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REVIEW ARTICLE

Cryogenic Dangers: Prevention and Treatment of Liquid Nitrogen Burns

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ABSTRACT

There exists a wide variety of corrosive chemicals having either acidic or alkaline nature which have the potential to cause chemical burns. Besides them, oxidative agents, solvents, vesicants, desiccants, toxic gases etc. , are also implicated in causing chemical burns. Exposure can occur both in workplaces as well as personal environments. Most of the paediatric cases are secondary to accidental ingestion or spillage of household products like phenol, bleaches, dyes etc. Domestic cases can be due to improper labelling, storage and handling of household chemicals like toilet cleaners, sink openers, nail polish removers etc. Intentional assaults, suicides, and chemical warfare are some of the darker aspects of chemical misuse. Chemical burns are nearly 1.4 to 8.5% of all types of burn injuries. Through this article, we would like to shed light on one of the most commonly used chemical liquid nitrogen, which is widely used in agriculture, aerospace, food industry, healthcare, automobiles etc. But contrary to its immense usage, the available literature fall short of data regarding safety pitfalls and potential hazards it poses to people dealing with it. Though liquid nitrogen induces 'frostbite' like changes in tissues, its management is different from it. The adverse effects of this obnoxious chemical has a wide spectrum ranging from ulcerations in limbs, perioral skin and gastrointestinal tract to peritonitis, asphyxiation, barotrauma, permanent eye damage etc.

Conclusion: Liquid nitrogen can be said to act as a double-edged sword. Despite it having usage in innumerable work sectors, one cannot overlook the health risk it poses to its users. Considering it as an emerging occupational hazard, it needs to be addressed in terms of establishing and implementing safety protocols, guidelines for management in cases of mishaps and the creation of public awareness by the governing bodies.

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INTRODUCTION

Nitrogen makes up major portion of the atmosphere (78% by volume, 75.5% by weight). It is a non-flammable gas and doesn't support life. The process of manufacture of liquid nitrogen is a staged process, where initial liquefaction of atmospheric air is done at air separation plants to produce nitrogen. Through continuous cryogenic distillation, liquid nitrogen is produced.

Liquid Nitrogen (N_2) is an inert, colourless, low viscous, non-corrosive, non-combustible, odourless, and extremely cold liquid obtained by fractional distillation of liquid air. Liquid N_2 comes under the category of cryogenic liquids. Cryogenic liquids are actually liquefied gases having normal boiling point below –130°F (–90°C). Liquid N_2 has a boiling point of –196°C (–320°F) and remains in liquid form at very low temperatures.[1] Being non-corrosive, the requirement of special materials for construction is not required. However, the vessels and pipes used for storage and transport should be sturdy enough to withstand low temperature of liquid N_2. Because of its

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cooling properties, it found its widespread usage in industries such as agriculture, automobiles, aerospace and the healthcare sector (cryotherapy, cryosurgery).[1] Also nowadays, it is used in instant cooling of cocktails, ice creams and Dragon breath cookies to create a "cloud" or "smoke" effect and is referred to as molecular gastronomy.[2]

Most injuries caused by liquid nitrogen are accidental in nature and occur mainly at workplace because of carelessness or unsafe handling. It is generally advisable to store liquid nitrogen in containers containing loose-fitting lids and never in tight sealed containers because of dangers of explosion due to build up of pressure. There are special Dewar storage tanks that are non-sealed and allow the passage of expanding gases, hence avoiding risks of explosion due to increased pressure. It is the gaseous state of Nitrogen that is commonly used, but storage and transportation in liquid form becomes cost-effective. On direct exposure, it causes irreversible ischaemic damage to small vessels leading to tissue destruction with intracellular ice formation. Though rare, death can occur because of widespread tissue damage or burns.

We have described a case of liquid nitrogen burn in the digits of upper limb which was managed conservatively. Further, an overview of the mechanism of injury by liquid N_2, possible preventive measures and treatment methodology will be discussed.

