

Nerve agents: a guide for emergency nurses. Part 1

Stephen McGhee, Alan Finnegan, Neil Angus, John M Clochesy

Citation

McGhee S, Finnegan A, Angus N et al (2018) Nerve agents: a guide for emergency nurses. Part 1. *Emergency Nurse*. doi: 10.7748/en.2018.e1896

Peer review

This article has been subject to external double-blind review and checked for plagiarism using automated software

Correspondence

stephenmcghee@health.usf.edu

Conflict of interest

None declared

Accepted

28 November 2018

Abstract

Recent events in the UK and the alleged chemical attacks on the Syrian people by the Bashir Al Assad regime have brought the subject of chemical weapons back into the public domain. To date these events have been relatively rare as terrorist plans to harm large numbers have been thwarted. This is the first part of a two-part article that gives an overview of nerve agents and provides emergency nurses with the historical background, their manufacture and how these agents affect normal physiology. The second article considers initial treatment including effective triage, decontamination and medical management.

Author details

Stephen McGhee, Director of global affairs, College of Nursing, University of South Florida, Tampa, FL, US; Alan Finnegan, Professor of mental health nursing, University of Chester, Chester, England; Neil Angus, Senior lecturer, University of the Highlands and Islands, Inverness, Scotland; John M Clochesy, Executive dean, School of Nursing, University of Miami, Coral Gables, FL, US

Keywords

chemical weapons, nerve agent, Novichok, nurses

Key points

-
-
-
-

Gas! GAS! Quick, boys! — An ecstasy of fumbling,
Fitting the clumsy helmets just in time;
But someone still was yelling out and stumbling,
And flound'ring like a man in fire or lime ...
Dim, through the misty panes and thick green light,
As under a green sea, I saw him drowning.
In all my dreams, before my helpless sight,
He plunges at me, guttering, choking, drowning.
(Wilfred Owen 1917)

Historical background

The military recognises that an enemy may attempt to inflict harm through nerve agents. This possibility is registered in armed forces medical philosophy and dates back to chemical weapons delivered through poison arrows stemming from ancient Greece

(Mayor 2003). World War I witnessed the emergence of killing or maiming on a massive scale through novel mechanisms such as mines, mortars, tanks and lethal nerve gas. At that time, it was impossible for nurses and clinical staff to prepare for the emerging injuries. However, more recently military clinical practitioners can prepare for worst-case scenarios so that they can respond emotionally and with competency to the most severe and traumatic of incidents.

The military mental health philosophy preparing staff to deal with emotionally distressed patients also stems from World War I in during which the ramifications of lethal chemical weapons resulted in widespread shock, panic and public revulsion. Soldiers coined the term ‘shell shock’ (Myers 1915) but many of those presenting with signs and symptoms of fatigue, tremor, confusion, nightmares, sight/hearing difficulties and inability to function had been nowhere near the battlefield. It was their fear of being exposed to gas that led to their presentation (Jones 2002). These anxieties shaped practical medical training in World War II (Munro et al 1990) and the real threat of nerve agents being used by terrorist organisations was first seen in the Tokyo subway attack in 1995. Such events have shaped civilian medical training and response activities (Martin and Lobert 2003).

In 2018 the audacious attack on former soviet spy Sergei Skirpal and his daughter Yulia in Salisbury, England brought one of the most dangerous nerve agents into the public eye (Brunning 2018). Before this few people had heard the name Novichok other than serving members of the military, scientists and intelligence services. The Salisbury Novichok incident had consequences for emergency services personnel and it is well known that a first responder developed signs and symptoms of nerve agent poisoning (Brunning 2018). This demonstrated that the substance had a high degree of persistency. This was because the nerve agent was contained in a liquid rather than a gas which would have been less persistent and therefore reduced the threat of secondary contamination (Calder and Bland 2018). Almost 100 Wiltshire police officers and affiliated staff sought psychological support after the nerve agent incident and continued to do so for months afterwards (Morris 2018).

The group of nerve agents called Novichok was developed by the Russians between 1971 and 1993 and has five variants numbered one to five. All nerve agents are chemically related to organophosphate insecticides originally developed to protect crops (Bailey et al 2014). However, at the beginning of World War II the German military began to develop organophosphate-based nerve agents for military purposes (Barthold and Schier 2005). Following this the nerve agent tabun was used during the Iran/ Iraq war with devastating effects (Barthold and Schier 2005). More recently, a Japanese terrorist group Aum Shinriko used sarin gas in two attacks in the Tokyo underground which affected 5,000 people with 19 fatalities (Brunning 2018). While many countries have decommissioned their stocks of nerve agents, the recent attack in England shows that nerve agent reserves still exist.

