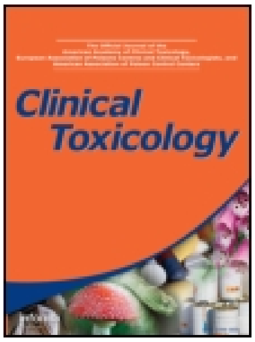

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BRIEF COMMUNICATION

Ice water submersion for rapid cooling in severe drug-induced hyperthermia

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Context. The optimal method of cooling hyperthermic patients is controversial. Although controlled data support ice water submersion, many authorities recommend a mist and fan technique. We report two patients with drug-induced hyperthermia, to demonstrate the rapid cooling rates of ice water submersion. *Case details.* Case 1. A 27-year-old man presented with a sympathomimetic toxic syndrome and a core temperature of 41.4°C after ingesting 4-fluoroamphetamine. He was submerged in ice water and his core temperature fell to 38°C within 18 minutes (a mean cooling rate of 0.18°C/min). His vital signs stabilized, his mental status improved and he left on hospital day 2. Case 2. A 32-year-old man with a sympathomimetic toxic syndrome after cocaine use was transported in a body bag and arrived with a core temperature of 44.4°C. He was intubated, sedated with IV benzodiazepines, and submerged in ice water. After 20 mins his temperature fell to 38.8°C (a cooling rate of 0.28°C/min). He was extubated the following day, and discharged on day 10. *Discussion*. In these two cases, cooling rates exceeded those reported for mist and fan technique. Since the priority in hyperthermia is rapid cooling, clinical data need to be collected to reaffirm the optimal approach.

Keywords Hyperthermia; Heat stroke; Cooling; Sympathomimetic toxic syndrome; Amphetamine

Context

Heat stroke is a form of thermoregulatory dysfunction that can result from overexposure to environmental heat (classic heat stroke) or strenuous physical exercise (exertional heat stroke), and is defined as a core temperature greater than 40°C (104°F) with altered mental status.[1] The term drug-induced hyperthermia indicates a toxicological etiology. Serotonin toxicity, neuroleptic malignant syndrome, malignant hyperthermia, and the sympathomimetic and anticholinergic toxic syndromes can all produce drug-induced hyperthermia, with mechanisms varying from oxidative phosphorylation uncoupling, increased basal metabolic rate, and/or increased psychomotor activity. While adjunctive agents such as benzodiazepines and paralytic agents may be used empirically to treat undifferentiated patients with drug-induced hyperthermia, targeted antidotes such as cyproheptadine, bromocriptine, and dantrolene are recommended only once the etiology is known. Regardless of etiology, the initial management must prioritize rapid cooling. If the elevated core temperature is not identified and rapidly lowered, multi-organ system failure, disseminated intravascular coagulation (DIC), and death will ensue.

Traditional methods of conduction cooling include ice water submersion, ice packs, cooling blankets and cold intravenous, gastric lavage and bladder irrigation fluids. Standard modes of convection (evaporative) cooling include cold-water sprays or mists plus fans. With the advancement of targeted temperature management for post-cardiac arrest patients, a number of new devices have been designed for use in initially normothermic patients to achieve and maintain cooling with a greater degree of control or ease. However, their utility in hyperthermia is not studied. Meanwhile, case reports suggest a failure of these devices to achieve adequate cooling rates in heat stroke and drug-induced hyperthermia.[2,3]

While the efficacy of ice water immersion for rapid cooling is well documented in the experimental literature, direct comparison with evaporative methods and a clear choice of techniques is lacking. A systematic review of cooling methods in heatstroke patients found that evaporative cooling methods appeared to be less efficient than ice water in dissipating heat, although direct comparison studies were absent and cooling rates for indirect comparison were not provided.[4] Here we report two cases of patients with drug-induced hyperthermia to demonstrate the cooling rates achievable with ice water submersion. These cooling rates are compared to those in the experimental literature.

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This Brief Communication is linked to the Commentary - DOI (10.3109/15563650.2015.1009995) Cooling it after drug induced hyperthermia in this issue.

