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Title - EXTENDING PATIENT SIMULATION: A NOVEL PROTOTYPE TO PRODUCE TYMPANIC THERMAL OUTPUT

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The authors would be happy to discuss this initiative with other simulation users or with prospective industry partners.

Abstract

Introduction

Despite technological advances in task trainers and manikins, there persists an inability to replicate key clinical skills as would occur in clinical settings. This report provides details of a project to develop a functional and reliable tympanic thermal simulator prototype which could be embedded into the ear of a manikin to enable tympanic thermometers to be used during simulation encounters.

Methods

A simple electrical circuit was built using: i) a standard 9 V battery; ii) a switch; iii) 5 x 62Ω resistors in parallel for circuit stability; iv) a 62Ω resistor in parallel with v) a 1 kΩ potentiometer to vary the IRLED intensity; and vi) two IRLEDs. After confirming reliability of circuit performance, the IRLEDs were implanted into the ear of a manikin. Over 3 consecutive days, 3033 samples were recorded simulating a range of human body temperatures, controlled by altering current flow.

Results

Initial testing of the thermal simulator prototype indicates that a range of human temperatures (34.0 – 41.9^{O} C) can be generated using high intensity IRLEDs. Although at higher applied current levels, the variation in measured temperature was larger (2.4^{O} C) that at lower applied currents (0.2^{O} C), reasonably precise temperatures were achieved.

Discussion

Testing and reporting initial prototype results is an important first step in developing and refining a useful product to enhance manikin capabilities associated with patient physical assessment in the simulation setting. Despite the undesired variation, the current design could still be employed for teaching purposes in educational settings. Retrieving tympanic temperatures during "patient assessment" of the simulator benefits nursing, midwifery and other health care students by enabling authentic practice. Further development of this prototype is required to improve the reliability, precision and accuracy of the device.

Keywords

Tympanic temperature, simulators, clinical assessment.

Introduction

Despite the expanding range of manikins and task trainers on the market for skill training and team based simulations, limitations persist in the ability to replicate key clinical assessment skills and parameters. There have been several areas of development to extend simulator features and provide realistic patient assessment data (1, 2). Creative moulage techniques provide some additional clinically relevant data for participants to take account of during simulations. However, the ability to measure and record body temperature from the human patient simulator would add another level of authenticity to simulation learning experiences and replicate clinical practice. This key clinical skill is important for all health care students to master and repeated practice within the simulation setting can enable proficiency prior to clinical experiences. This report describes the development and bench testing of a tympanic thermal simulator prototype using infrared light emitting diodes (IRLEDs) as a heat source to mimic temperature measurement. When embedded in the ear of the simulator, measurement of tympanic temperature may be possible.

The Faculty of Nursing, Midwifery and Health (FNMH) at the University of Technology, Sydney (UTS) is a leader in the use of simulation learning experiences across nursing and midwifery programs in Australia. The FNMH sponsors a UTS engineering student to undertake a 6 month internship as a simulation technician to provide support for a variety of simulation activities for undergraduate and graduate nursing and midwifery students. In addition to providing technical and audiovisual support during the internship, there is scope for project work to satisfy internship requirements and explore ways to improve technical capabilities of simulators.

The prospect of measuring an actual body temperature on a simulation manikin using a tympanic thermometer was raised by the primary author as a project for the first engineering intern. To the authors' knowledge, there is no such prototype or product on the market. This opinion was formed from searching relevant internet sites, seeking opinion of university marketing and commercial personnel and knowledge of existing commercial simulation products. Hence, the project aimed to develop a functional and reliable thermal simulator prototype that enables tympanic thermometers to be used on patient simulators. Tympanic thermometers function by reading the intensity and frequency (approximately 9000nm) of black body radiation emitted from a tympanic membrane. Normal human tympanic membrane temperature ranges from 35.5-37.5°C (3). By simulating the radiation emission of an inner ear, temperature readings can be obtained with commonly used tympanic thermometers.

Methods

Based on investigation of the radiation frequency range from the human ear, an appropriate emitter was selected for the prototype. IRLEDs were selected to provide radiation output to mimic the range of human temperatures, be small enough to implant into a manikin's ear and be cheap and easily obtainable. A simple electrical circuit (Figure 1) was built using the following materials sourced from Jaycar Electronics (4): i) a standard 9 V battery; ii) a switch; iii) 5 x 62Ω resistors in parallel for circuit stability; iv) a 62Ω resistor in parallel with v) a 1 kΩ potentiometer to vary the IRLED intensity; and vi) two IRLEDs (Catalogue Number ZD-1946). The 1 kΩ potentiometer was used due to limited availability of components at the time of purchase.

