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BRIEF RESEARCH REPORT

Emergency Medical Services

A simple improvised prehospital method to warm intravenous fluid

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Abstract

Study Objective: Use of warmed intravenous fluid by emergency medical services (EMS) for prehospital injured patients is recommended to avoid iatrogenic hypothermia. We hypothesized that an improvised heating method would significantly increase the temperature of an intravenous fluid bag in a simulated prehospital environment.

Methods: The change from baseline in the temperature of a 1-L intravenous fluid bag positioned above the vehicle windshield defroster vent was measured for 30 minutes using a thermocouple probe. Temperature changes were compared with a control fluid bag positioned on the vehicle console armrest. A total of 10 independent experiments were performed.

Results: The defroster vent method increased intravenous fluid bag temperature from a mean starting temperature of 19.4°C (95% confidence interval [CI], 17.4°C–21.4°C) to a mean end temperature of 32.6°C (95% CI, 30.6°C–34.6°C) after 30 minutes. The temperature of a control intravenous fluid bag (mean starting temperature of 20.1°C; 95% CI, 19.0°C–21.2°C) exposed to a warmed (mean 33.2°C) passenger compartment changed little during the same time period (mean end temperature of 22.3°C; 95% CI, 19.4°C–25.2°C).

Conclusions: Convective warming of an intravenous fluid bag using the dashboard defroster vent significantly raised the fluid temperature. Such a method should be readily available to EMS or first responders.

KEYWORDS
emergency medical services, hypothermia, trauma, resuscitation, prehospital, austere environments

1 | INTRODUCTION

1.1 | Background

Hypothermia is frequently present in patients with severe injury,[1,2] and mortality rates were higher in trauma patients with admission temperatures <35°C.[3] In the prehospital emergency medical services (EMS) setting, reasonable efforts should be made to mitigate further decreases in body temperature. Level 1 warming measures to prevent hypothermia in the prehospital setting include warm intravenous fluids, warm environment, and warm blankets.[1,4] The American College of Surgeons recommends that ideally intravenous fluid warmed to 39°C be administered to resuscitate injured patients.[4] The Wilderness Medical Society guidelines suggest that resuscitation with 40°C–42°C normal saline may help to rewarm victims of accidental hypothermia.[5] It is generally impractical, and often impossible, to achieve intravenous

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The Bottom Line

Warmed fluids have been shown to be useful in treating hypothermia. This exploratory study tests a pragmatic and novel technique (warming fluids on the vehicle windshield vent) in a simulated prehospital environment, resulting in significantly warmer intravenous fluids.

fluid temperatures of 39°C–42°C in the prehospital setting, but infusion of ambient temperature (21°C) intravenous fluid may be a significant risk factor for severe hypothermia.[3]

1.2 | Importance

A study examining the impact of infusing warmed (32°C) versus control (23.2°C) fluid during air-ambulance transport found that patients who received warm fluid had a higher core temperature (36.8°C vs 35.5°C) on arrival to the emergency department.[6] The unavailability of devices designed for heating intravenous fluid in the field has led some EMS personnel to improvise methods using available resources.[7]

1.3 | Goals of investigation

In the present study, we used a simulated "benchtop" method to assess the feasibility and utility of convective heating using a vehicle's windshield defroster vent to warm a bag of intravenous fluid. We hypothesized that this improvised method would be able to raise the temperature of an intravenous fluid bag in a simulated winter EMS field environment.

2 | METHODS

2.1 | Study design and setting

A total of 20 1-L intravenous fluid bags of 0.9% sodium chloride bags were acclimated to steady-state ambient indoor room temperature (~21°C) for >8 hours and stored in an Igloo (Katy, TX) cooler. Two bags were removed from the cooler at the start of each experiment. The experimental setup is illustrated in Figure 1. One intravenous fluid bag was placed over the dashboard defroster vent (experimental bag) and another on top of the center console armrest (control bag) of a 2005 Mercury Mountaineer sport utility vehicle (Ford Motor Company, Detroit, MI). The vehicle had been idling in a cold winter environment such that the heater delivered warmed air before the first, and between subsequent, experiments. The vehicle was driven the same route during each of the 10 experiments, predominately on city streets, observing posted traffic signs and speed limits. A total of 10 independent experiments were performed on a single day.

2.2 | Measurements

Hypodermic thermocouple probes (21 g 38-mm solid needles, model HYP-2, HYP2-21-1-1/2-T-G-48-OST-M; Omega Engineering, Inc., Stamford, CT) were used to measure intravenous fluid temperature. The probes were inserted into each intravenous fluid bag through the rubberized medication port. Separate probes were positioned within the passenger cabin and outside to record the ambient vehicle and external environmental temperatures, respectively. Data were gathered using an 8-channel data acquisition module (TC-08 8-channel thermocouple data acquisition module; Omega Engineering, Inc.) connected to the USB port of a Windows-based personal computer. Temperature measurement data were automatically recorded at 10-second intervals and compiled using Microsoft Excel (Microsoft, Inc., Seattle, WA).

