Utility of Aluminized Mylar to Decrease Radiative Heat Loss

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Abstract

Heat is lost by conduction, convection, evaporation, and radiation. When packaging a patient in a litter for transport one uses insulation and a vapor barrier to address the first three. It is unclear whether radiation can be addressed during packaging. Aluminized Mylar reflects more than 90% of infrared heat so it could make a difference in heat retention. Some rescuers believe that putting a vapor barrier next to the skin makes more of a difference than outside. We attempted to look at both issues by looking at heat loss from bottles of hot water with different hypothermia wraps. We made 5 envelopes of packaging material to hold a 125 ml polyethylene bottle. A control group had simply a layer of tarp acting as a vapor barrier. Four other groups had a layer of lightweight fleece serving as insulation. In two of these the fleece was against the bottle and in two it was against the tarp. Two had aluminized Mylar and two had thin non-reflective plastic. This made for 5 different wraps. Five runs were made, switching bottles with each run so that each bottle was in each envelope. Boiling water was put into each bottle and temperatures were taken each minute for 10 minutes. The envelopes were stood up in a wire basket to avoid conduction losses. Temperature change was measured as the 1 minute value minus the 10 minute value. The control bottles lost 11.8 degrees compared to a 7.05 degree Celsius loss for the Mylar group and an 8.7 degree loss in the non-Mylar group which was shown to be a significant difference (p=0.04). There was no difference using the plastic layer next to the bottle versus outside the fleece insulation. These data show that an infrared reflective layer does help with heat retention in a bottle of hot water and suggests that it might make a difference in a packaged patient. The next step is to replicate this in a colder environment and in a situation where more conductive heat losses might occur to see if this effect is still relevant.

Key Words: Hypothermia, Radiation, Heat loss, Aluminized Mylar

Introduction

Patients transported in a wilderness setting are at risk for hypothermia. Preventing heat loss through passive rewarming is the core of field treatment. Heat can be lost through conduction, convection, evaporation, and radiation. The proportion of heat lost by each mechanism varies depending on environmental factors and what measures have been taken to prevent heat loss. A typical wilderness casualty will be wrapped with insulation which prevents both conductive and convective losses as well as a vapor barrier to keep the patient dry and prevent evaporative losses. The now classic method of wrapping a casualty in an insulating layer surrounded by a vapor barrier has been shown superior to just using quilts or wrapping in bubble wrap.¹

Infrared radiation can be a significant loss in the right environment. Some studies attribute 50-60% of heat loss to radiation at low temperatures, but this is for a near naked person in a still room.²
Surrounding cold objects will receive more infrared than they emit, despite a higher air temperature making the perception of cold worse. An insulation layer as slight as a cotton blanket can reduce heat loss by 30% and three of them can reduce heat loss by 50% in the operating room. A potential way to decrease radiation losses is to reflect back whatever is radiated out. In the OR reflective blankets have shown mixed results. A thermal drape with a reflective metal side was barely better than a cotton blanket at reducing heat loss. Aluminized Tyvek improved core temperature by 0.25°C compared to standard surgical draped after 60 minutes.

Reflective surfaces may become less effective as distance increases between the emitter and the reflector. A reflective sheet may be most effective next to the skin where it is most likely to be uncomfortable. Some agencies do this as their standard protocol. At the same time, a Mylar layer applied directly to the skin will allow for maximum conduction through it.

Aluminized Mylar can reflect back up to (90)% of infrared. What is not clear is whether radiation losses are significant in someone already insulated from the cold. In the operating room, reflective blankets by themselves have not helped hypothermic patients to reheat. We looked at whether using aluminized Mylar helps to prevent heat loss compared to non-aluminized, equivalent weight vapor barrier and to see whether placing this reflective layer next to the skin works better than outside an insulating layer.

Methods

Inspired by Beeghly and Caudell, we used a patient surrogate by looking at heat loss from bottles of hot water. The containers were 125 ml low density polyethylene sample bottles with a #6 rubber stopper drilled to accept a Fisher Scientific thermometer probe. Each probe extends 8.5 cm from the top of the stopper so the tip will be in the middle of the water sample. The small volume is chosen to maximize surface to volume ratio and thus see a result more quickly. This also reduced the amount of water boiling required.

