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Short Communication

Novel Recommendations to Enhance the Quality of Life in Patients with Neuropathy in Hansen's Disease

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Patients with leprosy (Hansen's disease) may have peripheral neuropathy leading to loss of thermal and tactile sensitivity which may further lead to disabilities and deformities. Those patients with nerve function impairment in their hands while tending to everyday activities such as holding utensils, consuming hot beverages, and handling sharp objects during household chores are prone to develop trauma on their hands leading to ulceration. For prevention of heat induced and other mechanical trauma, we propose innovative solutions such as using thermochromic painted utensils, corrugated paper cups, and cut-resistant gloves to overcome these hindrances. These will avoid the chances of developing non-healing ulcerations and thereby improve the quality of life of the patient.

Keywords : Pigment Changing Paints, Thermochromic Paints, Corrugated Drinking Cup, Cut-resistant Gloves, Neuropathy

Introduction

Hansen's disease caused by *Mycobacterium leprae* has a predilection for Schwann cells thereby affecting the peripheral nerves much before the appearance of symptoms on the skin. There is a loss of thermal sensitivity which is mediated by thin myelinated A-delta type fibres and thin unmyelinated C-type fibres. This is followed by the loss of tactile sensitivity which is mediated by thick myelinated A-beta type nerve fibres. When the disease process is left unchecked, there is further loss of pain sensation resulting in glove and stocking anaesthesia.

A thermal injury occurs when heat energy from a source is transferred to the exposed part of the body. This calorie change causes an increase in the temperature of the local tissue. Beyond the threshold, irreversible cellular injury along with coagulation occurs resulting in the interruption of metabolic processes. Exposure to temperatures beyond 51°C leads to almost immediate destruction of the epidermis while a temperature of above 70°C results in full-thickness tissue destruction (Ong 2005). In leprosy patients with loss of sensation (touch, pain, heat, or cold) over hands, thermal injuries such as burns, blisters,

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and ulcers are likely to occur unless preventive measures are not followed meticulously through counselling and change of behaviour.

Materials and Methods

Thermochromic paints are those containing thermochromic pigments in them, which have the property to reversibly change their colour and optical properties based on the surface temperature they are exposed to. Thermochromic materials are organic leuco-dye mixtures with an amalgamation of a colour former (cyclic ester) providing the base colour of the pigment, a colour developer (weak acid) which determines the final change in colour and its intensity (Granadeiro et al 2020). The temperature at which such conversion of pigment colour takes place is called the 'transition temperature' and it can be modified based on specific needs. The transition temperature depends upon the solvent used which can either be alcohol or an ester (Seeboth & Lötzsch 2013). We propose the use of utensils whose external surface is painted with thermochromic paints. The utensil when at room temperature will show one pigment and when beyond the transition temperature will exhibit another pigment (Fig. 1). Thereby, the user can visually take a cue of the temperature and prevent thermal injury induced by it. They are durable and considerably improve the quality of life of the patient by avoiding thermal injury.

In those patients with neuropathy, weakening and loss of grip over intrinsic muscles of the hand can hinder everyday activities and predisposes one to trauma. Chores such as cutting vegetables, handling sharp instruments, and picking up shards of glass may be challenging for the individual.

We suggest the usage of 'cut-resistant gloves' which have been designed to protect the wearer's hands from cuts while working with sharp tools. It forms a part of personal protective equipment (PPE) and was initially introduced for factory workers who handle heavy trauma-inducing machinery. Varying combinations of fiberglass, stainless steel, high-performance yarns are used to manufacture such gloves and are available in

Fig. 1 : Demonstration of pigment change in a thermochromic cup, on exposure to hot liquid. From left to right - A-Hot water poured into a thermochromic cup, B - Gradual colour change in the exterior of the cup, C - Cup while retaining the hot water, D - Transition back to the initial colour once the water is at room temperature.

