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Nuclear and Biological

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Introduction

Terrorist attacks on the US World Trade Center and subsequent anthrax threats have brought the universal awareness that terrorists would not refrain from using any device, however destructive, to terrorize. In fact the more destructive and terrorizing the device, the better is the purpose of terrorists served. Two innovative devices, which could be used in the near future by terrorists are nuclear bombs and microorganisms and their toxins.

Nuclear Terrorism

Nuclear terrorism is defined as the illegitimate use of radioactive material in any of its several forms to produce maximum disruption, panic, injury, and fear in the general population. Terrorists need not acquire an actual nuclear bomb to terrorize people. There are a number of different scenarios, with or without nuclear bombs, where terrorists can cause panic among general public.

Violation of Safe Operation of Nuclear Facilities

This is perhaps the simplest terrorist scenario involving nuclear and radiation terrorism. A legitimate employee of a nuclear power plant, sympathetic to the terrorists' cause, simply violates norms regarding the safe operation of nuclear facilities, resulting in release of radioactivity.

Radioactive Contamination

This is another simple terrorist scenario involving nuclear terrorism. Today radioactive elements are used for a number of legitimate purposes. These include nuclear power and engineering, metallurgy, geology, mining, meteorology, chemical and petroleum industries, medicine, and agriculture. Among others, ^{60}Co is used to irradiate food to kill pathogens and in cancer treatment, ^{137}Ce in medical and scientific equipment, ^{241}Am in smoke detectors and engineering gauges that measure moisture content in asphalt, tritium for emergency-exit signs that glow in the dark, ^{192}Ir in cameras that detect flaws in concrete and welding, and ^{63}Ni for chemical analysis. Almost all countries have these radioactive elements, and these can potentially be acquired very easily. Once radioactive material is acquired, it could be used to contaminate a number of commodities, such as public drinking water and foodstuffs. It could also be placed at public places, agricultural land, apartment houses, production facilities, storehouses, and transport communications. Such a device is called a "simple radiologic device" (SRD).

Radiation Device

Brachytherapy sources, radiation oncology teletherapy devices, an industrial radiography source, an X-ray machine, or perhaps even a discarded medical irradiator could be misused for terrorist purposes. These devices could be hidden at public sites, causing radiation exposure for an unsuspecting public. Recently, 16 brachytherapy sources of ^{137}Cs have been stolen from a hospital in North Carolina, and in Florida an industrial radiography source of ^{192}Ir was stolen. None of these sources have been found to date. These devices may not cause much harm, but can create untold panic amongst the public, which is the main aim of terrorists.

Nuclear Material Theft and/or Nuclear Hoax

Theft of nuclear materials such as fissile ^{235}Ur, or weapons-grade plutonium can in itself cause panic among people, without terrorists ever having to use them. After a nuclear threat, the terrorists can simply use "nuclear hoaxes."

Radionuclide Dispersal Device (RDD) or a "Dirty Bomb"

Radioactive material, such as ^{137}Ce, ^{131}I, ^{32}P, and ^{67}Ga, could be mixed with a conventional explosive. The resultant explosion would scatter radioactive material in the surrounding atmosphere, resulting in general panic. An attack on radioactive material in transit, such as crashing a bomb-laden truck, would have the same consequences.

Nuclear Plant Sabotage

There are 440 nuclear power reactors around the world today, and all of them are highly vulnerable to an attack similar to those launched on September 11, 2001. Most modern reactors are designed to withstand earthquakes, hurricanes, and impacts of a small plane. They have several concrete and steel barriers, yet crashing a large plane at high speed into a reactor could cause severe damage. This can trigger either a full-scale nuclear explosion or certainly a disaster like the one that occurred in Chernobyl. There is some evidence that United Airlines 93, traveling between Newark and San Francisco on September 11, 2001, but that crashed in rural Pennsylvania, may have been targeted at one of the three nuclear reactors in the south of the state, namely Three Mile Island, Peach Bottom, or Hope Creek, Salem.

