CASE REPORT

Phosphorus Burn Management with Multimodal Analgesia

Luc Saint-Jean, MD[1]*; Simon-Pierre Corcostegui, MD[2]; Julien Galant, MD[3]; Clément Derkenne,MD[4]

ABSTRACT

We report the case of a patient suffering from a chemical burn caused by white phosphorus, for whom initial management required decontamination using multimodal analgesia. This case report should be familiar to other military emergency physicians and Tactical Emergency Medical Support for two reasons: 1) A phosphorus burn occurs from a chemical agent rarely encountered, with minimal research available in the medical literature, despite the use of this weapon in the recent Ukrainian conflict, and 2) We discuss the use of multimodal analgesia, combining loco-regional anesthesia (LRA) and an intranasal pathway, which can be used in a remote and austere environment.

Keywords: *phosphorus burn; analgesia; intranasal*

Case Report

We report the case of a patient suffering from a chemical burn caused by phosphorus, for whom initial management required decontamination using multimodal analgesia. This patient, a 42-year-old Explosive Ordnance Disposal (EOD) specialist for the "Groupe d'Intervention de la Gendarmerie Nationale" (GIGN), was handling an exercise smoke grenade as part of an investigation. It contained a chemical agent known as white phosphorus. When handling the ammunition, some of its contents spread onto the patient's left hand, with an orange dust-like appearance (Figure 1).

Contact with the skin immediately caused a sharp burn on the palm and back of the hand. He was then treated urgently at the 1st Specialized Medical Unit (1ere Antenne Médicale Spécialisée (AMS)), where he received his first treatment. 1st AMS is a French military medical facility, that ensures the medical support of the GIGN. The accident happened during EOD training inside GIGN. It took 15 minutes for the patient to arrive at 1st AMS. The patient's watch and wedding ring were removed, and these items were placed into a bath of copper sulfate solution. His hand was put under a continuous cold-water jet. The phosphorus stuck to the skin, visibly orange in color, and continued to burn the patient (Figure 2). The phosphorus ignited on contact with air, a particular difficulty associated with white phosphorus burns. We observed white smoke on the patient's hand as the burning process continued. It took approximately 45 minutes for the burning process to extinguish until it was completely removed by using a surgical brush. The patient's pain was sharp and evaluated as a 8/10 in severity. The question of analgesia immediately arose to allow effective decontamination. In the first instance, we opted for a hand block by regional anesthesia (RA) of radial, median, and ulnar nerves. A total of 3mL of non-adrenaline lidocaine 20% was injected into each nerve, according to the appropriate anatomical landmarks for each of the different nerves. RA made it possible to brush the skin, thus removing the chemical agent in its entirety. The burn was evaluated at 2.50% of total body surface area (BSA), non-circular, 2nd degree, and severe by its localization on an anatomical extremity with potential implications for functional prognosis (Figure 3).

According to French guidelines, we sought out an expert burn specialist's opinion in order to consider hospitalization in a burn treatment center. However, after sending pictures of the wound, it was agreed upon that initial management could be carried out at the 1st AMS using the usual care for a thermal burn.[1] This includes adorning the blisters, followed by local application of silver sulfadiazine (flamazine) in a thick layer and covering it with a dry dressing.

The incision and debridement of the phalanges was a very painful procedure, despite the regional anesthesia hand block. Approximately 30 minutes after the hand block, and just prior to beginning debridement, it became evident that the pain control was insufficient. We then opted for additional analgesia using intranasal (IN) procedural sedation. The protocol of the 1st AMS combines ketamine at the dosage of 0.6mg/kg and sufentanil at 0.5µg/kg.

In the following days, the patient was evaluated daily at the 1st AMS to check healing. The patient benefited from a consultation in the burn center on the seventh day for further debridement of skin necrosis (Figure 4, 5). Once the patient arrived at the hospital, he first received an intravenous (IV) treatment of propofol mixed with ketamine (unknown dosage). The analgesia performed at 1st AMS was local by spraying lidocaine, and an intranasal bolus of ketamine alone at 0.6mg/kg was also added. No hemodynamic adverse effects were observed.

*Correspondence to luc-1.saint-jean@gendarmerie.interieur.gouv.fr
[1]**Dr Saint-Jean**, [2]**Dr Corcostegui**, and [4]**Dr Derkenne** are all affiliated with the 1st Specialized Medical Unit (1ère Antenne médicale spécialisée Satory), 2nd Army Medical Center of Versailles (2e Centre Médical des Armées de Versailles), Versailles, France. [3]**Dr Galant** is affiliated with the Marseille Battalion of Navy Firefighters, Marseille, France.

