Warmed Blankets are Safe

By Jon K. Moon, PhD

Summary

Chilled patients feel better immediately after being covered with a warmed blanket. Blankets taken from warmers operated at temperatures up 93°C (200°F) have almost no effect on skin temperature so are safe for both the patient and hospital staff. The direct benefit of a warmed blanket lasts for only a few minutes, but the improved comfort and psychologic perception can last much longer.

Patient Benefit

The temperature in most western hospitals is set low for the comfort of staff, who are fully dressed and moving about. It is especially cool in surgical areas where staff wear layers of specialized clothing. So patients easily become chilled. Peri-surgical patients may be vulnerable to hypothermia because they are immobile or unconscious. Lightly-clad patients lose heat rapidly to their environment: by radiation to cold walls, by conduction to metal furnishings, and by convection to moving air that can be as cold as 20°C (68°F). Sessler et al. found that under these conditions even healthy and alert volunteers could experience low skin temperatures within 20 minutes. Hospital staff have recognized the problem of keeping patients comfortable and employ a variety of measures to aid thermoregulation.

When patients cannot generate enough metabolic heat to warm themselves then a warmed blanket may be just what they need. Chilled patients prefer warmed blankets to room-temperature blankets even though the actual thermal effect of warmed blankets lasts no more than 10 minutes. Clearly, the blanket doesn't transfer significant heat to the patient. The benefit comes instead from immediately interrupting heat loss to the environment. Humans are sensitive to heat transfer through the skin, as well as temperature, which can explain the comforting effect of a warmed blanket. And warmed blankets avoid the discomfort of accelerated heat loss caused when a patient is draped with a blanket colder than their skin.

Hot water and skin

What happens to skin temperature when hot water is spilled? The water will spread out and cover the skin in a layer of about the same thickness as the skin. If the water isn't constantly replenished then the skin and water will equilibrate to a new, intermediate temperature. Because skin and water have similar specific heat and density (skin, like the rest of the body, has a high water content) the equilibrium temperature will be between the two starting temperatures. Boiling water at 100°C will bring skin at 31°C to more than 55°C (not half way between 100 and 31°C because a large amount of heat is carried away by blood and air). In this temperature range tissue damage occurs very rapidly.

Warm blanket and skin

What about skin in contact with a hot blanket? A calculation for this situation is shown in Box 1. Let's say the cotton blanket is 90°C. However, it has less than 1/3 the specific heat of skin. And the blanket has less than 1/1000 the density of skin (the density of a blanket is about 1 kg/m^3 because it is roughly half cotton and half air – the purpose of weaving cotton is to trap air). So the blanket can give up all of its heat to the skin yet raise skin temperature no more than 1/80 of the 70°C temperature difference, or about 1°C. The blanket doesn't raise skin temperature even to core temperature.

EC340 with optional bumper

Box 1: Warming Skin

This detailed calculation explains heat transfer from a warm blanket to a chilled and essentially naked patient. The blanket (50% cotton, 50% air) is taken from a warmer at 93°C (200°F) and releases all of its stored heat to the topmost layer of skin (epidermis). Let's see how much skin temperature rises.

t_o = oven temperature = 93°C
t_b(initial) = blanket temperature when placed on patient = 93°C
t_e(initial) = epidermal temperature when blanket placed on patient = 33°C
t_{eq} = equilibrium temperature (when blanket is the same temperature as skin)
Constants for specific heat of the skin, c_e, and blanket, c_b, come from the table in Box 2. The density of epidermis, ρ_e = 1200 kg/m^3 ; and blanket, ρ_b = 1.0 kg/m^3 (about half air and half cotton).
The thickness of epidermis, h_e = 0.008 cm; blanket, h_b = 0.3 cm.
A = the unit cross section area for skin contacting blanket.

The heat equation is $\Delta Q = m \cdot c \cdot \Delta T$. Mass can be found from $m = A \cdot h \cdot \rho$, where A is the area where skin and blanket touch. Because the A are the same they cancel from the equations.

$$\Delta Q_e = c_e \cdot A \cdot h_e \cdot \rho_e \cdot \Delta t = 346 \cdot A \cdot (t_e(\text{initial}) - t_{eq})$$
$$\Delta Q_b = c_b \cdot A \cdot h_b \cdot \rho_b \cdot \Delta t = 3.1 \cdot A \cdot (t_b(\text{initial}) - t_{eq})$$

We assumed heat is exchanged between only the blanket and skin, so $\Delta Q_e = -\Delta Q_b$, and $346 \cdot (t_e(\text{initial}) - t_{eq}) = -(3.1 \cdot (t_b(\text{initial}) - t_{eq}))$