Improvised Nuclear Device (IND)

This is the so-called homemade nuclear bomb. It could perhaps be a suitcase-sized bomb, and one in which there would be "real" conversion of nuclear energy into blast, shock, and heat. The terrorists would need extensive technical capability to make this kind of device, but help from rogue nations could make their task easier. The yield would however be much less than that of the actual nuclear device, causing most of the radioactive material to be dispersed in the surrounding atmosphere. It would thus be a hybrid between a true RDD and a true nuclear weapon.

Tactical Nuclear Weapon

This is a true nuclear bomb having a yield ranging from 0.5 to 50 kT (Hiroshima and Nagasaki bombs had yields of 15 and 21 kT respectively; Tables 1–5 and Figure 1). Tactical nuclear weapons could be as small as a suitcase. It would be well nigh impossible for terrorists to construct such a bomb on their own, but stealing or illegal trading of an already made bomb from regular nuclear nations cannot be ruled

Table 1 Nuclear terrorism – basic facts

- Uranium, radioactive in all its isotopes, naturally consists of a mixture of uranium-238 (99.27%, 4 510 million-year half-life), uranium-235 (0.72%, 713 million-year half-life), and uranium-234 (0.006%, 247 000-year half-life)
- Fission occurs with slow neutrons in the relatively rare isotope uranium-235 (the only naturally occurring fissile material), which must be separated from the plentiful isotope uranium-238 for its various uses. To make a nuclear weapon, uranium-235 must be concentrated to about 90% (from its natural state of 0.72%)
- After absorbing neutrons and undergoing negative beta decay, uranium-238 becomes the synthetic element plutonium, which is fissile with slow neutrons. Natural uranium can therefore be used in converter and breeder reactors, in which fission is sustained by the rare uranium-235 and plutonium is manufactured at the same time by the transmutation of uranium-238
- The world's first atomic bomb, the test bomb Trinity, tested by the USA at Alamogordo, in New Mexico on July 16, 1945, was of this type (also popularly known as a plutonium bomb). It did not kill anyone, because it was only a test bomb
- Fissile uranium-233 can be synthesized for use as a nuclear fuel from the nonfissile thorium isotope thorium-232, which is abundant in nature
- The explosive force, or yield, of a nuclear device is measured in the number of thousands of tons (kilotons) or millions of tons (megatons) of trinitrotoluene (TNT) it would take to generate an equivalently powerful blast. Fission bombs are usually measured in kilotons, while fusion bombs with yields of up to about 60 Mt have been tested
- Fission releases an enormous amount of energy relative to the material involved. When completely fissioned, 1 kg (2.2 lb) of uranium-235 releases the energy equivalently produced by 17 kt of TNT. The test bomb Trinity had a yield of 21 kt
- The Hiroshima bomb was the first atomic bomb to be used in warfare. Less than 60 kg (130 lb) of uranium was used in its manufacture. It was dropped by the USA on Hiroshima, Japan, on August 6, 1945. The explosion instantly and completely devastated 10 km^2 (4 square miles) of the heart of this city of 343 000 inhabitants. In addition to the injuries and fatalities, more than 67% of the city's structures were destroyed or damaged
- The Nagasaki bomb, made of plutonium, was dropped on August 9, 1945. Although it had a greater yield than the Hiroshima bomb, the terrain and smaller size of Nagasaki reduced the destruction of life and property; nevertheless, in addition to human losses, about 40% of the city's structures were destroyed or seriously damaged

	Hiroshima bomb	Nagasaki bomb
Name	Little Boy	Fat Man
Weight	4100 kg	4536 kg
Length	3 m	3.5 m
Diameter	0.75 m	1.5 m
Isotope used	Uranium-235	Plutonium-239
Yield	15 kt	21 kt
Killed	66 000	39 000
njured	69 000	25 000

- The amount of material needed for an explosive is 5–10 kg of plutonium or uranium-233 or 15–30 kg of highly enriched uranium, i.e., uranium containing 90% or more of the isotope uranium-235. Uranium enriched to as low as 20% could be used in nuclear weapons, but much more material would be required. Fissile material may be obtained by one of three routes.
  1. Diversion of material from a civilian nuclear power program
  2. Construction of facilities specifically designed to produce nuclear weapons material. Examples of such dedicated facilities are a small reactor to produce plutonium or an enrichment plant to yield highly enriched uranium
  3. Purchase or theft of fissile material or even a complete weapon
- The Chernobyl accident occurred at 1.23 A.M. on April 26, 1986. Initially, the Chernobyl accident caused the deaths of 32 people. Dozens more developed serious radiation sickness. A terrorist nuclear plant meltdown scenario could have similar implications