A small Vero board was used as the circuit matrix and all components were soldered to the board directly or had lead off wires. The IRLEDs were housed in a socket (3 pin locking and polarising header and locking and polarising pin plug) to allow detachment from the board, and were connected via a 2 pair telephone line cable. The black wire of each pair was tied to (earth) ground, with the yellow and green wires used as the positive connection to each IRLED. A small section of heat shrink tubing was used for insulation and protection near the connection of the IRLED to the telephone cable wires.

Design & Bench Testing

The prototype was tested in a laboratory setting by the (then) engineering intern under the supervision of the other authors. The circuit underwent a number of revisions until a functioning prototype was achieved. All components, except the switch and power source, needed to be adjusted during the course of prototype development. The initial IRLED (www.x-on.com.au, Catalogue Number OP290A) had a peak emission wavelength of 890 nm but did not produce the desired intensity required for the tympanic thermometer, particularly in the high temperature range. The final version of the prototype consisted of two parallel high intensity IRLEDs (Jaycar Electronics, Catalogue Number ZD-1946) which had a brighter intensity and longer wavelength (940 nm) than the previous IRLED. It should be noted that although these wavelengths were lower than the desired output wavelength, there was enough output in the 900 nm range to allow suitable readings to be achieved. The connection between the IRLED and the circuit was made long enough so that the control device could be located away from the manikin's ear. The emitter was implanted in the base of the manikin's ear so the emitted radiation left the ear cavity as would occur naturally.

Before testing commenced, a multi-meter was used to verify that circuit resistance and current were fixed. Slight drift of resistance occurred due to heating of the circuit. However this drift became negligible after a short time and the circuit entered a steady state condition. Final testing was done once the circuit had reached a steady state.

Two types of commonly available tympanic thermometers (Liberty® Health Products and Livingstone GT-302A) were used in the initial testing. Once it was established that both thermometers gave consistent results relative to radiation input, one of the thermometers (Livingstone CT-302A [product code CTSBEARTM]) was selected for subsequent prototype testing. By securing the thermometer to a workbench fixture and taping the "on" button to the depressed position, automated readings from the

IRLED were possible as axes were aligned and distance remained constant. Sampling was performed under the same environmental conditions over 3 consecutive days. Temperature ranges were controlled by altering the current flow.

Readings were produced by the thermometer at 5 second intervals and entered into a spreadsheet of results. In total, 3033 samples were taken over the 3 day testing period with samples taken at each input current to determine the variability of the temperature reading over time while the current was kept constant. Mean and standard deviation (SD) values of temperature readings were calculated for each current level.

Results

The initial design, using medium intensity IRLEDs was unable to produce sufficient intensity or the appropriate wavelength. Test results from the final design of this thermal simulator prototype indicate that a range of human temperatures (34.0^{O} – 41.9^{O} C) can be generated using high intensity IRLEDs (Figure 2). The voltage drop over the diodes was approximately 1.2 V, which resulted in a maximum current to each IRLED of 63 mA, or 126 mA in total.

Mean and SD values of ^{O}C for each current reveal generation of reasonably precise temperatures, reflected in small SDs (0.3 – 0.82 ^{O}C) as depicted in Figure 2 and Table 1. Although there was greater variation in temperatures for higher currents (e.g. 37.8^{O} – 40.2^{O} C at 0.19 A) the majority of recorded temperatures showed narrow range (Table 1).

Discussion

Testing and reporting these results is an important first step in developing and refining a useful product to enhance manikin capabilities associated with patient physical assessment in the simulation setting. This prototype was based on an analogue circuit with no form of feedback control and hence susceptible to noise in terms of changing environmental temperatures. Despite the undesired variation, the current prototype could still be employed to mimic thermal temperature measurement for teaching purposes in higher education settings. Additionally, the device is small enough that it can easily be installed or removed from the ears of a range of simulation manikins.

Accurate temperature measurement in the clinical setting can be challenging depending on method, conditions and patient gender. As Sund-Levander et al. (3) revealed in a systematic review to establish normal body temperature in adults, there was variability in readings depending on the place of measurement and also on gender. With oral temperature recordings there can be as much as 2^{O} C difference between male and female patients, but less variation via rectal and tympanic measurements (0.4^{O} and 0.1^{O} C respectively). Testing of the prototype with practicing clinicians and simulation instructors would provide useful data regarding feasibility in the educational / simulation setting. Key aspects of temperature measurement within practice, which also relate to use with the prototype, include correct axial alignment of the tympanic thermometer and distance from the “heat source”. Further, an agreement of clinically acceptable temperature variation would be useful to incorporate into subsequent prototype designs.

