

## Frostbite injuries from recreational nitrous oxide use

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### Abstract

#### *Introduction*

Recreational use of inhaled nitrous oxide is rapidly increasing. As liquid nitrous oxide (N<sub>2</sub>O) is cooled to its gaseous form for inhalation, container mishandling can cause frostbite injuries to the face and extremities.

#### *Cases*

(1) 19-year-old male with 2% total body surface area (TBSA) frostbite burn to bilateral inner thighs; (2) 18-year-old female with 1.5% TBSA burn to palm and fingers; (3) 14-year-old female with 4% TBSA burn to bilateral inner thighs; (4) 23-year-old female with 0.5% TBSA burn to fingers; (5) 22-year-old female with 0.2% TBSA frostbite burn to fingers; (6) 21-year-old female with 1.5% TBSA burn to volar forearm; (7) 17-year-old female with 0.5% burn to lips and chin.

#### *Outcome*

Two patients required debridement and skin grafting, which resulted in significant scarring and contour deformity. One patient presented with toxic shock syndrome and required management in the paediatric intensive care unit. All patients required specialised dressings and occupational therapy for scar management and/or hand rehabilitation.

#### *Discussion*

We have observed a cluster of frostbite burns sustained from recreational use of N<sub>2</sub>O. Healthcare workers should be aware of the practice and be able to recognise and manage the associated injuries.

## Introduction

The recreational use of inhaled nitrous oxide (N<sub>2</sub>O), colloquially known as 'laughing gas' or 'hippy crack', is rapidly increasing. A 2022 study of 1,193 attendees at music festivals in Ireland found that 28% had used N<sub>2</sub>O in the last year<sup>1</sup>.

The popularity of N<sub>2</sub>O as a recreational drug can be attributed to the fact that it is cheap, readily available and undetectable on routine drug screening. The proposed mechanism of action is inhibition of *N*-methyl-d-aspartate (NDMA) receptors via glutamatergic neurotransmission, resulting in a pleasant, euphoric dissociation<sup>2</sup>. Documented side effects of sustained use include vitamin B12 deficiency and subacute combined spinal cord degeneration (SCD), manifesting as progressive neurological dysfunction<sup>3</sup>.

In addition to neurological sequelae, an increasingly-encountered presentation is frostbite injury secondary to inhalation of compressed N<sub>2</sub>O from metal gas cannisters. Frostbite injury can occur due to direct spraying or spilling of the liquified gas on to the skin, with temperature on contact of approximately -55 to -88 degrees Celsius (the boiling point of the compound)<sup>2</sup>. Alternatively, as N<sub>2</sub>O is discharged from the highly-pressurised container (for direct inhalation or to fill a balloon) the metal cannister briefly decreases its temperature to approximately -40°C due to the physical property of adiabatic cooling<sup>4,5</sup>. If the container is mishandled, this may result in significant contact frostbite injury.

Over the six-month period from September 2022 to March 2023, seven frostbite injuries as a result of recreational N<sub>2</sub>O use were managed by the national adult and paediatric burns services. The aim of the current study was to describe this case series and to highlight the risk of frostbite injuries associated with this popular recreational practice.

### Case 1

A 19-year-old male presented 3 days after injury with 2% total body surface area (TBSA) full thickness contact burns to his bilateral inner thighs sustained while filling balloons from a frozen N<sub>2</sub>O cylinder. At presentation the wounds were infected, necessitating inpatient admission, intravenous antibiotics and ultimately debridement down to subcutaneous fat and resurfacing with split thickness skin graft. Wounds healed without complication but with significant scarring and contour deformity of the thighs.

### Case 2

An 18-year-old female presented immediately after sustaining a frozen N<sub>2</sub>O spray injury to the fingers and palms of both hands, which resulted in 1.5% TBSA partial thickness burns. Of note, in spite of giving an accurate history, on initial presentation, the injury was correctly identified

as a burn but was incorrectly treated with 20 minutes of water cooling. The patient required 4-day admission for analgesia, deroofting of blisters and hand elevation. Wounds healed without complication in 4 weeks but ongoing hand stiffness necessitated an intensive course of hand therapy.