We used 5 bottles and five thermometers and repeated the measure 5 times, rotating bottles and wrappings to eliminate any systematic errors from the bottles. Each thermometer was constant to one bottle. To minimize any variation in the way that the insulation layers were arranged, they were sewn into envelopes and then lettered. This greatly speeded up the process as a bottle can be simply inserted into its envelope. Envelopes were stood up in wire racks so that each had little direct contact with solid media so that conductive losses were minimized.

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<th>Wrap</th>
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<tr>
<td>A</td>
<td>Mylar by “skin”</td>
<td>Fleece by skin</td>
<td>Mylar outside</td>
<td>Plastic by skin</td>
<td>Fleece by skin</td>
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<td>B</td>
<td>Fleece outside</td>
<td>Mylar outside</td>
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<td>C</td>
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Each bottle was numbered 1 to 5. Before each round, the bottles were put into a 24 degree C pool for 5 minutes so that they always started at the same temperature. Each was removed from the pool, dumped and then filled with boiling water. Thermometers were inserted and then the flasks were put in envelopes. The temperature was measured each minute for 10 minutes. After each run, the bottles were cooled again and then refilled with boiling water and put into the next envelope for a total of 5 runs.
Instrumentation

The thermometers were Traceable Digi-Thermo digital thermometers (Control Co, Friendswood, TX). Prior to use all thermometers were put into the same pot of boiling water to compare readings. Readings were all within 0.5 degrees.

Analysis

We calculated heat loss by change in temperature from minute one to minute 10. Heat loss will be directly proportional to temperature change as each bottle holds the same amount of water. A preliminary run showed a fast drop in the first minute followed by a linear decline from minute 1 to minute 15 (data not shown). This initial drop comes from the calorimetry effect of heating up the bottle. After the initial drop heating the bottle, the rest of heat loss is to the environment through the packaging.

Results

Initial repeated measures ANOVAs demonstrated that inside or outside placement of material was irrelevant for Mylar temperatures (F (1, 9) = .70, p = .43) and plastic temperatures (F (1, 9) = .11, p = .75) (see Figure 1). Because of these findings the following tests were performed with the two Mylar groups combined and the two plastic groups combined.

A two way repeated measures ANOVA revealed a significant main effect of temperature difference for type of insulation used (F (2, 220 ) = 7.01, p = .004) (see Figure 2). Tests were conducted using Bonferroni adjusted alpha levels of .025 per test (.05/2) to explore specific jacketing differences. These post hoc analyses of mean differences revealed that the tarp jacketed bottles cooled significantly more quickly than the Mylar jacketed ones (M difference = -3.12, p = .006), the plastic jacket bottles cooled more quickly than the Mylar jacketed ones (M difference = -1.96, p = .04), and that there was no significant difference in cooling rates between the tarp and plastic jacketed bottles (M difference = -1.16, p = .63).

The two way repeated measures ANOVA also demonstrated a highly significant main effect of temperature difference over time (F (9, 220 ) = 2390.98, p < .001), such that overall the bottles cooled as time progressed. Finally, it demonstrated a significant interaction between type of insulation and time (F (18, 220 ) = 47.75, p<.001), such that the tarp only bottles were cooling more quickly than the Mylar jacketed ones, with the plastic jacketed ones showing an intermediate trend.
Temperature Loss between Minute One and Minute Ten by Insulation

Temperature Decay over Time by Insulation
Discussion

This experiment shows that adding an aluminized Mylar layer in packaging does prevent heat loss, at least in a low conductivity situation, and suggests it might make a difference with a packaged patient. It remains to be seen whether this is true in a higher contact situation where conductivity will be more of an issue. A patient wrapped and placed in a litter will have more chance of conductivity into the litter itself as well as the environment. An aluminized Mylar sheet more closely applied to the patient without an air separation may simply conduct heat rather than reflect it. So whether the benefit of reflection applies to a patient packaged for transport remains to be seen.

The follow up experiment will be to replicate this in an underground environment where the temperature will be cooler and more constant. For the replication we will use more tightly fitting sleeves for the bottles to more closely approximate real patient packaging. Besides a series of tests in the air we will also repeat this with the bottles and sleeves partially buried in sand to simulate a maximally conductive environment to contrast with the minimally conductive situation we have already done.

Bibliography