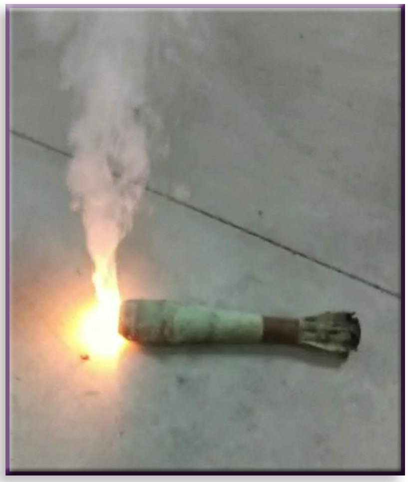

FIGURE 1. *Ammunition causing the burn, containing white phosphorus producing orange smoke in contact with air.*

FIGURE 2. **(A)** *White phosphorus burn,* **(B)** *orange related to a chemical dye.*

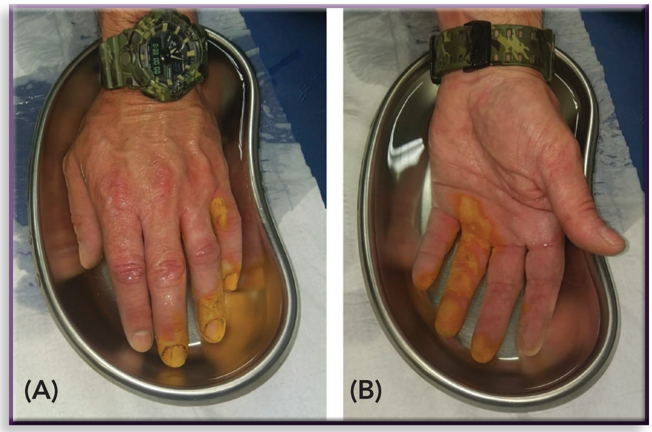

FIGURE 3. **(A)** *Management after debridement and* **(B)** *debridement of phlyctenes.*

FIGURE 4. **(A)** *Secondary necrosis at 48h,* **(B)** *resumption of debridement.*

FIGURE 5. *Healing on day 15.*

FIGURE 6. *Healing on day 21.*

Healing occurred by the 21st day of treatment without complications (Figure 6). Of note, the therapeutic protocol of a thermal burn and a chemical burn is essentially identical.

Discussion

This case report should interest emergency physicians because of two original points. First, white phosphorus is a chemical agent rarely encountered, with little information available in the medical literature. However, the use of this weapon has been suspected in the recent 2022 Ukrainian conflict.[2] Second, the use of multimodal analgesia—combining regional anesthesia with lidocaine and intranasal ketamine—is unique.

Elemental phosphorus exists in several forms. The two main ones are white phosphorus, which is extremely reactive and highly toxic, and red phosphorus, which is stable and has low toxicity. White phosphorus is obtained by electrothermal process or is more readily available as a chemical. The majority of the element produced is oxidized by combustion in phosphorus pentoxide, which, by hydration, leads to phosphoric acid. The rest is used as a reagent in the chemical industry (insecticides, rodenticides) and in the armament or leisure industries. These can include the manufacturing of tracer shells, incendiary grenades and smoke bombs for camouflage or training, and fireworks. The translucent and waxy substance form of the chemical is the form that ignites spontaneously when in contact with air.[3]

White phosphorus adheres to the skin. Because of its very low self-ignition temperature, it produces a yellow flame and the emission of whitish smoke on contact with skin.[3] The result is deep bedsores that are extremely painful, quickly suppurated, and whose healing is very slow. White phosphorus burns require a debridement and removal of phosphorus particles; this can be accomplished via a thorough and prolonged wash under cold running water. Then, a large excision of the affected tissues must be carried out before wet dressings or hydrogels are placed. The possible use of skin covering techniques (artificial skin and/or autografts) is decided at the hospital, under the guidance of a specialist.[4–7]

In the case report, we described the use of a copper sulfate buffer solution for the decontamination of the watch and the patient's wedding ring. This solution is known to be a chelator of phosphorus, forming copper phosphate. Copper phosphate precipitates in the form of black granules, which can be removed easily, and hence why we used it on the patient's watch and ring. A 2014 Cochrane review based on two older observational studies concluded that there was no recommendation for the use of copper sulfate directly on burn.[4] Their analysis was concerning for possible systemic iatrogenic harm.[4]

Phosphorus can cause systemic effects and electrolyte abnormalities, such as hyperphosphatemia and hypocalcemia, as well as acute renal failure and hemolytic anemia. There is no link between the severity of the burn and the risk of systemic impairment. The patient's prognosis is linked to the likelihood of hypocalcemia, which can lead to lengthening the QT segment and subsequent ventricular rhythm abnormalities. It is thus necessary to carefully monitor the patient, perform an EKG, and finally to carry out a phospho-calcium assessment by blood test.[4] We did not perform a blood sample during the initial management of our patient, as we are a primary-care facility.