### **Case 3**

A 14-year-old female presented 2 days after sustaining contact burns to bilateral inner thighs (4% TBSA) from direct contact with a frozen nitrous oxide cylinder (Figure 1). An accurate history was not forthcoming and she was haemodynamically unstable with no other obvious source of sepsis. A diagnosis of toxic shock syndrome as result of infected burn wounds was made and she was admitted to the paediatric intensive care unit (PICU). She was resuscitated and treated with intravenous antibiotics and immunoglobulin. The wounds, which evolved to be full-thickness, required debridement down to subcutaneous fat and split thickness skin grafting. The areas were fully healed by day 21, with follow-up at six months demonstrating significant scarring and contour deformity of the inner thighs.

### **Case 4**

A 23-year-old female presented immediately following a contact burn injury to her fingertips, sustained while filling balloons from a small, frozen N<sub>2</sub>O cannister. The injury amounted to 0.5% TBSA partial thickness burns, which were deroofted and treated as an outpatient. Wounds healed with silver dressings in two weeks but she went on to develop hypersensitivity in the fingertips, which was treated with a combination of neuropathic pain agents and hand therapy.

### **Case 5**

A 22-year-old female presented immediately following contact burns to the fingertips (0.2% TBSA), sustained from a nitrous 'cracker' device, which had frozen as a result of a leak of N<sub>2</sub>O gas. Blisters were deroofted in the clinic and wounds healed with silver dressings in 10 days.

### **Case 6**

A 21-year-old female presented 4 days following a contact burn to the volar forearm (1.5% TBSA), sustained from holding a large N<sub>2</sub>O cannister in the crook of her arm while filling balloons. At presentation the burn was cellulitic and oral antibiotics were commenced. The wounds were managed conservatively and healed within 4 weeks. The resultant scar was hypopigmented at 6 month follow-up.

### **Case 7**

A 17-year-old female presented immediately following a frozen N<sub>2</sub>O spray injury to the chin and lower lip (0.5% TBSA), sustained from direct inhalation of N<sub>2</sub>O gas from a cannister. The

areas of epidermal loss were treated conservatively with silver dressings to the chin and paraffin to the lower lip. Both areas had re-epithelialised within 10 days.

## Results

A cluster of seven cases of frostbite injuries from recreational use of N<sub>2</sub>O has been observed. Injuries tended to be of small TBSA but involved critical structures such as the hands or face. Presentation for medical care was often delayed with one patient requiring ICU-level care for toxic shock syndrome. Mechanism of injury was most commonly associated with filling of balloons from N<sub>2</sub>O cannisters and subsequent freezing of the cannister exterior. Larger commercial 2L cannisters (Figure 2) tended to cause bilateral thigh and forearm burns, whereas single-use 'bulb' cannisters were associated with smaller finger burns. Burden of care was significant, with 2 out of 7 patients requiring debridement and grafting and others attending for prolonged periods of dressings and/or rehabilitation. None of the patients exhibited any symptoms or signs of N<sub>2</sub>O toxicity on presentation or any other signs of chronic abuse or associated syndromes such as B12 deficiency or SCD.

**Figure 1.** Burns to bilateral inner thighs as result of frostbite injury from contact with a nitrous oxide cannister while filling balloons for inhalation. Images taken at day 4 post injury, demonstrating blistering at margins and deep dermal injury centrally. As is typical in a frostbite injury, the wound progressed over the coming days, ultimately involving the full-thickness of the skin and necessitating debridement to the level of subcutaneous fat and reconstruction with split-thickness skin grafting.



**Figure 2.** Disposed nitrous oxide cannisters, typical of those used for recreational inhalation and responsible for pathognomonic frostbite burns to bilateral inner thighs.



## Discussion

An increase in the presentation of frostbite injuries as a result of recreational use of N<sub>2</sub>O has been observed in many countries and the issue has been highlighted as an emerging public health concern<sup>3,8</sup>. Recreational users tend to obtain N<sub>2</sub>O in small silver canisters known as 'whippets' or 'silver bullets', which are attached to a palm-sized 'nitrous cracker' to fill a balloon, from which the gas is inhaled. N<sub>2</sub>O can also be obtained from larger-capacity cannisters, by inhalation of the gas via plastic bags or facemasks connected directly to screw-on nozzles<sup>9</sup>. With temperatures in the region of -55°C, significant frostbite injuries can occur if skin comes in contact with either the pressurised cannisters or liquid N<sub>2</sub>O<sup>4</sup>. As it releases endogenous opioids, N<sub>2</sub>O has a documented analgesic effect. It also has anaesthetic effects, through non-competitive NMDA inhibition in the central nervous system, and anxiolytic effects through GABA-A activation<sup>2</sup>. The resultant state of unawareness, in addition to the fact that it is often used in conjunction with other recreational drugs or alcohol, may render the user vulnerable to more significant frostbite injury<sup>7</sup>.