Table 2 Nuclear terrorism – some units

Unit	Details
Rad	The rad is a unit used by radiologists to denote the radiation (such as X-rays) absorbed by a patient during diagnostic or therapeutic procedures. It is an acronym of radiation absorbed dose. A patient is said to have absorbed 1 rad of radiation when 1 g of his/her tissue absorbs 100 ergs of radiation energy
Gray (Gy)	The gray is another unit of absorbed radiation (named after the twentieth-century British radiobiologist Louis Harold Gray). It is equal to 100 rads
REM	Rem is an acronym for radiation equivalent in man. The biological effect of radiation in man depends not upon the radiation absorbed dose but on rem. This is because different types of radiations (such as X-rays, gamma-rays, low-energy beta particles, neutrons, and alpha particles) have different damaging potentials or quality factors For all radiations used in diagnostic nuclear medicine, the quality factors are roughly equal to one. Thus in clinical practice Rads and rems are equal and are used quite interchangeably, although they are different quantities. Table 3 enumerates the biological effects of radiation in terms of rads of X-rays, which in effect are equal to rems
Sievert (Sv)	The rem has largely been superseded by the sievert (Sv) in the SI system of units. 1 rem is equivalent to 0.01 Sv (100 rem = 1 Sv). 1 rem is also equal to 10 mSv. Table 4 gives some common day-to-day events and the corresponding exposure level in rems
Becquerel (Bq)	The becquerel is a unit of quantity of radioactive material, and not of the radiation emitted by that material. One becquerel is that quantity of radioactive material in which one disintegration (or other nuclear transformation) occurs per second. 1 Bq = 2.703×10^{-11} Ci. Larger units such as thousand-becquerels (kBq), million-becquerels (MBq) or even billion-becquerels (GBq) are often used
Curie (Ci)	The curie is also a unit of quantity of radioactive material. It is equal to that quantity of radioactive material in which 37 billion disintegrations occur every second. It is the radioactivity associated with the quantity of radon in equilibrium with 1 g of radium. 1 Ci = 3.7×10^{10} Bq
Roentgen (R)(C kg^{-1})	The roentgen is a unit of radiation intensity. 1 R is the intensity of radiation that would produce 2.58×10^{-4} coulombs of electric charge in 1 kg of dry air around it. It is also equal to the intensity that would create 2.08×10^{-9} ion pairs in a cubic centimeter of air, i.e., 1 R = 2.08×10^{-9} ion pairs per cm^3. 1 rem is approximately equal to 1 R of 200-kV X-radiation. For most medical purposes, 1 rad = 1 rem = 1 R

Table 3 The biological effects of radiation in terms of rads of X-rays

Rads (of X-rays)	Effects
0.5	Average background radiation
1	Radiation absorbed by a patient during one computed tomography scan of head, or after 80 X-rays. Considered safe by most radiation biologists
10	Possible increase in cancer and birth defects
25	Hematopoietic depression tends to appear
50	Increased cancer. Severe fetal damage
75	Changes begin to occur in hair follicles
100	Symptoms of radiation sickness start (nausea, vomiting, and diarrhea)
300	Hair epilation occurs
500	50% of exposed persons would die within 60 days from marrow damage
600	Erythema. Hematopoietic depression is maximized. Gastrointestinal tract threshold begins with a significant inflammatory response, culminating in desquamation of the gastrointestinal epithelial lining. This interferes with nutrition and may cause life-threatening bacterial invasion
800	Prognosis is poor in patients who have acute whole-body exposures greater than this
1000	Dry desquamation of skin. Death within 7 days from gastrointestinal damage
1500	Entire gastrointestinal epithelium is desquamated
2000	Wet desquamation of skin
3000	Radionecrosis of deep tissue
5000	Death within 48 h from central nervous system injury
10 000	Immediate incapacitation. Death within 24 h

out. J Deutch, the former director of the US Central Intelligence Authority, testified in 1996 that diversion of nuclear warheads or components had occurred in more than 100 instances. With the breakdown of the former Soviet Union, a nuclear nation, much of the nuclear components and/or weapons may have fallen into unauthorized hands. A Russian general has stated publicly that 50–100 nuclear weapons with 1 kT

