

Physiologic and Chemical Simulation of Cyanide and Sarin

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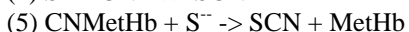
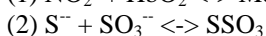
Simulation is particularly well suited for learning about chemical warfare. BODY Simulation can, for example take you through the pathophysiology of cyanide poisoning, as well as its treatment. This includes the blocking of O₂ consumption; the conversion by nitrite of HbO₂ to MetHb; the “transfer” of CN⁻ from the tissue to bind with MetHb, to form CNMetHb; the reduction in CN⁻ concentration, in blood and tissue; the production of sulfur from thiosulfate, the production of thiocyanate from S⁻ and CN⁻, as well as from CNMetHb, and the blood and tissue concentrations of all these agents, as well as their disposition. One can also plot the species of Hb that are involved: Hb, HbO₂, MetHb and CNMetHb, as well as concentrations of CN, nitrite, sulfide, etc., in the blood and tissues.

Cyanide works by blocking a site on cytochrome oxidase, so that the body cannot utilize oxygen. One cannot monitor cyanide toxicity with most monitors. Because the mechanism is the intracellular blocking of oxygen utilization, the arterial O₂ saturation (from the pulse oximeter), for example, will remain normal, until the patient is essentially terminal from hypoxia.

Anyone who administers sodium nitroprusside (SNP) should know how to treat cyanide poisoning, because cyanide is a breakdown product of SNP. The formula for cyanide is surprisingly simple (CN⁻), and that has many implications. One of the most important implications is that it is everywhere. Because of our continual exposure to cyanide, we all have measurable levels of the agent. This means that the body has developed several ways to dispose of cyanide, and the treatment of cyanide poisoning simply facilitates and hastens the body’s mechanisms for deactivating cyanide.

To treat cyanide poisoning, we use two of these mechanisms for its disposition. The first is the conversion of Hb to methemoglobin (MetHb). MetHb has a strong affinity for cyanide, essentially “pulling” it out of the cells into the blood. Nitrites do a wonderful job in this area. Nitrite therapy is quick acting, but it can drop blood pressure (consider nitroglycerine and nitroprusside). More importantly, MetHb is toxic, since the patient has proportionately less HbO₂ to release oxygen (MetHb binds O₂, but does not release it). The slower acting therapy with thiosulfate facilitates the conversion of cyanide into thiocyanate by copiously supplying the critical elemental sulfur. The resulting thiocyanate is toxic, although considerably less so than cyanide.

The following mass equations are used in BODY’s simulation of cyanide therapy. The user can set the rate constants in all equations and the equilibrium constants in those equations that do not go completely to the right.



Sarin works by forming a “permanent” bond with acetylcholinesterase. Acetylcholine accumulates, producing a cholinergic crisis, with combined muscarinic and nicotinic effects. One treats the muscarinic effects by giving enormous doses of atropine. The nicotinic effects can be treated with ventilation. One must still try to reverse/break the bond between the agent and the acetylcholinesterase site. The drug of choice in the US is 2-PAM (pralidoxime chloride). It is very important to administer 2-PAM as soon as possible, because the process of “aging,” which can take place in a matter of minutes or hours, depending on the nerve agent, will render the bond between agent and acetylcholinesterase permanent. The only recourse then is to wait out the regeneration of the enzyme, a matter of days to weeks.

Purpose of BODY Simulation and the Scenarios

1. Define the challenges of providing quality care to patients suffering from chemical warfare agents.

2. Learn about the mechanism of action of two representative chemical warfare agents: cyanide and sarin.
3. Observe the untreated course of events of cyanide and sarin—both non fatal and lethal.
4. Learn the pharmacologic therapy required for cyanide and sarin.
5. Enforce why anesthesiologists should become leaders in the treatment of chemical-warfare agents.

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Selected References

1. Abraham R, Rudick V, Weinbroum A. Practical guidelines for acute care of victims of bioterrorism: conventional injuries and concomitant nerve agent intoxication. *Anesthesiology* 2002;97(4):989-1004.
2. Baskin S, Brewer T. Cyanide poisoning. Medical aspects of chemical and biological warfare, Chapter 10: US Army Medical Research Institute; 2000. p. 271-86, http://ccc.apgea.army.mil/reference_materials/textbook/HTML_Restricted/chapters/chapter_10.htm#cyanide.
3. Sidell F. Nerve agents. Medical aspects of chemical and biological warfare, Chapter 5: US Army Medical Research Institute; 2000. p. 129-79, ccc.apgea.army.mil/reference_materials/textbook/HTML_Restricted/chapters/chapter_5.htm#nerveagents.
4. van Heijst A. IOCS monograph on cyanide: IPCS; 1997. p. 1-49, <http://www.inchem.org/documents/pims/chemical/pimg003.htm>