2.3 | Outcomes

The primary outcome of the study was assessing how much the temperature of a bag of intravenous fluid could be increased using the described improvised dashboard defroster method for 30 minutes. The secondary outcome was to compare the dashboard warming method to the simultaneous warming achieved in a control bag of intravenous fluid exposed to the warmed air in the vehicle interior.

2.4 | Analysis

Microsoft Excel was used to aggregate and compile the data from the 10 individual experiments. The mean temperature and 95% confidence interval (CI) at 30-second intervals were calculated using the probe data. Repeated measures analysis of variance (ANOVA) was used to compare mean group temperatures over time. Student's *t* test was used to compare the mean group start and end temperatures. An α value of 0.05 was used to determine statistical significance.

3 | RESULTS

The final temperature of the experimental dashboard intravenous fluid bags across the 10 trials ranged from 27.7°C to 38.1°C, with a mean end temperature of 32.6°C (95% CI, 30.6°C–34.6°C), was compared to the mean start temperature ($t = 0$ minutes) of 19.4°C (95% CI, 17.4°C–21.4°C). There was a highly significant change in the temperature of the dashboard intravenous fluid bag ($P < 0.001$ by ANOVA), whereas the mean temperature of the control (console) intravenous fluid bag was unchanged (mean start temperature 20.1°C [95% CI, 19.0°C–21.2°C] to mean end temperature of 22.3°C [95% CI, 19.4°C–25.2°C]; $P = 0.17$). The difference in the dashboard start and end temperatures was highly significant ($P < 0.0001$) by Student's *t* test, whereas there was no statistical difference in the mean start and end temperature of the console intravenous fluid bag during the 30-minute experiment

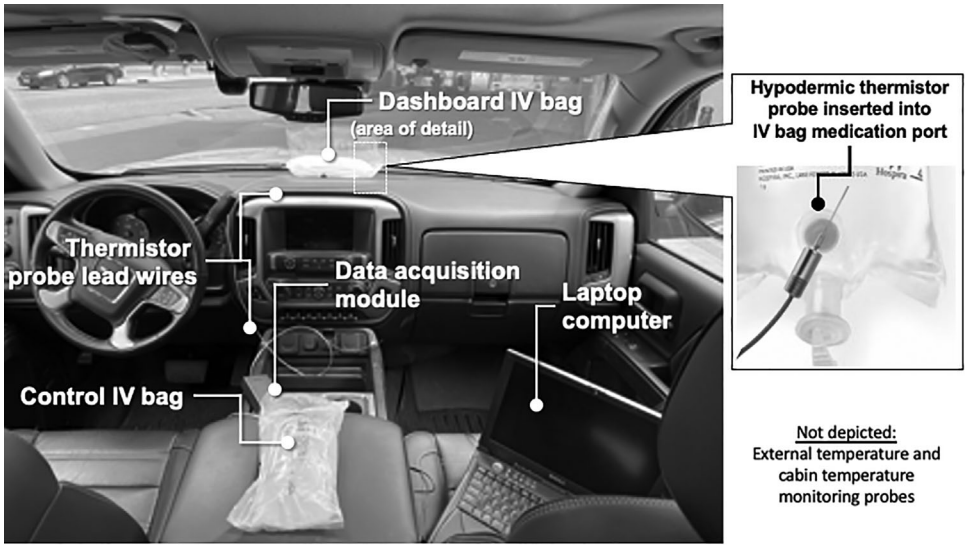

FIGURE 1 Illustration of the experimental design used to compare dashboard defroster vent improvised warming method to temperature of an intravenous fluid bag placed on center console. Thermocouple probes were placed in the dashboard and console fluid bags, along with additional internal and external environmental probes. Data were recorded at 10-second intervals and stored on a laptop computer. IV, intravenous