Table 4 Common day-to-day events and the corresponding exposure level in rems

S. no.	Exposure type	Exposure level
1.	Viewing color television	1 mREM/yr
2.	Sleeping next to someone	5 mREM/yr
3.	Drinking water	5 mREM/yr
4.	Transcontinental flight	5 mREM/flight
5.	Dental x-ray	10 mREM/film
6.	Chest radiograph	12 mREM/film
7.	Background radiation	250–400 mREM/yr
8.	Smoking	280 mREM/year
9.	CT head (nonspiral scanner)	1 REM
10.	Currently accepted average annual dose allowed for radiation workers	2 REM
11.	CT abdomen (nonspiral scanner)	2–5 REM
12.	Bone scan	5 REM
13.	Radiation treatment	250–300 REM

rating are unaccounted for in the former Soviet Union. The yield of a strategic nuclear weapon is typically greater than 1 MT (1000 kT).

Effects of Nuclear Weapons

After a nuclear blast, almost half of the total energy (50%) is released in the form of blast and shock, 35% in the form of heat, 5% in the form of an initial nuclear radiation, and 10% in the form of residual nuclear radiation. This percentage is constant and does not increase with weapon yield (unlike the blast and thermal effects). If a 1 kT nuclear weapon were to detonate, the blast and thermal effects would reach 360 m, and nuclear radiation would reach 800 m. Immediate radiation is in the form of alpha, beta, and gamma radiations and neutron radiation. Residual nuclear radiation can be subdivided into two types: induced radiation and fallout. Induced radiation, also known as neutron-induced gamma activity, is produced when certain materials are bombarded with neutrons. In biologic systems, the most important element to undergo this kind of change is the body sodium, which becomes ^{24}Na (half-life, 15 h). “Fallout” is the falling-off on earth of the various fission products that are produced during nuclear detonation. Radioactive residues that fall within the first 24 h comprise the early fallout. Residues falling after 24 h are classified under late or delayed fallout. Radioactive elements lingering in the atmosphere may cause an additional source of radiation in the form of “cloud shine.” Early and late fallouts are potential sources of radiation hazards.

Rule of Seven

Reduction of radioactive fallout can roughly be calculated by the rule of seven, which states that the radioactive fallout reduces by one-tenth after every 7 h and its multiples thereof. Thus, after 7 h, the radioactive fallout reduces by one-tenth; after 49 h (7×7) by another tenth; after 343 h ($7 \times 7 \times 7$) by another tenth; and so on. Sheltering for about 2 weeks would reduce the fallout to insignificant levels, and from this arises the concept of sheltering for at least 2 weeks following a nuclear detonation.

Types of Contamination

Following a nuclear terrorism event, human bodies would suffer from three types of contamination: (1) irradiation; (2) external contamination; and (3) internal contamination. X-rays, gamma-rays, and neutrons can pass through human flesh; therefore, they will mainly cause the first type of contamination, irradiation. Beta-particles may penetrate up to about 1 cm of exposed skin. Thus they also cause irradiation. Alpha-particles (consisting of two protons and two neutrons) are massive. They only travel for a few centimeters in air and do not penetrate the epidermis of the skin. They are even stopped by ordinary paper (Figure 2).

Ordinary clothing worn by people would be enough to stop alpha radiation. Alpha-particles can settle on clothes and skin, and cause external contamination. After a nuclear terrorist event, it is advisable to take a shower and to discard all clothing worn at the time of disaster. Alpha-particles can also contaminate open wounds, which may be common in any nuclear event, and hence become internalized, causing internal contamination. They can also be inhaled or ingested through contaminated foodstuffs, causing further internal contamination.

Acute Radiation Syndrome

In a nuclear event involving terrorism, how much radiation would be lethal to human beings? Almost everyone would perish within about 7 days if exposed to 10 Gy (1000 rads). Higher doses would kill much sooner. Whole-body exposure of 100 Gy or 10 000 rads would kill within 24 h, but local exposures of much greater amounts may be tolerated.

