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MILITARY

Explosives - Injuries

Bombs and explosions can cause unique patterns of injury seldom seen outside combat. The predominant post explosion injuries among survivors involve standard penetrating and blunt trauma. Blast lung is the most common fatal injury among initial survivors. Explosions in confined spaces (mines, buildings, or large vehicles) and/or structural collapse are associated with greater morbidity and mortality. Half of all initial casualties will seek medical care over a one-hour period. This can be useful to predict demand for care and resource needs. Care providers expect an "upside-down" triage - the most severely injured arrive after the less injured, who bypass EMS triage and go directly to the closest hospitals.

Background

Explosions can produce unique patterns of injury seldom seen outside combat. When they do occur, they have the potential to inflict multi-system life-threatening injuries on many persons simultaneously. The injury patterns following such events are a product of the composition and amount of the materials involved, the surrounding environment, delivery method (if a bomb), the distance between the victim and the blast, and any intervening protective barriers or environmental hazards. Because explosions are relatively infrequent, blast-related injuries can present unique triage, diagnostic, and management challenges to providers of emergency care.

Few U.S. health professionals have experience with explosive-related injuries. Vietnam era physicians are retiring, other armed conflicts have been short-lived, and until this past decade, the U.S. was largely spared of the scourge of mega-terrorist attacks. This primer introduces information relevant to the care of casualties from explosives and blast injuries.

Classification of Explosives

Explosives are categorized as high-order explosives (HE) or low-order explosives (LE). HE produce a defining supersonic over-pressurization shock wave. Examples of HE include TNT, C-4, Semtex, nitroglycerin, dynamite, and ammonium nitrate fuel oil (ANFO). LE create a subsonic explosion and lack HE's over-pressurization wave. Examples of LE include pipe bombs, gunpowder, and most pure petroleum-based bombs such as Molotov cocktails or aircraft improvised as guided missiles. HE and LE cause different injury patterns.

Explosive and incendiary (fire) bombs are further characterized based on their source. "Manufactured" implies standard military-issued, mass produced, and quality-tested weapons. "Improvised" describes weapons produced in small quantities, or use of a device outside its intended purpose, such as converting a commercial aircraft into a guided missile. Manufactured (military) explosive weapons are exclusively HE-based. Terrorists will use whatever is available – illegally obtained manufactured weapons or improvised explosive devices (also known as "IEDs") that may be composed of HE, LE, or both. Manufactured and improvised bombs cause markedly different injuries.

Blast Injuries

The four basic mechanisms of blast injury are termed as primary, secondary, tertiary, and quaternary (Table 1). "Blast Wave" (primary) refers to the intense over-pressurization impulse created by a detonated HE. Blast injuries are characterized by anatomical and physiological changes from the direct or reflective over-pressurization force impacting the body's surface. The HE "blast wave" (over-pressure component) should be distinguished from "blast wind" (forced super-heated air flow). The latter may be encountered with both HE and LE.

Table 1: Mechanisms of Blast Injury

Category	Characteristics	Body Part Affected	Types of Injuries
Primary	Unique to HE, results from the impact of the over-pressurization wave with body surfaces.	Gas filled structures are most susceptible - lungs, GI tract, and middle ear.	Blast lung (pulmonary barotrauma) TM rupture and middle ear damage Abdominal hemorrhage and perforation - Globe (eye) rupture- Concussion (TBI without physical signs of head injury)
Secondary	Results from flying debris and bomb fragments.	Any body part may be affected.	Penetrating ballistic (fragmentation) or blunt injuries Eye penetration (can be occult)
Tertiary	Results from individuals being thrown by the blast wind.	Any body part may be affected.	Fracture and traumatic amputation Closed and open brain injury
Quaternary	All explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanisms. Includes exacerbation or complications of existing conditions.	Any body part may be affected.	Burns (flash, partial, and full thickness) Crush injuries Closed and open brain injury Asthma, COPD, or other breathing problems from dust, smoke, or toxic fumes Angina Hyperglycemia, hypertension

LE are classified differently because they lack the self-defining HE over-pressurization wave. LE's mechanisms of injuries are characterized as due from ballistics (fragmentation), blast wind (not blast wave), and thermal. There is some overlap between LE descriptive mechanisms and HE's Secondary, Tertiary, and Quaternary mechanisms.

