Modular Incubation System for the Developing World

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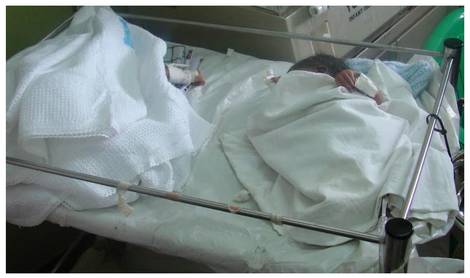
Motivation: Combat infant hypothermia

- Hypothermia contributes to 18% - 42% of 4 million annual infant deaths in the developing world [1].
- Current solutions (e.g., incubators and kangaroo care) can be expensive, high maintenance, or impractical.
- Hospitals lack sufficient staff, space, and funding.
- Mulago Hospital in Kampala, Uganda:
  - Two nurses for 60 neonates per day in the NICU
  - Only two (out of 20) incubators working

The lack of affordable and functioning incubators in low-resource settings makes it difficult to effectively combat infant hypothermia in the third world.



Objective: Provide a warm and safe environment

Our modular system is an innovative, effective, and viable solution against infant hypothermia.

Functional Requirements

1. Increase infant temperature
   - Based on gestation, age, and weight of the baby
   - Controlled heating to achieve normal temperature range of 36.5-37.5 ºC [2,3]
2. Maintain temperature range
   - Continuous monitoring of infant temperature
   - Feedback mechanism
   - Alarm LED which signals infant overheating or fever

Constraints

- Affordable
- Biocompatible and Safe
- Durable
- Easy to Maintain and Repair
- Easy to Sterilize and Clean
- High Controllability
- High Infant Visibility
- Intuitive
- Easy to Use
- Versatile

Our Solution: Warm water circulation system

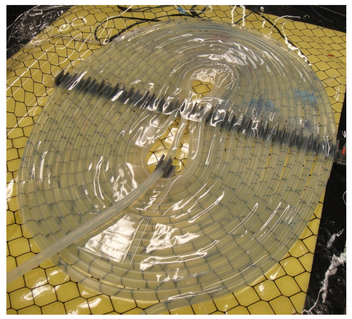


Figure 1. Mat prototype

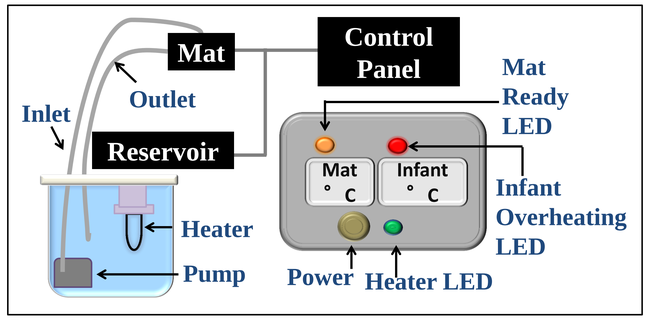


Figure 2. System diagram

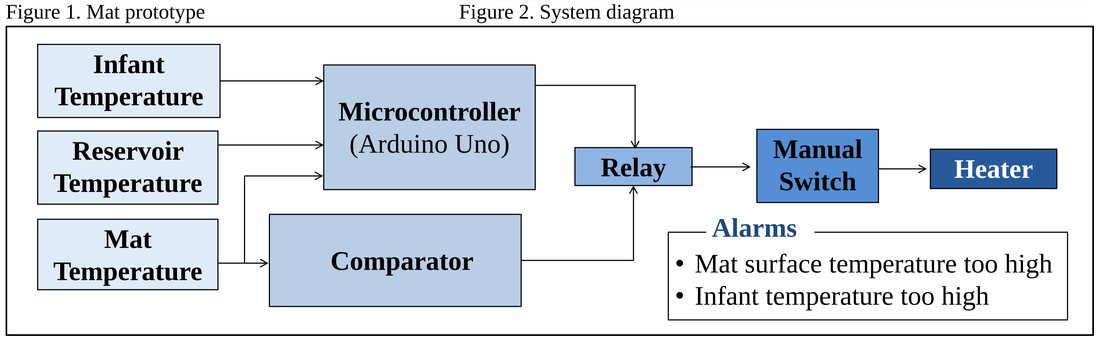


Figure 3. Schematic diagram of the feedback system

Feedback Algorithm

1. Heats and maintains the reservoir at a certain temperature
2. Once the mat reaches the set temperature, feedback switches to maintaining mat temperature
3. Monitors the temperature of the infant and maintains it at 37 ºC