Classification

Nerve agents are organophosphate derivatives of phosphoric acid and are generally divided into the V (venomous agent) and G series of agents (named after Gerhard Schrader for German chemical company IG Faben) (US Army, 1967). G nerve agents were initially developed by IG Faben just before and during World War II while V agents were developed by British scientists based at the Porton Down research facility in the early 1950s (Sidell, 2008). The main difference between the G and V series of nerve agents are their persistency. The G series of nerve agents are delivered in vapour form and thus half-life much quicker, unlike the more potent V series of agents that tend to be delivered in liquid or powder format therefore degrading much slower and the effect lasting much longer (Newmark 2004). In March 2018 the public became aware of a more dangerous type of nerve agent Novichok (Brunning 2018) which means newcomer in Russian. From a chemical perspective Novichok is similar to the V series of organophosphate nerve agents that includes VX and the older G series of agents such as sarin (Table 1).

Due to the clandestine nature of nerve agent development there is minimal evidence on Novichok within the public domain and much of what scientists know about Novichok was disclosed by Vil Mirzayanov and Lev Fedorov, Russian chemical weapons scientists who claimed to have been involved in its development (Brunning 2018). Although the exact chemical structure of Novichok is uncertain it is believed that the group of Novichok nerve agents are 10 times more potent than VX which is lethal at just 10mgs in contact with skin (Brunning 2018). Table 1 lists know nerve agents.

Table 1. Nerve agents

G Nerve agents	V Nerve agents	Novichok agents
Sarin (German Agent B)	VX(Venomous Agent X)	Novichok 5
Cyclosarin (German Agent F)	VR(Venomous Agent Russian)	Novichok 7
Soman (German Agent D)		
Tabun (German Agent A)		

Pathophysiology

Contamination by nerve agents is most likely through dermal contact or inhalation although ingestion is also possible. Presenting signs and symptoms vary and the rate of onset depends on the dose and characteristics of the causative agent, the exposure route and the premorbid health status of the affected individual. Generally, nerve agents and organophosphate-based insecticides act by altering the effects of the neuro-transmitter acetylcholine (Sidell and Borak 1992). In the human nervous system acetylcholine regulates nicotinic and muscarinic receptors found in the central, sympathetic and parasympathetic nervous systems and in skeletal muscles (Bailey et al 2014). Normally neuro-transmission takes place when an action potential is conducted along a neuron to the distal portion of the telodendria called the axonal terminus where acetylcholine is released (Huether and McCance 2016). Once released, acetylcholine can cross the neuromuscular junction separating one neuron from another.

The net effect of the binding of acetylcholine to the postsynaptic receptor is to produce an action potential that will induce contraction of muscle. Following contraction, acetylcholine detaches from the postsynaptic receptor, hydrolysed and then deactivated by acetylcholinesterase (Sidell and Borak 1992). Therefore, the consequences of blocking acetylcholinesterase are overpowering amounts of acetylcholine in the synaptic cleft (Bailey et al 2014). Classically nerve agents attach themselves at the active site of acetylcholinesterase thus blocking the deactivating function of acetylcholinesterase on acetylcholine.

Signs and symptoms

Nerve agents are chemically related to organophosphate insecticides and are among the most toxic and lethal substances known to mankind (Bailey et al 2014). Therefore, early recognition is vital to manage affected patients safely and effectively and to assure the health and safety of healthcare staff (Candiotti 2017).

In the acute post-exposure phase excess acetylcholine accumulation is signalled by the production of copious respiratory and oral secretions, gastrointestinal effects including diarrhoea and vomiting, profuse sweating, autonomic instability and generalised muscle weakness that can progress rapidly to paralysis, respiratory arrest and death (Candiotti, 2017). Subsequent to the acute cholinergic effects of nerve agent exposure, survivors may develop an 'intermediate syndrome' (Bailey et al 2014) which can result in appreciable ongoing morbidity characterised by cranial nerve and proximal muscle weakness and respiratory failure. This is thought to reflect ongoing, sustained and sometimes irreversible acetylcholinesterase inhibition at nerve junctions (Abdollahi and Karami-Mohajeri 2012).

Nerve agents affect virtually all body systems (Candiotti 2017). The attributable signs and symptoms can be classified in terms of time of onset, specific nerve receptor (muscarinic or nicotinic) or major body system affected. For the purpose of this article the latter classification has been adopted and is summarised in Box 1. It should be noted that the presence, ordering and intensity of signs and symptoms vary and do not necessarily correlate with the level of nerve agent exposure or predict the outcome.