In the current series, injuries to the fingers, hands and lips tended to be more superficial than those to thighs and forearm. This observation is similar to that of a comparable UK series and may be due to the increased sensitivity of hands and lips to injury and temperature change<sup>4</sup>. Though not seen in our series, intra-oral injuries have also been described<sup>10,11</sup>, with associated upper airway obstruction recorded in at least one case<sup>12</sup>.

Both injuries to the inner thighs were sustained from prolonged positioning of a large cannister of N<sub>2</sub>O between the thighs while filling balloons with the gas. The resulting injuries involved full-thickness necrosis of skin and underlying fat, which necessitated deep debridement and reconstruction with split-thickness skin grafting. This pattern of injury can be considered pathognomonic of an inhaled N<sub>2</sub>O-associated frostbite injury, with multiple such cases described in recent years<sup>4, 13-17</sup>. The deforming nature of the resultant concave scars in young patients has been emphasized, as well as the potential for psychological consequences as a result<sup>4</sup>.

Three of the 7 cases described here presented late, an observation which is also consistent with previous studies<sup>4,13,15-17</sup>. Reasons for delay in the current series included lack of recognition of the severity of the injury, embarrassment and fear of punishment by parents. In their UK study, Chen et al. observed delayed presentation in 50% of cases, attributing this to the characteristic slow progression of the injury over several days from initial erythema only to superficial blistering and tissue necrosis<sup>4</sup>. Particularly in cases where a detailed history may not be forthcoming, emergency department clinicians and general practitioners may require a high index of suspicion for referral to plastic surgery early in the evolution of the injury.

Lack of public awareness of frostbite injury, particularly in association with N<sub>2</sub>O inhalation can contribute to both delayed presentation and inappropriate first aid. It is interesting to note that one of the cases in the current series was initially managed with cooling, which is the standard of care for warm thermal burns. For frostbite injuries, rewarming of the area in a water bath at 37-39°C with active movement of affected digits is recommended<sup>4-7,18</sup>.

N<sub>2</sub>O use in Ireland is not currently captured in the National Drugs and Drug Use Survey, an observation which has been echoed by international researchers<sup>20</sup>. The majority of data appears to be sourced from internet surveys and may not reflect the extent of its use<sup>8,20</sup>. Current legislation in Ireland under the Misuse of Drugs Act 1977 allows the sale of cannisters of N<sub>2</sub>O for industrial purposes, however the Psychoactive Substances Act 2010 prohibits its sale or importation for its psychoactive properties<sup>21</sup>. How exactly this can be policed and enforced is a more difficult question, when cannisters are reportedly easily accessible online or through 'nitrous dealers' according to one government report<sup>21</sup>. Ireland is not alone in this and researchers in Australia, the Netherlands and the UK have made similar observations<sup>13,14,22</sup>.

In a comprehensive mixed methods review published in 2022, Allan et al. described key areas requiring further consideration with regard to recreational N<sub>2</sub>O use<sup>3</sup>. At a national policy level, the authors recommended that the same approach be taken as with other drugs: reduce supply and treat N<sub>2</sub>O problems as a health issue rather than a criminal one<sup>3,23</sup>. To improve the health service response, it was highlighted that clinicians, community and treatment agencies needed greater awareness of the prevalence and harms of N<sub>2</sub>O use. The inclusion of N<sub>2</sub>O in routine drug assessment tools and processes was also recommended. For recreational users, the authors concluded that more information about risks and harms available in accessible places such as music festivals and entertainment venues would be more effective than information at point of treatment such as medical centres or drug and alcohol services. Finally, it was noted that while there has been a spike in research relating to N<sub>2</sub>O since 2019, there is a dearth of intervention studies examining psychosocial methods of reducing N<sub>2</sub>O use.

We have observed a cluster of frostbite burns sustained from recreational use of N<sub>2</sub>O. Healthcare workers should be aware of this activity and be able to recognise and manage the associated injuries. Of particular note is the pathognomonic bilateral inner thigh burn, which should raise suspicion for frostbite, even if a history of N<sub>2</sub>O use is not forthcoming. Public health messaging delivered at point of use, which informs potential users about the risks associated with inhalation of N<sub>2</sub>O is warranted.



### Declarations of Conflicts of Interest:

None declared.

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