Table 2: Overview of Explosive-Related Injuries

System	Injury or Condition

* FBI; pg.3

Explosives - ANFO (Ammonium Nitrate - Fuel Oil)

- Explosives
- Explosives - Primary
- Explosives - Booster
- Explosives - Nitroaromatics
- Explosives - Nitramines
- Explosives - Nitrate esters
- Explosives - Compositions
- Explosives - ANFO
- Explosives - Mining Types
- Explosives - Mining Industries
- Liquid Explosive Compositions
- Novel Energetic Materials
- Insensitive Explosives
- Insensitive Munitions (IM)
- Dense Inert Metal Explosive (DIME)
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- Explosives - UN List
- Explosives & the Environment

Ammonium nitrate-fuel oil (ANFO) blasting agents represent the largest industrial explosive manufactured (in terms of quantity) in the United States. This product is used primarily in mining and quarrying operations. The components are generally mixed at or near the point of use for safety reasons. The mixed product is relatively safe and easily handled and can be poured into drill holes in the mass or object to be blasted.

Melvin A. Cook's life is intimately connected with the history of explosives, he is a scientist,, inventor, teacher, businessman, theorist, consultant, expert witness, entrepreneur, and author. Cook, a professor of metallurgy at the University of Utah, was a businessman and author of works on explosives. He also published works on creationism, particularly on the relationship between science and Mormonism. Cook's personal involvement in both the theoretical and practical aspects of the field of explosives spans more than fifty years.

Cook's greatest commercial explosives invention was formulated in December of 1956, when he created a new blasting agent using an unusual mixture of ammonium nitrate, aluminum powder, and water. The safety and efficiency of this new explosive were apparent, and the use of water was revolutionary. Tests that followed resulted in the development of a new field of explosives: slurry explosives. This invention converted the commercial explosives industry from "dangerous dynamite" to "safe slurry" and dry blasting agents [ANFO]. In 1972 Cook developed the BLU-82, the largest and most powerful chemical bomb, using aluminized slurry.

Blasting agents consist of mixtures of fuels and oxidizers, none of which are classified as explosive. Nitrocarbonitrate is a classification given to a blasting agent under the US Department of Transportation regulations on packaging and shipping. A blasting agent consists of inorganic nitrates and carbonaceous fuels and may contain additional nonexplosive substances such as powdered aluminum or ferrosilicon to increase density. The addition of an explosive ingredient such as TNT changes the classification from a blasting agent to an explosive. Blasting agents may be dry or in slurry forms. Because of their insensitivity, blasting agents should be detonated by a primer of high explosive.

Ammonium nitrate- fuel oil has largely replaced dynamites and gelatins in bench blasting. Denser slurry blasting agents are supplanting dynamite and gelatin and dry blasting agents. The most widely used dry blasting agent is a mixture of ammonium nitrate prills (porous grains) and fuel oil. The fuel oil is not precisely CH2, but this is sufficiently accurate to characterize the reaction. The right side of the equation contains only the desirable gases of detonation, although some CO and N02 are always formed. Weight proportions of ingredients for the equation are 94.5 percent ammonium nitrate and 5.5 percent fuel oil. In actual practice the proportions are 94 percent and 6 percent to assure an efficient chemical reaction of the nitrate.

Uniform mixing of oil and ammonium nitrate is essential to development of full explosive force. Some blasting agents are premixed and packaged by the manufacturer. Where not premixed, several methods of mixing in the field can be employed to achieve uniformity. The best method, although not always the most practical one, is by mechanical tier. A more common and almost as effective method of mixing is by uniformly soaking prills in opened bags with 8 to 1O percent of their weight of oil. After draining for at least a half hour the prills will have retained about the correct amount of fuel oil.