Box 1. Toxic nerve agent syndrome: signs and symptoms attributable to nerve agent exposure from all variants

System	Potential signs and symptoms
Central nervous	<ul style="list-style-type: none">» Miosis (unilateral or bilateral)» Blurred vision» Headache» Altered consciousness (irritability to coma)» Seizures
Respiratory	<ul style="list-style-type: none">» Rhinorrhoea» Bronchorrhea» Wheezing, dyspnoea, chest tightness» Altered respiratory rate and depth: tachypnoea (early) bradypnoea (late)» Respiratory arrest
Cardiovascular	<ul style="list-style-type: none">» Altered heart rate: tachycardia (early) bradycardia (late)» Altered blood pressure: hypertension (early) hypotension (late)» Cardiac arrhythmias, for example prolonged QT on EKG, ventricular tachycardia
Gastrointestinal	<ul style="list-style-type: none">» Abdominal pain» Nausea and vomiting» Diarrhoea

Urogenital	<ul style="list-style-type: none"> » Urinary frequency » Incontinence
Musculoskeletal	<ul style="list-style-type: none"> » Fasciculations (localised or general) » Generalised weakness (may lead to paralysis)
Skin and mucous membranes	<ul style="list-style-type: none"> » Profuse perspiration » Salivation » Runny eyes » Conjunctival injection

Implications for clinical practice

The existence of stockpiles of nerve agents, along with the ease of producing new nerve agents, leads experts to believe that further incidents are inevitable (Marin and Lobert, 2003). The Novichok attack in Salisbury was targeted and had relatively minimal impact on the general public. However, it is important to recognise that the intent of nerve agents is to create widespread effects and disorder. In the 1990s Osama bin Laden planned to smear nerve agents on car handles and al Qaeda developed a viable distribution device for a nerve agent in the New York subway system (Newmark 2004).

Emergency nurses have a vital role to play in reducing the mortality and morbidity associated with such attacks. While many countries have decommissioned their nerve agents, the recent attack in England shows they still exist. Within this context emergency nurses must know about the different agents and how they interact with human physiology, and how to use treatments. Emergency nurses should also be vigilant in patients with potential occupational exposure, for example those who work with sheep dip, pesticides or insecticides.

This article outlined the historical background, development and classification of nerve agents and discussed the potential pathophysiological effects and presentation in affected individuals. Part 2 considers the prehospital response, including effective triage and decontamination, and in-hospital treatment.

References

- Abdollahi M, Karami-Mohajeri S (2012) A comprehensive review on experimental and clinical findings in intermediate syndrome caused by organophosphate poisoning. *Toxicology and Applied Pharmacology*. 25, 8, 309-314.
- Bailey A, Baker S, Baum R et al (2014) Being prepared. *Advanced Emergency Nursing Journal*. 36, 1, 22-33.
- Barthold C, Schier J (2005) Organic phosphorus compounds-nerve agents. *Critical Care Clinics*. 21, 4, 673-689.
- Brunning A (2018) What are Novichok agents? *American Scientist*. 106, 3, 139.
- Calder A, Bland S (2018) CBRN considerations in a major incident. *Surgery*. 36, 8, 417-423.
- Candiotti K (2017) A Primer on nerve agents: what the emergency responder, anesthesiologist and intensivist needs to know. *Canadian Journal of Anesthesia*. 64, 10, 1059-1070.
- Huether S, E, McCance K, L (2016) *Understanding Pathophysiology*. Elsevier, St Louis MO.
- Jones E (2002) Shell shocked. *American Psychological Association*. 43, 6, 1.
- Martin T, Lobert S (2003) Chemical warfare. Toxicity and nerve agents. *Critical Care Nurse*. 23, 5, 15-20.
- Mayor A (2003) *Greek Fire, Poison Arrows and Scorpion Bombs: Biological and Chemical Warfare in the Ancient World*. Overlook Books, New York NY.
- Morris S (2018) Almost 100 police have received psychological help after Salisbury attack. *The Guardian*, 17 May. www.theguardian.com/uk-news/2018/may/17/almost-100-police-have-received-psychological-help-after-salisbury-attack-wiltshire-force (Last accessed: 4 December 2018.)
- Munro N, Watson A, Ambrose K et al (1990) Treating exposure to chemical warfare agents: implications for health care providers and community emergency planning. *Environmental Health Perspective*. 89, 205-215.
- Myers C (1915) A contribution to the study of shell shock. *Lancet*. 1, 316-320.
- Newmark J (2004) Nerve agents: pathophysiology and treatment of poisoning. *Seminars in Neurology*. 24, 2, 185-196.
- Owen W (1917) *Dulce et Decorum est*. www.poetryfoundation.org/poems/46560/dulce-et-decorum-est (Last accessed: 4 December 2018.)
- Sidell F (2008) Soman and sarin: clinical manifestations and treatment of accidental poisoning by organophosphates. *Clinical Toxicology* 7 (1): 1-7

Sidell F, Borak J (1992) Chemical warfare agents: II. Nerve agents. *Annals of Emergency Medicine*. 21, 7, 865-871.

United States Army (1967) Field Manual: Chemical Reference Handbook. FM3-8