CASE REPORT

A 23-year-old female presented to casualty with complaints of burns due to spillage of liquid Nitrogen on her right hand. On taking history, it was revealed that she was a student working as a research scholar at a Drug & Research institute. Her research work was related to finding out the effect of changing climate on growth and productivity of crops for which she was crushing herbal plant leaves in a pestle and mortar. While adding Liquid Nitrogen to the paste, it accidentally spilled on her right hand, immediately after which she felt cooling effect on fingertips for a while followed by burning and stinging sensation. On clinical evaluation, there were blisters on dorsal and volar aspects of distal phalanx of right hand (Figure 1). Also, the patient revealed that she didn't wear protective gloves in the laboratory when the unfortunate event happened.

Figure 1: Photo showing blistering of digits post liquid nitrogen spillage

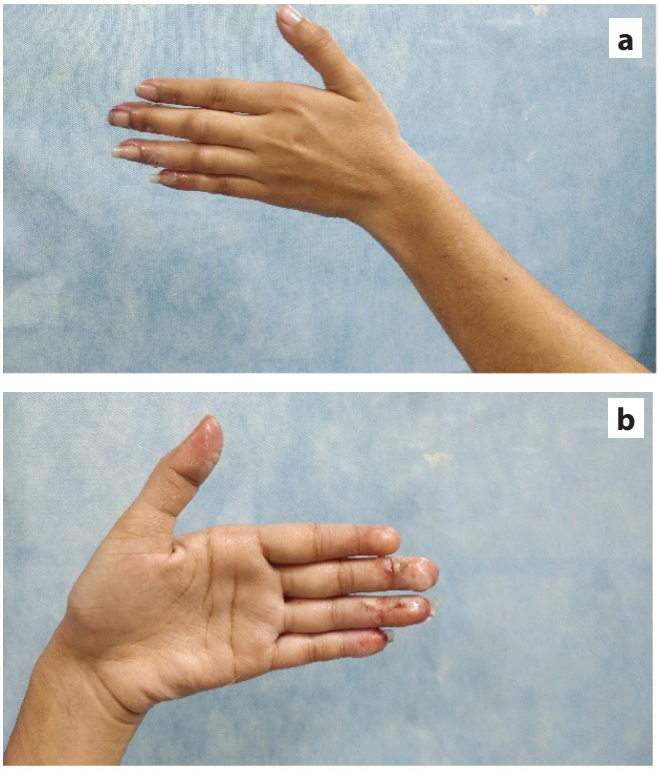

Figure 2: Post deroofing of blisters **(a)** dorsal side **(b)** volar side

Under due sterile technique, the blisters were de-roofed/aspirated with 24-gauge needle (Figures 2a, and b) and hand-dressed with Neosporin ointment and paraffin gauze (Figure 3a, and b). Oral antibiotics and analgesics were prescribed besides limb elevation to decrease edema. The patient was kept on regular follow-up with dressings every alternate day. The burn wound healed with minimal scarring after 2 weeks. After a follow-up period of

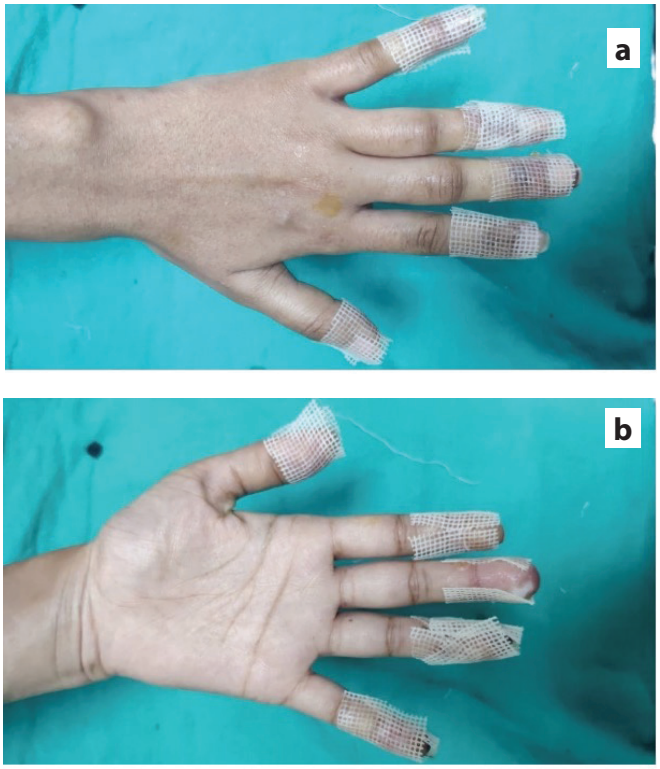

Figure 3 (a, and b): Dressing with paraffin gauze

3 months, the patient had no pain or any discomfort. She had full sensory perception in the involved digits besides having a full range of motion (Figures 4a, b, and c)