Case 1

A 27-year-old man with polysubstance dependence presented to the ED after he was found agitated and lying on the street. Initial vital signs were: heart rate (HR), 156 beats/minute (bpm); rectal temperature (T), 41.4°C (106.5°F); oxygen saturation (O_2 sat), 90%; finger-stick glucose (FS), < 46 milligrams/deciliter (mg/dL); blood pressure (BP) and respiratory rate (RR) were unable to be obtained. On examination, he was agitated with non-sensible speech, diaphoresis, dilated pupils, and hyperreflexia without clonus. He was immediately given dextrose (50 g IV) and midazolam (2 mg IV), transferred to a water-impermeable bed, and submerged in ice water. Core temperature was recorded via a rectal probe immediately prior to ice bath submersion, at 41.4°C (106.5°F), and every 30–60 seconds (s) until a target temperature was achieved (Fig. 1). The patient was actively cooled for 22 min, during which his temperature dropped 4°C, to 37.4°C (99.3°F), yielding a mean cooling rate of 0.18°C/min. During treatment he received multiple IV boluses of midazolam totaling 28 mg. Shivering was absent during active cooling. Once transferred to a warm dry bed, his mental status and hemodynamics improved. Initial laboratory values were notable for: white blood cell (WBC) count $18.8 \times 10^3/mm^3$, serum bicarbonate 19 millimoles/liter (mmol/L), anion gap 19 mmol/L, venous blood gas pH 7.34, lactate 8.1 mmol/L and TSH 6.989 international units/ milliliter (IU/mL) with free T4 1.20 mg/dL (normal 0.9–1.9). Liver and kidney function tests, creatine kinase and troponin were normal. Urine toxicology, analyzed by EMIT, was positive for amphetamines and phencyclidine (PCP) and negative for barbiturates, benzodiazepines, cocaine, methadone, opiates and tetrahydrocannabinol (THC). A head CT was unremarkable.

The patient was admitted to an intensive care unit where he had minor elevations of aspartate aminotransferase (AST) (62 U/L), prothrombin (13.3 s; INR 1.26), and creatine kinase (2306 U/L). On hospital day (HD) 1, he admitted to ingestion of 200 mg of 4-fluoroamphetamine powder, approximately four hours prior to ED presentation. Serum and urine specimens, analyzed by triple quadrapole mass spectrometry, confirmed 4-fluoroamphetamine. On HD 2, he left the hospital against medical advice.

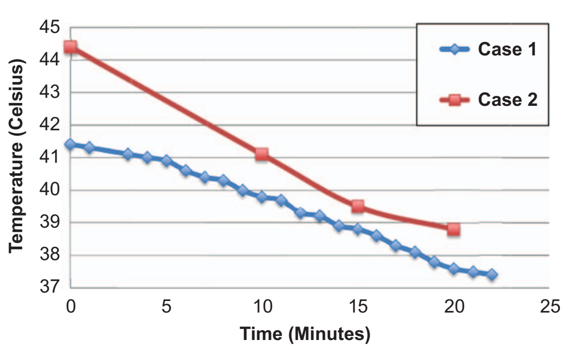

Fig. 1. Temperature trends of case 1 and case 2 during period of ice water immersion (colour version of this figure can be found in the online version at www.informahealthcare.com/ctx).

Case 2

A 32-year-old man was brought to the hospital after being found agitated and hallucinating on the street. During transport, he was place in a body bag because of uncontrollable behavior. On arrival to the ED, he was hot to the touch, agitated, disoriented, and diaphoretic with 6 mm pupils. Triage vital signs were: BP, 216/142 mm Hg, HR, 176 bpm; RR, 38/min; and FS, 183 mg/dL. He was given IV diazepam 10 mg, twice, with minimal behavioral response. Rapid sequence intubation was performed with succinylcholine (120 mg) and an additional 20 mg of diazepam was given as he was placed in an ice water bath (as described above), with a recorded rectal temperature of 44.4°C (112°F). After 20 mins of immersion, his temperature had fallen to 38.8°C (102°F), at a cooling rate of 0.28°C/min (Fig. 1). Because of paralysis no shivering was observed. He was removed from the ice water bath, dried and placed on a clean stretcher. Laboratory studies were remarkable for: WBC count 22,000/mm^3, serum bicarbonate 10 mEq/L, anion gap 22 mEq/L, and creatinine 2.2 mg/dL. His peak AST was 3800 U/L with a creatine kinase 32,856 U/L. Urine toxicology, analyzed by EMIT, was positive for cocaine metabolites alone. The patient was extubated the next day and admitted to cocaine use. Over the next 3 hospital days his CPK, creatinine and liver function tests returned to normal, but his hospital course was complicated by recurrent temperature elevation (101.2°F, 38.4°C) on HD 1 and one blood culture that was positive for E. coli, which may have been introduced by a femoral venous line. After 10 days of antibiotics (originally vancomycin and gentamicin, which were changed to cefoxitin after sensitivities returned) he was discharged in stable condition.