Fail-safes

Circuitry
- Resistors to drive voltage down in case of thermistor disconnection
- Comparator in case the microcontroller fails

Code
Heater turns off if:
- Thermistor disconnects
- System overheats
- Mat overheats
- Infant overheats

Test: Raise and maintain biofluid temperature

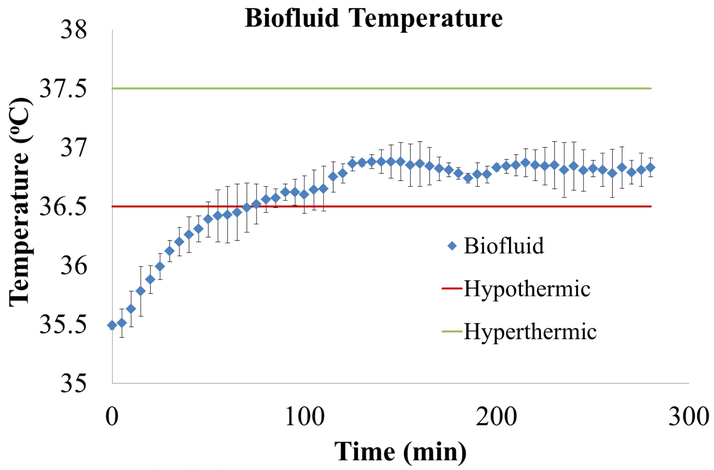


Figure 4. Average biofluid temperature vs. time (n = 3)

Procedure

- 1L biofluid model (35.5 ºC) was placed on the mat. The temperature of the biofluid was monitored.

Results

- Heated and maintained the biofluid to within normal range of 36.5 - 37.5 ºC
  - Control (no heating): biofluid decreased from 37 ºC to 34 ºC in 18 minutes
- 2.3 kWh ($0.36) per day with continuous use
  - Equivalent to using a 100W light bulb for 24hr

Cost: Use of readily available and cheap components

Component	Cost ($)
PVC Tubing	9.20
PVC Sheet	12.34
1000 W Heater	11.00
200 gal/hr Pump	19.36
3.5 gal Bucket and Lid	13.96
Arduino Uno	15.88
Electronics & Misc	25.00
Total	**106.74**

Table 1. Manufacturing cost

Modularity

- Thermostat heater
- Microcontroller ($0.50)
- Tubing
- Case/Mat

Sterilization

- Water: bleach
- PVC sheet and tubing: ethanol

Conclusions and Future Work

Conclusions

- Can effectively raise the temperature of a biofluid baby model
- Can maintain the temperature of the biofluid within the normal range (36.5-37.5 ºC) for up to 5 h. Expect that the heating time can be significantly extended

Future Work

- Optimize design and minimize cost and power consumption
- Fold over component to heat infant from both sides.
- Increase heating unit versatility to allow multiple mat unit warming
- Implement a back-up power source (e.g., battery) in case of power failure

References

[1] UNICEF. Progress for children: a world fit for children statistical review. New York, NY: United Nations Children`s Fund; 2007.
[2] Voorhoeve, H. Aspects of adapted newborn care in rural hospitals. University of Leiden, The Netherlands. October 2005.
[3] Hypothermia. *The Merck Manuals: The Merck Manual for Healthcare Professionals*. http://www.merckmanuals.com/professional/print/sec21/ch319/ch319d.html. Accessed March 1st, 2012.

Acknowledgements

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[1]Biomedical Engineering Dept., Columbia University, [2]Mulago Hospital, Uganda, [3]CUMC Pediatrics, [4]UCSD, [5]Electrical Engineering Dept., Columbia University.