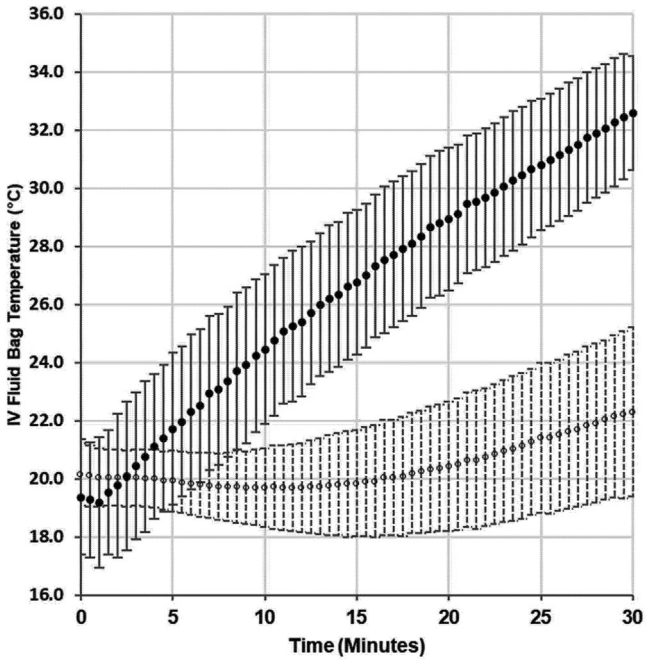

FIGURE 2 Mean change in intravenous fluid temperature (°C) over time compared with starting temperature: solid circles and lines indicate experimental dashboard intravenous fluid bag, and open circles and dashed lines indicate control intravenous fluid bag. Vertical lines represent ± 95% confidence intervals. IV, intravenous

($P = 0.138$). The data are displayed graphically in Figure 2. The figure shows a time-dependent steady increase in mean intravenous fluid temperature of the experimental (dashboard) bag, with visual separation of the means and 95% CIs after 7 minutes. The ambient vehicle temperature increased in all cases (data not shown), but the rise in passenger compartment temperature did not alter the fluid temperature of the console bag. The external environmental temperature (mean ± SD, −2.9°C ± 0.2°C) had no discernible impact on the overall rate of rise of the fluid temperature in the dashboard bag.

3.1 | LIMITATIONS

The current study has several limitations. The greatest limitation was the fact that simulated conditions were used rather than real-world field conditions. The temperature of the intravenous fluid was also measured in the bag rather than at the delivery end of intravenous tubing; therefore, the results probably represent an "upper limit" for improvised intravenous fluid warming. Another limitation was the use of a standard sport utility vehicle to perform the experiments rather than an actual type I or II ambulance. The choice of the 30-minute experimental duration to simulate the time from dispatch to scene departure may be unusually long in many urban locales, although this might not be uncommon for suburban and rural EMS agencies. Because the dashboard heat source is not portable, any heated fluid might need to be administered promptly to avoid heat loss, but we did not examine how long the warmed intravenous fluid bag maintained its temperature. Finally, we did not examine the potential seasonal impact of higher or lower ambient and/or starting temperatures.

4 | DISCUSSION

In the current study, convective heating using the dashboard defroster vents produced statistically significant increases in the temperature of an intravenous fluid bag. The study found that having the intravenous fluid bag within the warmed passenger compartment maintained the baseline temperature but was ineffective at raising it for 30 minutes. The current study resulted in a mean temperature change of 14.1°C,

but did not identify an achievable plateau temperature. The mean intravenous fluid temperature of 32.6°C after 30 minutes of warming was 4.4° lower than the "normal" body temperature (~37°C). The literature pertaining to warmed intravenous fluid identified 39°C to 42°C as the recommended target temperature range for resuscitation intravenous fluid.[4,5] Although the improvised methods and results described herein fell short of that target, it is likely that infusion of fluid warmed to any temperature higher than room temperature is beneficial. At least 1 published report showed that infusion of room temperature fluid was associated with a higher mortality,[3] and a small study showed that infusion of 32°C intravenous fluid better maintained core body temperature.[6] The forthcoming HYPOTRAUM 2 multicenter study being conducted in France has proposed 35°C as the goal temperature for warmed intravenous fluid.[8]

Factors that may impact the utility of any improvised heating methods to warm intravenous fluid in the prehospital setting include available equipment and supplies, surface area available for heat exchange, the environment, warming time, and infusion rate. The method described herein could also be used to heat intravenous fluid bags before dispatch. Using a benchtop operating room simulation, it was found that the actual temperature of intravenous fluid infused through a 38°C to 39°C in-line warmer achieved a maximal temperature of 35°C and lower temperatures at infusion rates greater than 30 mL/minute.[9] The environmental temperature also impacts how quickly warmed intravenous fluid cools before administration. Fluid warmed to 37°C lost 3°C in 5 minutes and 5°C in 15 minutes when left at room temperature.[10] The duration of intravenous fluid exposure to cold environments before administration may be impacted by patient location, the EMS response travel distance, and geography. Finally, the surface area of the heat source, the intravenous fluid container, and the environment could impact the usefulness of any improvised method. An advantage of the heating method employed in the current study is its use of equipment available in all ground-based EMS vehicles.

In summary, convective warming of intravenous fluid using vehicle dashboard defroster vents significantly raised the fluid temperature and should be readily available to EMS or first responders. We conclude that dashboard defroster vent heating of fluid in winter may be an option for improvised heating of intravenous fluid in the prehospital environment.

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AUTHOR CONTRIBUTIONS

John W. Lyng conceived and designed the study and acquired the primary data. John W. Lyng and Michaela A. West analyzed the data. John W. Lyng and Michael C. Perlmutter drafted the manuscript, and all authors participated in the interpretation of the data and editing the manuscript. John W. Lyng takes responsibility for the paper as a whole.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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