Discussion

For years, conduction cooling via ice water submersion was the preferred method in the management of hyperthermia. In 1980, Weiner and Khogali challenged this concept, suggesting that conduction cooling produces extensive cutaneous vasoconstriction and promotes shivering, limiting heat dissipation.[5] Additionally, ice water was perceived as extremely uncomfortable. They evaluated a novel evaporative cooling device that sprayed water over the body while circulating warm air above, maintaining peripheral vasodilation in a controlled hyperthermia model with healthy volunteers. Mean cooling rates of 0.3°C/min were produced, compared with 0.19°C/min with cold water (15°C) immersion. Unfortunately, when tested on 18 actual heat stroke patients, mean cooling rates were only 0.046°C/min.[6]

In 1987, Poulton and Walker published a case series of convection cooling in three exertional heat stroke patients. Utilizing downdraft from a helicopter and warm ambient temperatures on the hospital roof, they achieved mean cooling rates of 0.104°C/min.[7] Although their methods placed limits on the external validity of their data, their findings have provided support to proponents of evaporative cooling.

In 1995, Armstrong et al., performed a controlled comparison of ice water immersion to air exposure with wet towels while cooling 21 long distance runners with exertional heat stroke. Mean cooling rates achieved for ice water immersion were 0.2°C/min, compared to 0.11°C/min for air exposure with wet towels.[8] In 2011, Proulx et al, studied the effect of water temperature on cooling rates in healthy volunteers with induced hyperthermia. Mean cooling rates in subjects cooled in an 8°C circulating water bath were 0.19°C/min, while those cooled in 2°C water were 0.35°C/min.[9] Interestingly, they noted an absence of shivering in 2°C water.

With the advent of targeted temperature management, new devices offer promise for heat stroke and hyperthermia patients. Unfortunately, at least two case reports suggest that these devices are wholly inadequate. A 52-year-old man with classic heat stroke and a temperature of 43°C cooled at a rate of 0.7°C/hour with the Coolguard® endovascular cooling system.[2] Similarly, a 40-year-old man with drug-induced hyperthermia and a temperature of 42°C took 1 h to cool 2.1°C with the Coolguard® system.[3]

Although ice water submersion has established benefit for rapid cooling of heat stroke and drug-induced hyperthermia patients, widespread implementation has been limited by those who favor a mist and fan technique. While perceptions of superior efficacy may be influenced by a review of the literature, concerns of ease of use may be alleviated by an understanding of the equipment, supplies, personnel and logistics required to quickly mobilize an ice water bath in a hospital setting.

The steps to performing ice water submersion are straightforward. Once hyperthermia is documented, the patient should be immediately undressed, wrapped in a sheet, and placed in a water-impermeable bed (when available) (Fig. 2), while indirect patient care staff fill large plastic bags with ice to cover and surround the patient. Important nursing and patient care technician roles include establishment of IV access, administration of medication, and placement of cardiac leads, pulse oximetry and a rectal probe for continual core temperature monitoring. Benzodiazepines may be indicated to treat psychomotor agitation. Rapid sequence intubation and advanced cardiac life support measures, if indicated, can and should be performed with the patient in the ice bath. While a lack of evidence exists to guide a specific endpoint temperature, we recommend an endpoint core temperature of 39°C (102.2°F), at which point the patient should be moved to a new hospital bed and dried completely, to avoid an overshoot towards hypothermia. Coordination of this effort requires leadership, teamwork and constant communication, as in a code scenario. Finally, care should be taken to keep the floor as dry as possible for the safety of all health care providers involved.

Fig. 2. Water-impermeable bed used for ice water immersion (colour version of this figure can be found in the online version at www.informahealthcare.com/ctx).

Limitations

This paper has a few important limitations to address. While the documented cooling rates in our patients exceed what have been published for mist and fan technique, our sample size is limited to two. The appropriate administration of adjunctive therapies, such as benzodiazepines and/or paralytic agents, likely contributed to temperature reduction by limiting psychomotor agitation, an important source of heat production in drug-induced hyperthermia. While co-administration of these agents with ice water immersion impacts cooling, our interventions reflect real world management, and are perhaps more relevant than experimental cooling rates obtained in the absence of such adjuncts, as similar therapies would be given to patients cooled with mist and fan. Finally, some concern has been voiced regarding patient tolerance to ice water immersion, especially the elderly, listing shivering, agitation and combativeness as potential complications.[4] Our patients, both young and otherwise healthy, presented agitated and combative requiring sedation (plus intubation in case 2), prior to active cooling. Because of the presence of psychomotor agitation in most cases of drug-induced hyperthermia, sedation would be expected to be a routine part of management, thereby alleviating some concerns of patient tolerance.

Conclusion

Patients with both heat stroke and drug-induced hyperthermia require rapid cooling for an optimal outcome. These case reports describe conductive cooling rates in excess of those reported with evaporative techniques. While we would not endorse a randomized trial of cooling techniques, we encourage systematic collection and reporting of others' experiences.

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Declarations of interest

The authors report no declarations of interest. The authors alone are responsible for the content and writing of the paper.

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