Solving for t_{eq} gives,

$$346 \cdot t_e(\text{initial}) - 346 \cdot t_{eq} = -3.1 \cdot t_b(\text{initial}) + 3.1 \cdot t_{eq}$$

$$t_{eq} = (3.1 \cdot t_b(\text{initial}) + 346 \cdot t_e(\text{initial})) / 349$$
$$= (3.1 \cdot 93 + 346 \cdot 33) / 349$$
$$= 33.8°\text{C}$$, a skin temperature rise of <1°C or about 1.4°F

No Harm to Patients

There are no published or other public reports of patient injury caused by warmed hospital blankets. The FDA Manufacturer and User Facility Device Experience Database contains 192 problem entries from 1992 through 2004 in the category of patient thermal regulating systems (DWJ) [MAUDE]. This is the category for active warming devices [870.5900], but blanket warmer events are also reported with the DWJ code. All but four of the reports relate to active devices such as those that circulate hot water or air, or contain electric heating elements in contact with a patient. Patients have occasionally experienced serious injury from failure of these active devices. The four reports that involve warmers describe control or safety circuits

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Box 2: Holding heat

Can a hot blanket be as dangerous as hot water? The answer is no. To understand why it helps to understand how much heat a warm object can transfer to a colder object. The parameters are the weights (mass) of the objects, the difference in their temperatures and a property of each object called "specific heat". Specific heat (c) is the heat needed to raise the temperature of a unit mass of some material by one degree. So the heat that is added or removed (called ΔQ, or heat transfer) from an object by a temperature change (ΔT) equals the mass times c: $\Delta Q = c \cdot m \cdot \Delta T$. The table below shows specific heats for several materials. Skin and water have similar specific heat, as do air and cotton. The table also shows density, which relates the size of an object to its mass. From specific heat and density we can find the relative heat capacity, the amount of heat a material can store by volume. This is more convenient for things we can hold and move (a kilogram of water is reasonable to manage, a kg of blanket would be very bulky). Looking at the heat capacity column we see that skin and water can store several thousand times more heat in the same space as a blanket.

Multiplying specific heat and density gives a parameter called relative heat capacity (the symbol is a capital "C"). Heat capacity:

Material	Specific Heat $\left(\frac{J}{kg \cdot °C}\right)$	Heat capacity $\left(\frac{J}{m^3 \cdot °C}\right)$	Density $\left(\frac{kg}{m^3}\right)$
Air	1004	1305	1.3
Water	4200	4200000	1000
Skin	3600	4320000	1200
Cotton	1021	408	0.4

altered by users and one case of the warmer not heating adequately. Patient impact isn't mentioned in any of these four reports.

No problem for staff

Temperatures that staff experience in handling warmed blankets can be described by the same parameters as patient contact. Warmed blankets can be handled without risk. On contact, the blanket will only feel warm. Even by grasping multiple layers there is no significant heat transfer. You can try this experiment by heating a blanket to 93°C (200°F) in a warmer capable of this set point, such as those manufactured by Enthermics Medical Systems, Inc, and then sliding your hand within the folds.

No problem for the blanket

Blankets made of cotton can be maintained at temperatures up to 93°C (200°F). Cotton, for example, is primarily cellulose and has an ignition temperature of about 250°C (482°F). Per ANSI standard Z21.5.1 gas dryers are required to have temperature safety limits at 121°C (250°F) at the air outlet. Inlet temperatures of dryers can be as high as 175°C (347°F) [CPSC]. These temperatures are well above the highest settings available from hospital blanket warmers.

Blanket and skin physics

Heated blankets transfer very little energy to a patient. For example, a cotton blanket heated to 93°C (200°F) would raise the temperature of the topmost layer of skin (the epidermis) by about 0.8°C (1.4°F) [see Box 1 for calculation]. Of course, there are many factors that complicate calculation of epidermal temperature change from applying a heated, woven fabric. For example, the patient is unlikely to be naked, so the insulating effect of at least a hospital gown must be considered.

It is impossible to transport a blanket from a warmer and drape it on a patient before it cools substantially, perhaps by as much as 28 to 42°C (50 to 75°F). Consequently, a blanket warmer should be most effective when set between 65 and 93°C (150 to 200°F). The outer epidermis is composed primarily of keratinized epithelial cells and lacks nerve endings that sense pain or living cells that could be injured by heat. Moritz and Henriques determined that a constant flow of water at approximately 44°C (111°F) for several hours can cause pain and basal cell injury in some people (basal cells are the living cells closest to the surface of the skin). Since their study was published in 1947, 42 to 43°C has generally been used as the maximum safe temperature for prolonged skin exposure. The temperature of exposed skin of chilled patients is around 31 to 33°C (88 to 92°F). Raising this temperature by 1°C (1.8°F) with a warmed blanket would still be much lower than body core temperature. In addition, the basal cell layer is perfused tissue. During the 30 s or longer that it takes to equilibrate the basal dermal layer to topically-applied constant heat the blanket would have given up all its available heat.

About the author

Dr. Moon is biomedical engineer and a partner at the medical device design firm Devicix, LLC. Further biographical detail is available at the Devicix web site: www.Devicix.com

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