Fuel oil can also be poured onto the ammonium nitrate in approximately the correct proportions as it is poured into the blasthole. For this purpose, about i gal of fuel oil for each 100 lb of ammonium nitrate will equal approximately 6 percent by weight of oil. The oil can be added after each bag or two of prills, and it will disperse relatively rapidly and uniformly. Inadequate priming imparts a low initial detonation velocity to a blasting agent, and the reaction may die out and cause a misfire. High explosive boosters are sometimes spaced along the borehole to as sure propagation throughout the column.

As in other combustion reactions, a deficiency of oxygen favors the formation of carbon monoxide and unburned organic compounds and produces little, if any, nitrogen oxides. An excess of oxygen causes more nitrogen oxides and less carbon monoxide and other unburned organics. For ammonium nitrate and fuel oil (ANFO) mixtures, a fuel oil content of more than 5.5 percent creates a deficiency of oxygen.

Ammonium nitrate and fuel oil (ANFO) has a broad spectrum of Velocities of Detonation according to numerous references. However, some of these references are more specific when establishing parameters. A military catering charge lists a VOD of 10,700 feet per second (fps). A 4" diameter steel tube confinement is at 10,000 fps, while a 16" diameter tube is at 16,000 fps. In charge diameters of 6 in. or more, dry blasting agents attain confined detonation velocities of more than i2,000 fps, but in a diameter of 1- 1/2 in., the velocity is reduced to 60 percent. When ANFO is used in boreholeing, the VOD has a positive slope as a function of depth, the VOD increases as the detonation front progresses down the borehole. Enhanced effects of very large quantities, which is essentially self tamping, the VOD is expected to be in the 13,000-15,000 fps range. A ballpark approximation for very large quantities of blasting agents, which is accepted in the commercial industry, is roughly half the VOD of C-4/plastics, which equates to 13,000 fps. The recognized VOD of urea nitrate, however, is 11,155 to 15,420 fps.

The specific gravity of ANFO varies from 0.75 to 0.95 depending on the particle density and sizes. Confined detonation velocity and charge concentration of ANFO vary with borehole diameter. Pneumatic loading results in high detonation velocities and higher charge concentrations, particularly in holes smaller than 3 in. (otherwise such small holes are not usually recommended for ANFO blasting).

The simple removal of a tree stump might be done with a 2-step train made up of an electric blasting cap and a stick of dynamite. The detonation wave from the blasting cap would cause detonation of the dynamite. To make a large hole in the earth, an inexpensive explosive such as ANFO might be used. In this case, the detonation wave from the blasting cap is not powerful enough to cause detonation, so a booster must be used in a 3- or 4-step train. The yield from the blasting caps and safety fuses used in these trains are usually small compared to those from the main charge, because the yields are roughly proportional to the weight of explosive used, and the main charge makes up most of the total weight.

Advantages of insensitive dry blasting agents are their safety, ease of loading, and low price. In the free-flowing form, they have a great advantage over cartridge explosives because they completely fill the borehole. This direct coupling to the walls assures efficient use of explosive energy. Ammonium nitrate is water soluble so that in wet holes, some blasters pump the water from the hole, insert a plastic sleeve, and load the blasting agent into the sleeve. Special precautions should be taken to avoid a possible building up of static electrical charge, particularly when loading pneumatically. When properly oxygen- balanced, the fume qualities of dry blasting agents permit their use underground. Canned blasting agents, once widely used, have unlimited water resist-ance, but lack advantages of loading ease and direct coupling to the borehole.

In 2001, US explosives production was 2.38 million metric tons (Mt), 7% less than that in 2000; sales of explosives were reported in all States. Coal mining, with 69% of total consumption, continued to be the dominant use for explosives in the United States. Kentucky, West Virginia, Indiana, Wyoming, and Virginia, in descending order, were the largest consuming States, with a combined total of 46% of US sales.

