed babies (n = 13)		p value
	Baseline Mean (±SD) 1	2 hour Mean (±SD) 2	Baseline Mean (±SD) 3	2 hour Mean (±SD) 4	1 with 2 3 with 4
Abdominal skin	36.36 (± 0.17)	36.66 (± 0.15)	36.50 (± 0.31)	36.73 (± 0.16)	NS/NS
Rectal	36.58 (± 0.21)	36.80 (±0 .10)	36.63 (± 0.21)	37.01 (± 0.18)	NS/NS
Foot	35.63 (± 0.25)	35.68 (± 0.34)	35.57 (± 0.23)	35.96 (± 0.18)	NS/NS
Incubator	27.8 (± 0.9)	33.2 (± 0.9)	28.2 (± 0.6)	33.9 (± 1.1)	<0.01/<0.01

minutes, respectively inside the incubator. Appropriate phototherapy as measured by the digital radiometer (Toptronic Limited) could be provided to the incubator babies through the plastic lid.

Skiagrams can be conveniently taken with the cassette placed underneath the box and through the closed lid. The mean value of relative humidity was measured as 61% (nursery RH being 68%).

Randomly obtained cultures were either sterile or showed insignificant colony count of *Staphylococcus albus*.

Discussion

When transportation of critically ill newborn baby is necessary, it is essential to provide a safe and warm environment to help the infant survive the journey. There is no ideal incubator at present which provides an absolute control over the environmental factors. The sophisticated electronic incubators are extremely expensive and need constant care for their use. The safety of incubator care can be assured only by a constant vigil by the nursery staff.

Our portable incubator which is cheap and light (weights 2 kg) have confirmed its safety and effectiveness to keep the healthy babies even prematures warm.

Various indigenous methods to keep the babies warm have been devised. These include the silver swaddler, transparent baby bag(4), kangaroo method(5). Though they are effective, yet observation of the baby for respiratory distress, apnea, bradycardia, intravenous leaks, *etc.* is compromised. Apart from keeping the babies warm, our incubator is easy to use and is effective for delivery of oxygen, and use of battery operated monitoring devices.

All babies produce heat continuously though at varying rates. Warmth is generated inside the incubator by localised warm convection air currents produced by the baby. The good insulation of polystyrene prevents this convective heat loss. It is maintenance and noise free. In extreme cold weather, it can be prewarmed with a lamp or hot water bottle. Once a temperature of 33°C is reached, usually within 30-45 minutes, baby is not exposed to cold stress. Continuous observation of ambient air temperature inside the incubator is most essential for its use. The incubator can also be used in the labor room for initial stabilization of temperature after mopping the baby dry.

In the evaluation of thermoregulation, heat production is usually measured by

indirect calorimetry which is difficult(6). Our experiments have relied on physical and behavioral parameters of thermomregulation(3,7). This has been combined with subtle biochemical parameters of oxygenation, carbon dioxide retention; acidosis and hypoglycemia to assess the safety and efficiency of the incubator.

Harpin *et al.*(7) studied the response of 83 healthy term and preterm infants to overheating upto 37.9°C. They monitored the activity, posture, heart rate, respiratory rate, skin color and difference of abdominal skin and hand temperature. They concluded that even immature newborn infants exhibit behavioral thermoregulation by altering their posture, being less active and falling asleep at the warmest setting. In a similar manner, oxygenation, heart rate and temperature in very low birth weight infants during skin-to-skin contact with their mothers has been studied by Acolet *et al.*(5)

The good thermal insulation of our polystyrene incubator prevents conductive and convective heat loss. Incubators utilize the 'green house' principle to provide optimal temperature whereby shortwave radiant heat waves can enter the incubator and long wave radiant exchange occurs between the baby and incubator surfaces(8). The thermoneutral range of ambient temperatures for babies weighing 1500-2500 g is in the range of 31.0-33.8°C during the first two weeks of life(9).

Bureau of Indian Standards (IS 3120 : 1978) specifications for baby incubator stipulates that the incubator should not take more than 45 minutes to attain the temperature of 32°C in the baby compartment from an ambient temperature of 27±2°C(10). Our incubator satisfied this important stipulation and we have observed that within 30-60 minutes, a temperature of 33-34°C is constantly maintained inside. In no case excessive evaporation resulted in condensation of water vapors over the lid. The relative humidity of 61% in our incubator is in the acceptable range.

In none of our babies, the extremities were pale and cool and the gradient of temperature was less than 3°F (1.7°C). No signs of hyperthermia or hypothermia were observed. Pomerance *et al.*(11) suggested that in mature healthy babies a gradient of upto 3°F could exist between rectal and peripheral (right leg) temperature.

Stabilization of the baby prior to departure is probably the most critical aspect of interhospital care(12). It is essential and mandatory that the baby is stable and his core temperature is normal before he is transported. Our endeavour to devise a transport incubator needs to be further strengthened by obtaining more data in field trials and specially in very small sick neonate. The designed incubator is cheap, safe and is likely to meet our requirements of harnessing appropriate technology to serve our needs in the community. A few improvements in order to make it more sturdy and enhance its portability need to be effected.

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NOTES AND NEWS

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