Case Study

On August 21, 1945, H K Daghlian, Jr. (1921–1945), a scientist who was involved in the Manhattan project to manufacture the first ever atomic bomb, accidentally dropped a tungsten carbide brick (from his left hand) into the center of an assembly containing ^{239}Pu, with the result that the assembly became supercritical for a fraction of a second. Although he realized his mistake and removed the brick immediately with

Table 5 Fifty major events in the history of bioterrorism and biowarfare

No.	Date	Event
1.	Mythological	In Indian mythology, the king of demons, Ravana, entangled the heroes Lord Rama and his brother Lakshamana with snakes – a phenomenon known in the vernacular as nagapash. Lord Rama and his brother were helped by a mythological bird Garuda, an enemy of the snakes, to get rid of them
2.	1500 BC and earlier	Ancient tribes hurled live beehives and hornets' nests into their enemy camps. The sacred text of the Maya in Central America, the Popol Vuh, described an ingenious bee boobytrap used to repel besiegers
3.	400 BC	Scythian archers used their arrows after dipping them in decomposing cadavers, feces, or blood mixed with manure
4.	Third century BC	During the Carthaginian wars (first Carthaginian war 264–241 BC, second Carthaginian war 218–201 BC), the Greco-Romans deliberately contaminated food and water sources with animal carcasses
5.	184 BC	Hannibal, the unorthodox Carthaginian military general, ordered earthen pots filled with deadly snakes to be thrown on to the decks of Perganum ships during their naval battle against King Eumenes II of Perganum. Hannibal won the war
6.	27 BC to fifth century AD	During the days of the Roman Empire, the Roman military would put bodies of dead animals into their enemy's drinking water
7.	c. 1000 AD	Mahmud of Ahazna, during the siege of Sistan in Afghanistan, ordered his men to catapult sacks of serpents into the stronghold to terrorize the defenders of the fort
8.	1155	The German king and Holy Roman Emperor Frederick I Barbarossa (1123–1190) used the bodies of dead soldiers to contaminate drinking wells during the battle of Tortona
9.	1171	Emperor Manuel of the Italian city of Ragusa deliberately delayed discussions with an invading army of Venetians (under the command of the Doge of Venice), knowing fully well that they would eventually require water from previously contaminated wells. The Venetian fleet was forced to winter at Chios, where they eventually used the contaminated water. The fleet contracted a contagious disease and was forced to return to Venice
10.	1339	The French cast dead horses and other carrion from their war engines into the castle of Thin on the Scheldt river during its storming
11.	1346	The attacking Tartar forces catapulted their own plague-infected cadavers into besieged Caffa, a well-fortified, Genoese-controlled port on the Crimean coast (now Feodosia, Ukraine). The inhabitants of the city are reported to have ''died wildly''
12.	1422	At the ineffectual siege of Carolstein, Commander Corbut had the bodies of the killed besiegers and 200 cartloads of manure thrown into the town. A great number of defenders fell victim to the resulting fever
13.	1495	During the Naples campaign, Spanish soldiers gave the French forces wine infected with blood from leprosy patients. They were unsuccessful in transmitting leprosy
14.	Fifteenth century	The Spanish conqueror Francisco Pizarro (1475–1541) presented indigenous peoples of South America with variola-contaminated clothing
15.	1650	The Polish artillery general Siemenowics suggested constructing hollow spheres, which could be filled with slobber from rabid dogs (or other substances that could poison the atmosphere and cause epidemics) and thrown in enemy camps. His idea was never put into practice
16.	1683	Anton van Leeuwenhoek (1632–1723), Dutch biologist and microscopist, saw and described bacteria. This was a watershed year in the history of biological warfare, as from now onwards, there would be a conscious shift away from using large animals like snakes (e.g., Hannibal in 184 BC) to microbes (e.g., anthrax spores in 2001)
17.	1710	Russian troops battling Swedish forces hurled the bodies of dead plague victims on to their enemies
18.	1754–67	During French and Indian wars, Sir Jeffery Amherst ordered smallpox-laden blankets to be given to indigenous Indians loyal to the French. The resulting epidemic led to the loss of Fort Carillon to the English
19.	1763	Captain Simeon Ecuyer of the Royal Americans, fearing an attack from Native Americans, acquired variola virus-contaminated blankets and handkerchiefs and distributed them to the Native Americans in a false gesture of good will (June 24). He recorded in his journal that ''he hoped it would have the desired effect.'' Several outbreaks of smallpox occurred in tribes in the Ohio region
20.	1785	Tunisian tribes that conquered the low areas of Tunisia became infected with plague. They tried to use this calamity to their advantage by throwing clothes from these plague victims over the fortification's wall in order to infect the Christians at La Calle
21.	1863 (July)	During the American Civil War, the Confederate army under the command of General Joseph E. Johnston drove farm animals into ponds and shot them. General William Tecumseh Sherman of the Union army had to haul the stinking carcasses out of the water, and this delayed his army's advances
22.	1870	During the siege of Paris in the Franco-Prussian war, a French physician proposed that smallpox-infected clothes be abandoned when the French forces retreated so that the attacking Prussian forces would become infected. However, the proposal was never put into action