After completing an investigation into dumping of ammonium nitrate from Ukraine that was begun in 2000, the US International Trade Commission (ITC) issued its final determination in August 2001. The ITC determined that imports of ammonium nitrate from Ukraine were sold in the United States at less than fair market value and that critical circumstances did not exist with regard to these imports. As a result of the negative determination regarding critical circumstances, the duties were not retroactive and only apply to ammonium nitrate that has been imported since March 5, 2001. The antidumping duty of 156.29% ad valorem that was finalized by the International Trade Administration in July 2001 was applied.

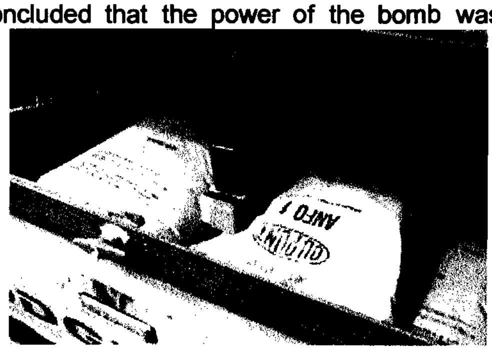
Sales of ammonium-nitrate-based explosives (blasting agents and oxidizers) were 2.34 Mt in 2001, which was an 8% decrease from that of 2000, and accounted for 98% of US industrial explosives sales. Sales of permissibles and other high explosives increased slightly. Data for 2001 are not exactly comparable to the 2000 data. One company, Nelson Brothers LLC, did not provide data to the Institute of Makers of Explosives (IME) in 2001, and no estimate for its sales was included in the totals.

By 2001 engineers in the Fuels and Lubricants Group of Shell Co. of Australia developed a technique to blend waste oil with ANFO for a product that can be used in blasting. Mines throughout the world produce thousands of liters of waste fuel oil that needs to be disposed of in an environmentally safe manner. By using the fuel oil in a blasting compound, transporting the waste oil is eliminated, the quantity of fuel oil needed for blasting is reduced, and potentially toxic hydrocarbons in waste oil can be destroyed by the high blast temperature. Shell tested the ANFO-waste oil blend at Hamersley Iron's Marandoo mine site, and found that the ratio of waste oil to ANFO blend could be as much as 50-50 without any detrimental effect to the final blasting performance.

Urea nitrate is also considered a type of fertilizer-based explosive, although, in this case, the two constituents are nitric acid (one of the ten most produced chemicals in the world) and urea. A common source of urea is the prill used for de-icing sidewalks. Urea can also be derived from concentrated urine. This is a common variation used in South America and the Middle East by terrorists. Often, sulfuric acid is added to assist with catalyzing the constituents. A bucket containing the urea is used surrounded by an ice bath. The ice serves in assisting with the chemical conversion when the nitric acid is added. The resulting explosive can be blasting cap sensitive. Urea nitrate has a destructive power similar to ammonium nitrate.

By one estimate, the bomb used to attack the Alfred Murrah Federal Building in Oklahoma City on April 19, 1995 consisted of an ANFO explosive main charge of approximately 4,000 pounds, based on an estimate of the Velocities of Detonation [VOD] of approximately 13,000 fps. Other estimates claim that the 1995 explosion that collapsed portions of the Murrah Federal Building in Oklahoma City contained 4,800 pounds of ammonium nitrate and fuel oil. Later estimates suggested that the bomb had in excess of 6,200 pounds of various energetic materials, including explosives other than ANFO, equivalent to 5,000 pounds of TNT. In the Salameh World Trade Center bombing case resulting from the bombing of the World Trade Center (WTC) on February 26, 1993, FBI Explosives Unit examiner David Williams opined that the main explosive used in the bombing consisted of 1,200 pounds of urea nitrate explosive. The FBI chemists specializing in the examination of explosive residue, however, did not find any residue identifying the explosive at the World Trade Center.