Analgesia is the second interesting point in this case report, as it was necessary to allow effective management of the burn, both in terms of decontamination and blister debridement. Indeed, the treatment of pain is a major issue in the overall care of the patient. Poor pain control is correlated with increased morbidity and mortality in those wounded by war. A corollary can be established for a severely traumatized patient in a civilian environment.[8,9] While treating this patient, it seemed wise to us to first propose a hand block by regional anesthesia, in order to achieve a peripheral nerve block of the radial, median, and ulnar nerves. There is strong interest in the use of peripheral nerve blocks for anesthesia in hostile environments.[10] Of note, the success of the procedure is correlated with the experience of the physician performing it.[11,12] In our case, the block proved to be partially effective. The volume of 3mL we injected per nerve was slightly lower than the amount recommended by the "Société Française d'Anesthésie-Réanimation" (SFAR), in the 2004 recommendations.[11] They recommended reducing volume to prevent local toxicity, though this probably explained its partial effectiveness in this patient. We chose to inject a smaller volume to avoid side effects, as we rarely perform regional anesthesia in emergency cases. We did not use ultrasound guidance and had no neurostimulator to assess the quality of the block performed. We then supplemented the analgesia with procedural sedation with via the IN route. The 1st AMS, as well as the other French medical units supporting the Special Operations Forces units, are particularly interested in this topic, given their practice in remote environments and care under fire.[8] The IN route has been the subject of numerous scientific evaluations over the past two years, alleging its advantages in tactical medicine.[13,14] The doses of the protocol used, as well as its ability to be titrated, allow the practitioner to limit undesirable effects.

Conclusion

The management of chemical injuries is time-consuming for emergency medical teams and can put them at risk. Until now, the occurrences of such chemical emergencies have been mainly accidental. However, recent international news regarding the conflict in the Ukraine serves as a reminder that these are not weapons of the past.[15]

References

1. **Recommendations de Pratiques Professionnelles.** *Societe Francaise d'Anesthesie et Reanimation.* https://www.sfmu.org/upload/consensus/rpp_brul%C3%A9_2019.pdf. Accessed 12 April 2023.
2. **Santora M, Specia M, Gladstone R.** Western powers look into an unverified claim of possible use of a chemical agent in Mariupol. *The New York Times*. https://www.nytimes.com/2022/04/12/world/europe/chemical-weapons-russia-mariupol.html. Accessed 12 April 2023.
3. **Testud F.** Phosphore et composés inorganiques. *EMC – Pathol Prof Environ.* 2011;6(3):1–10.
4. **Barqouni L, Abu Shaaban N, Elessi K.** Interventions for treating phosphorus burns. *Cochrane Database Syst Rev.* 2014;2014(6):CD008805.
5. **Al Barqouni LN, Skaik SI, et al.** White phosphorus burn. *Lancet*. 2010;376(9734):68.
6. **Eldad A, Simon GA.** The phosphorous burn — a preliminary comparative experimental study of various forms of treatment. *Burns*. 1991;17(3):198–200.
7. **Ng NYB, Abdullah A, Milner SM.** A phosphorus burn. *Eplasty*. 2015;15:ic15.
8. **Travers S, Carfantan C, Luft A, et al.** Five years of prolonged field care: prehospital challenges during recent French military operations. *Transfusion (Paris)*. 2019;59(S2):1459–1466.
9. **De Rocquigny G, Dubecq C, Martinez T, et al.** Use of ketamine for prehospital pain control on the battlefield: a systematic review. *J Trauma Acute Care Surg.* 2020;88(1):180–185.
10. **Mahiou P, Darren R, Desebbe O, et al.** Intérêts des anesthésies locorégionales périphériques en milieu périlleux. *J Eur Urgences Réanimation.* 2021;S221142382100078X.
11. **Freysz M, Ricard-Hibon A, Adnet F, et al.** Société française d'anesthésie et de réanimation. *Annales Françaises d'Anesthésie et de Réanimation.* 2004; 23:167–176
12. **Carles M, Beloeil H, Bloc S, et al.** Anesthésie loco-régionale périnerveuse (ALR-PN). *Anesth Réanimation.* 2019;5(3):208–217.
13. **Montagnon R, Dubecq C, Pasquier P.** Use of the intranasal route for administration of ketamine by Special Operations medical personnel during training mishaps. *J Spec Oper Med*. 2021;21(3):96–97.
14. **Butler FK Jr, Kotwal RS, Buckenmaier CC 3rd, et al.** A triple-option analgesia plan for Tactical Combat Casualty Care: TCCC guidelines change 13-04. *J Spec Oper Med*. 2014;14(1):13–25.
15. **Coleman A, Devlin K.** Ukraine conflict: Russian chemical attack claim fact-checked. *BBC News.* 15 May 2022. https://www.bbc.com/news/61439398. Accessed 12 April 2023.

PMID: 37302143; *DOI:* 10.55460/N0QE-PCTE

The Special Operations Medical Association's Official Journal

JSOM

JOURNAL *of* SPECIAL OPERATIONS MEDICINE™

20 YEARS
UNCONVENTIONAL WARFARE
JOURNAL OF SPECIAL OPERATIONS MEDICINE
www.JSOMonline.org
UNCONVENTIONAL MEDICINE
PUBLISHING EXCELLENCE

Fall 2023
Volume 23, Edition 3

THE JOURNAL FOR OPERATIONAL MEDICINE AND TACTICAL CASUALTY CARE

Inside this Issue:

Dedicated to the Indomitable Spirit, Lessons Learned & Sacrifices of the SOF Medic

A Peer Reviewed Journal That Brings Together The Global Interests of Special Operations' First Responders