The authors believe that the ability to record temperature from a human patient simulator provides valuable clinical information to incorporate into patient assessment and subsequent management. Undertaking temperature measurement also provides an opportunity to practice this fundamental skill while increasing the authenticity of the simulation experience and likely participant engagement. With a recorded patient temperature, learners can assimilate this information with other related clinical data, and initiate action or refer the situation to senior staff.

Future developments should be based on more specific requirements for accuracy and precision. For a subsequent prototype, calibrated current-temperature response curves should be established, before testing it further in a controlled laboratory setting. Subsequent prototypes could also incorporate either a closed loop feedback control system or production of a digital signal that can be read by a "simulated thermometer". A purpose built thermometer would be required in this case which would cost more to produce and may differ from those used in practice. As most simulation centres aim to use equipment similar to the clinical setting, the tympanic thermal simulator could be enhanced for continued use with the analogue based tympanic thermometer. In this case, a digital signal, rather than IRLED, could be emitted in parallel with the analogue intensity to achieve a functional and more reliable tympanic thermal simulator. This may also incur additional cost but with the benefit of using similar equipment to the clinical setting.

Conclusion

This report provides a description and initial test results of a thermal simulator prototype for generating human temperatures using IRLEDs. The temperature range achieved was 34.0^{O} to 41.9^{O} C. The magnitude of temperature variation at a given current level was smaller within normal human temperature range but greater with temperatures reflecting a fever state. Results arise from initial bench testing of the prototype and from embedding the device in the ear of a manikin, recording data from a tympanic thermometer. Embedding this prototype into the ear of a manikin enables learners to obtain a result during a simulation encounter which allows the technical skill to be rehearsed within context and provides opportunity for decision making regarding patient assessment and management.

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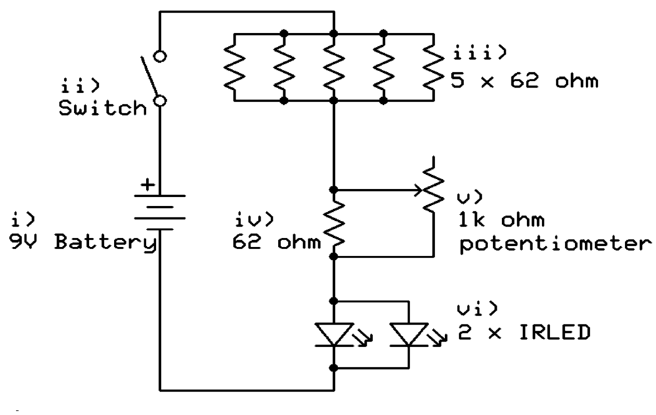

Figure 1 – Representation of the electrical circuit for testing IRLEDs and simulating tympanic temperature.

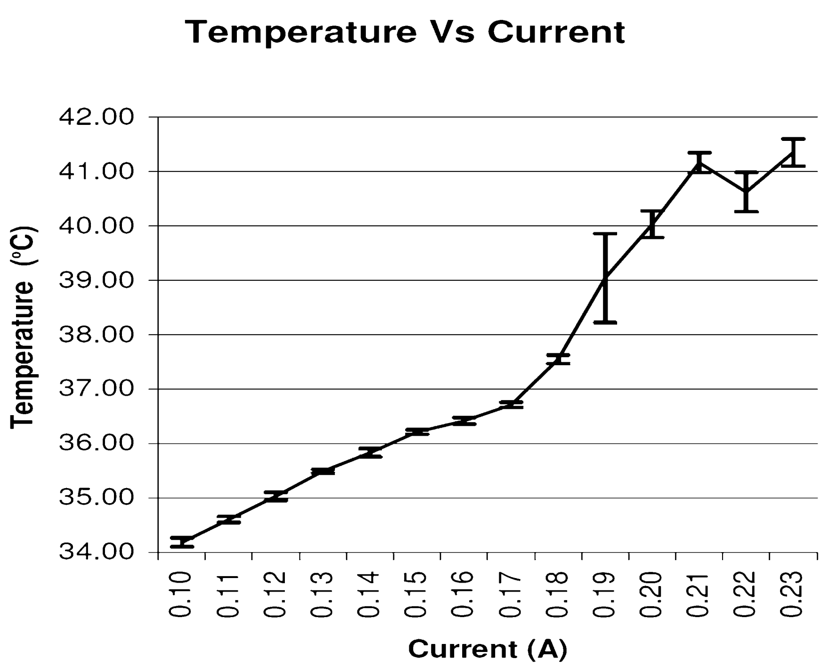

Figure 2 – Graphical representation of temperatures achieved with changes in current through the thermal simulator prototype. Mean (SD) values are shown for each incremental increase in current (A).