Not all large truck bombs have used ANFO. On June 25, 1996, Saudi terrorists sponsored by Iran attacked the Khobar Towers barracks, a high-rise building complex in a densely populated urban environment in Saudi Arabia. T tanker truck loaded with at least 5,000 pounds of plastic explosives was driven into the parking lot in front of the Khobar Towers residential complex in Dhahran. Nineteen American service members were killed in the blast, and hundreds of other service members and Saudis were injured. There is no doubt that the extent of the casualties at Khobar Towers resulted, in part, from the extraordinary size of the terrorist bomb. Reports initially estimated that the bomb contained the equivalent of 3,000 to 8,000 pounds of TNT, but a study by the Defense Special Weapons Agency concluded that the power of the bomb was actually closer to 20,000 pounds of TNT.

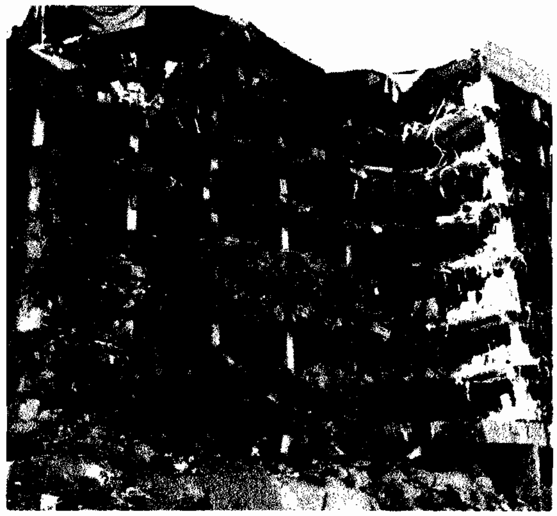
Oklahoma City Bombing.com
OCBombing.com

The Oklahoma City Bombing

by Kevin Caruso

On April 19, 1995, at 9:02 a.m. local time, a massive truck bomb exploded in front of the Alfred P. Murrah Federal Building in Oklahoma City, Oklahoma, killing 168 people (including 19 children) and injuring over 800.

The explosion destroyed about half of the Federal Building, damaged or destroyed an additional 300 buildings, and was felt as far as 30 miles away



The Alfred P. Murrah Federal Building after the explosion

The truck bomb was a rented Ryder truck filled with about 5,000 pounds of explosives, including ammonium nitrate, nitromethane, and agricultural fertilizer, and was driven by Timothy McVeigh, who was pulled over 90 minutes after the bombing for driving without a license plate. McVeigh was arrested on a firearms charge, spent two days in jail, and was then charged with the bombing.

Terry Nichols, McVeigh's accomplice, was arrested at a later date in Kansas, and was charged in the bombing on May 10.

Over 12,000 individuals assisted in the relief and rescue operations after the bombing, and many of them have suffered from post-traumatic stress disorder, clinical depression, anxiety, and additional problems because of the deeply traumatic nature of the bombing and its aftermath

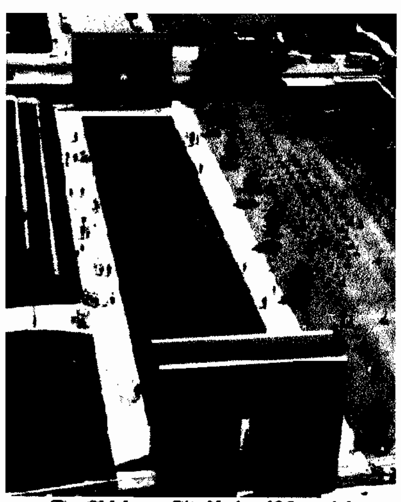
The Federal Building was demolished on May 23, 1995.

But the resilience, hope, love, and indomitable spirit of the wonderful people of Oklahoma has been an inspiration to the entire world.

The spectacular, beautiful, honorable, and inspirational Oklahoma City National Memorial was established on October 9, 1997, at the site of the Federal Building (see below).

God bless the people of Oklahoma.

And God bless America



The Oklahoma City National Memorial