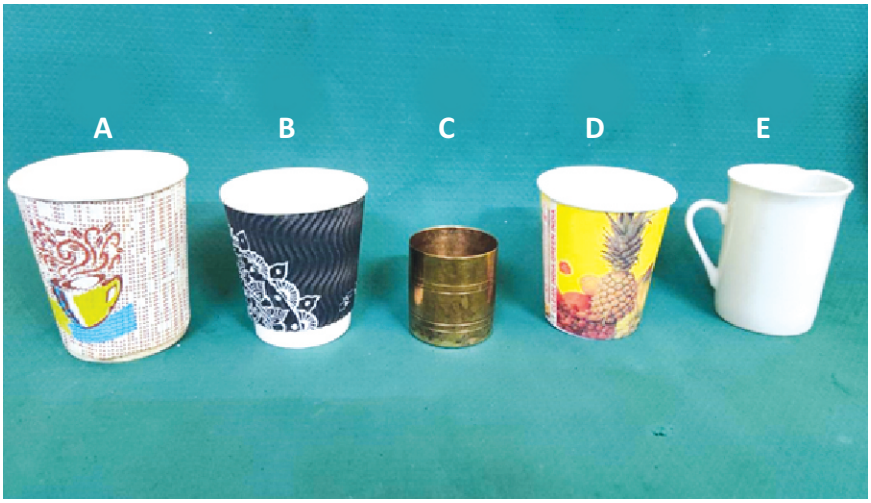

Fig. 2 : Cups of various materials tested in this study. From left to right - A-corrugated paper cup, B - jacketed paper cup, C - metal cup, D - wax-coated paper cup, and E - ceramic cup.

different strengths based upon the requirement (Malik et al 2019). They are reusable and cost-effective, providing an additional advantage of better grip. While preventing accidental minor cut injuries, they may not prevent penetrative injuries and are available for purchase from a range of ₹399.00 to ₹2,747.00.

Patients with sensory impairment have a deficient reflex arc, therefore, do not withdraw on exposure to heat. Commonly consumed beverages in India, such as tea and coffee are frequently served at a temperature range of 71.1°C to 85°C (Brown & Diller 2008). The structure of the cups has been found to be the most important parameter which strongly influences and determines the thermal insulation of a cup. In a regular Indian household, hot beverages are commonly consumed in stainless steel, ceramic, or glass cups. The thermal conductivity of a cup largely depends upon the material it is made of. Pure metals are excellent conductors of heat due to the presence of free electrons. However, alloys of such metals are used to manufacture the cups used in household and they have comparatively lower thermal conductivity as the impurities present in them distorts the motion of free electrons. The atomic structure of both glass and ceramic is highly disorganized and irregular. Thus, the thermal conductivity of steel (~16 W/m. K) is way higher than either glass (~0.8 W/m. K) or ceramics (~1.5 W/m. K). Stainless steel cups are generally made by a stamping process which further aligns the free electrons and makes the cup much thinner compared to glass or ceramics. This further enhances heat loss by the conduction method. However, ceramic and glass cups cannot be used regularly as there are still a good conductor of heat and are fragile to use. Styrofoam cups are excellent insulators, however, are made of polystyrene making them environmentally toxic to use (Hwang et al 2020). Plain paper cups are cheap, environmentally friendly but the insulation provided by them is not sufficient and is utilized on a 'use and throw' basis. Cup holders which provide a socket to accommodate a cup and a long handle offer some assistance because

of the temperature difference between the body of the cup with hot beverages and holder. These cups, however, are not easily available and are not user-friendly. Thus, with the lack of proper cups, there is a fear of acquiring thermal injury in patients with impaired sensation while consuming hot drinks without assistance.

We suggest the usage of corrugated and jacketed paper cups in place of the normal cups. A corrugated paper cup consists of three layers of paper, and the top layer has a relief structure. This relief structure ensures that there are air spaces in the walls of the cups. The hands come in contact only with the protruding parts of the screen thereby the surface area in contact is minimal. Jacketed paper cups have a coffee cup sleeve along the external surface of the paper cup which may or may not be corrugated. By preventing direct contact, they act as a good insulator.