DISCUSSION

The definition of a mutilated hand as per Reid was the one that "has suffered a severe injury involving loss of substance and is left lacking in prehension."[3] Hand burns caused by chemicals form a distinct subgroup of burn injuries. As previously stated, this can happen in households, at industrial workplace, wars etc. Mainly in occupational hazards, it is the hand that bears the brunt and unfortunately cripples the sole earner of the family. In context to chemical burns, depending on type of chemicals, duration of exposure and time of intervention, the presentation can fall in any of the spectrum like erythema, tissue destruction, deformity, disfigurement and limb loss to loss of life.

Despite widespread usage, there is a very meagre amount of information in available literature concerning liquid nitrogen injuries and emergency treatments. However with an increased surge of liquid nitrogen demand in the present scenario

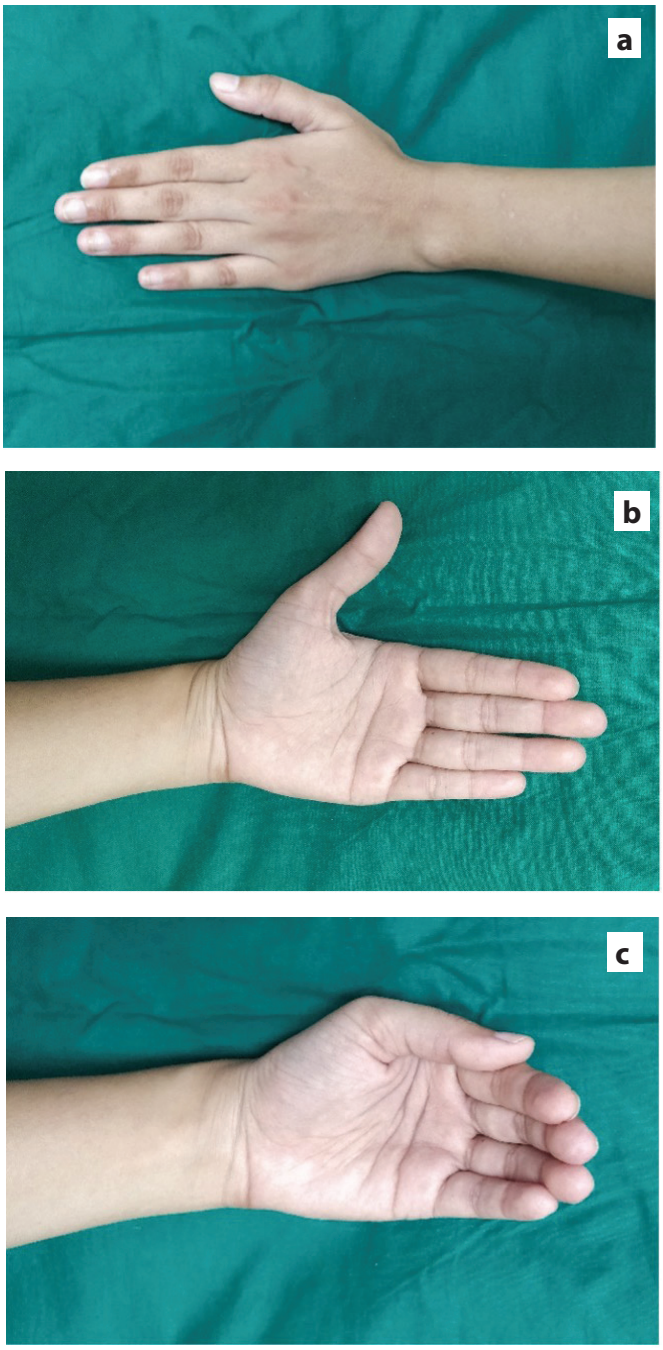

Figure 4 (a, b, and c): Follow up photographs after 3 months

in several industrial sectors, the risk of injuries associated cannot be overlooked.

As previously mentioned, liquid nitrogen is a cryogenic liquid, i.e., it comes in the category of liquefied gases that have a normal boiling point below –130°F (–90°C). Hence it is widely used for the freezing and transportation of food products. The coolant property of liquid nitrogen is utilized in vacuum pumps, superconductors, air conditioner compressors etc. The cryopreservative nature of

liquid nitrogen is used nowadays to store sperm, genetic samples, eggs[4] etc. Since the gas is colourless, odourless, tasteless, and non-irritant, it cannot be detected by human senses. Liquid nitrogen is stored in specialized cryogenic containers referred to as dewars. They are equipped with safety valves and are insulated and vacuum jacketed. [5]

When liquid nitrogen droplets come in contact with skin, the air encapsulates those droplets thus preventing any skin lesions. This phenomenon is termed as Leydenfrost phenomenon. It is named after Johann Gottlob Leydenfrost who first described it and published his study in 1756.[6] The problem arises when liquid nitrogen gets spilled onto bare skin or the gloves or protective gears like gloves, goggles etc. get wet with it.[6] The sequence of events that ensues causes instant numbness and freezing of tissues which causes intracellular ice formation, lipoprotein denaturation, shock, vascular stasis and disruption of cell membranes. The cell destruction is largely mediated by inflammatory mediators like bradykinins, thromboxane A2, prostaglandins, histamines etc. Upon melting back of intracellular crystals, water returns to the cells leading to tissue edema.[7] Clinically the skin changes manifest as skin necrosis and ulceration which becomes evident by the second day of exposure. Due to its ability to cause cell destruction, liquid nitrogen finds its applicability in treating warts, skin malignancies,[8] leucoplakia, keratosis etc.

Accidental or suicidal ingestion of liquid nitrogen cause oral frostbites, severe abdominal pain, gastric tract ulceration, peritonitis and perforation.[9] Liquid nitrogen on inhalation can cause asphyxia by displacing oxygen in the air to levels insufficient for survival. Delicate tissue of eyes if exposed to liquid N2 can result in damage and blindness

Liquid nitrogen burn emergency treatment information finds a scanty place in available literature.[10] Removal of the patient from the source, immediate rewarming in water bath (temperature 40 to 42°C), antibiotics and analgesics along with splinting of affected limbs should be done. The frozen tissue is usually waxy in consistency and has a yellowish tinge. If accidentally thawed, it will become extremely swollen and painful. In such cases, it is advisable to cover the affected area with sterile bulky dressing while waiting for medical attention. In case of liquid nitrogen ingestion or/and inhalation patient is immediately rushed to the emergency before its effects become catastrophic. The rewarming method as an immediate measure in cases of skin exposure to liquid nitrogen is controversial. Corn *et al.* in their study didn't find any advantage of rapid rewarming.[11] Nevertheless, it still can be used to provide symptomatic relief. In a single case study of accidental liquid N_2 burn of hand by Erin Orozco *et al.*, NAC (N-acetyl cysteine) was used as a 20% infusion (200 mg/mL for 16 hours) in 5% dextrose solution along with dressing changes.[12] The antioxidant property of NAC along with its ability to stimulate adipose-derived stem cells and inhibit IL8 production was thought to enhance wound healing.

Standard protocols for wound care like timely debridement, cover, or amputation in case of non-salvageability of digits/extremities should be done. Surgical management guidelines should be followed for peritonitis, perforation, gastric ulceration, etc.

CONCLUSION

Thoughts of Benjamin Franklin "*an ounce of prevention is worth a pound of cure*" can be used in our case scenario too. Protective gear like goggles, specially designed gloves and socks need to be donned at all times during tasks requiring the usage of liquid nitrogen. Besides having an immediate response medical team, every sector whether research, agriculture, factories, etc. should have strict protocols about liquid nitrogen storage and usage and also monitoring of personnel handling liquid nitrogen.

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