To identify the practical effectiveness and temperature difference inside and outside of the cups, water was heated to 75°C and poured into a corrugated paper cup, jacketed paper cup, metal cup, wax-coated paper cup, and ceramic cup simultaneously and was labelled as A, B, C, D, E respectively (Fig. 2). After 3 minutes, five consenting dermatologists were blinded and were asked to compare the temperature difference between the outer surfaces of the various cups. The test was repeated thrice, and the cups were jumbled each time. The results were then tabulated. All five participants chose the metal cup to be the hottest on the surface followed by the ceramic and wax-coated paper cup. The corrugated paper cup was selected as the cup with the least surface temperature in six out of nine trials followed by the jacketed paper cup was selected in three out of nine trials.

Table 1 : External surface temperature of different cups (recorded with a thermocouple at room temperature)

Trial	Corrugated paper cup	Jacketed paper cup	Metallic cup	Wax coated paper cup	Ceramic cup
			Temperature in °C		
Trial 1	47.7	50.5	65.9	53.7	55.7
Trial 2	47.3	50.3	65.5	53.7	55.6
Trial 3	46.6	50.1	65.1	53.5	55
Mean temp°C	47.2	50.3	65.5	53.6	55.4

Table 2 : Kruskal-Wallis equality-of-population rank test for individual perception of surface temperature

Based on individual perception of surface temperature			
Cup	Number of trials	Rank sum	P-value
Metallic cup (C)	3	75	0.0090
Ceramic cup (E)	3	60	
Wax coated paper cup (D)	3	44	
Jacketed paper cup (B)	3	27	
Corrugated paper cup (A)	3	18	

Table 3 : Kruskal-Wallis equality-of-population rank test for surface temperature as measured using a thermocouple

Based on surface temperature measured using thermocouple			
Cup	**Number of trials**	**Rank sum**	**P-value**
Metallic cup (C)	3	42	
Ceramic cup (E)	3	33	
Wax coated paper cup (D)	3	24	0.0091
Jacketed paper (B)	3	15	
Corrugated paper cup (A)	3	6	

The same was repeated and the results were documented simultaneously with the help of a thermocouple at normal room temperature (Table 1). The mean temperature of the corrugated paper cup is recorded to be the least at 47.2°C followed by the jacketed cup with a mean of 50.3°C. The metallic cup marked the highest with a mean of 65.5°C.

Statistical analysis by Kruskal-Wallis equality-of-population rank test was done for the perceived surface temperature data (Table 2) and the temperature measured using a thermocouple. (Table 3). Ranking of all the cups was done wherein, the cup showing least temperature was ranked as 1 while that with the maximum temperature was ranked 5 accordingly. The rank sum was calculated for different trials and probability value (p-value) was calculated between these rank sums.

Results and Discussion

The external surface temperature of various cups as experienced by different individuals and measured with a thermocouple (as shown in Tables 2 and 3 respectively) has a p-value of 0.0090 and 0.0091. The p-value is less than 0.05 making it statistically significant which suggests a low rank for corrugated and jacketed cups in comparison to the other tested materials, making it a better thermal insulator than the other tested cups.

The thickness of the paper cup, as well as the cup sleeve and the frequency of corrugations, determines the thermal conductivity of corrugated and jacketed cups. Its resultant thermal conductivity is much lower than that of other materials. Thereby, the patient can consume a hot/warm drink without the apprehension of burning oneself unlike metal or ceramic cups. It is also a cost-effective solution, as these cups can be purchased for around ₹ 1.50 and can be reused up to 2-3 times based on their quality.

The effectiveness of the proposed solutions is well established. However, further extended studies will be required to implement the same.

Conclusion

The proposed recommendations for use by patients affected by leprosy (PAL) with anaesthetic hands are effective, economic, and worthwhile. These methods can be adapted by neuropathic patients with sensory loss of any cause including leprosy and diabetes, there by patients can improve their quality of life by preventing injuries and avoid the psychological burden of dependency for day-to-day living.

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