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No.	Date	Event
23.	1892 (February)	Sir Arthur Conan Doyle published *The Adventure of the Speckled Band* in the Strand magazine, with nine illustrations by Sidney Paget. In this story, Dr. Grimesby Roylott terrorized his stepdaughter Helen Stoner by putting snakes in her room. This is perhaps the earliest fictional story dealing with bioterrorism
24.	1915	A German-American doctor in the USA, with the support of the Imperial German government, produced a quantity of *Bacillus anthracis* and *Pseudomonas mallei* (glanders). It was used to infect 3000 horses, mules, and cattle being sent to the Allies in Europe
25.	1917–1918	About 200 mules died of anthrax and glanders, probably as a result of infection by German saboteurs in Argentina
26.	1925	Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare, was signed at Geneva on June 17. It is popularly known as the 1925 Geneva Protocol
27.	1932	The Japanese Army created Unit 731, a biological weapons research center in Beiyinhe, Manchuria, under the command of Major Ishii Shiro. In late 1937, the unit transferred to a larger facility at Ping Fan near Harbin. It continued to operate there until it was burned in 1945. During this time approximately 1000 autopsies were performed in this unit on human guinea pigs, mostly prisoners and Chinese nationals, who had been killed with aerosolized anthrax
28.	1941	The USA started a biological warfare research program at Camp Detrick, MD, in response to a perceived German biological warfare program threat (just as their nuclear program was in response to a perceived German bomb)
29.	1942 (July)	Major Ishii led a biological weapons expedition to Nanking, China, where he distributed chocolates filled with anthrax spores to youngsters
30.	1945	The Japanese stockpiled an estimated 400 kg of anthrax to be used in a specially designed fragmentation bomb
31.	1957	The UK became one of the first nations voluntarily to halt research on offensive biological weapons. It had earlier manufactured 5 million anthrax-impregnated cattle cakes and a 225-kg (500-lb) anthrax bomb. By 1942, the UK had developed strategic amounts of anthrax. Their experiments on Gruinard Island made it uninhabitable for almost four decades because of high-level anthrax contamination
32.	1966	A Japanese research bacteriologist contaminated food with microbes, causing several outbreaks of typhoid fever and dysentery in Japanese hospitals. Over 100 people were affected, of whom four died
33.	1969	President Nixon put a stop to all offensive biological and toxin weapons research and production by an executive order
34.	1970	In February, in Canada, a postdoctoral student in parasitology contaminated the food of four of his roommates with *Ascaris suum*, a pig parasite, causing them to become seriously ill. This relatively simple method could be used by terrorists
35.	1971–1972	Between May 1971 and May 1972, the USA destroyed all stockpiles of biological agents and munitions in the presence of monitors. Agents destroyed included botulinum toxin, staphylococcal enterotoxin B, Venezuelan equine encephalitis virus, and bacteria such as *Bacillus anthracis*, *Francisella tularensis*, *Coxiella burnetti* and *Brucella suis*
36.	1972	Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction (popularly known as Biological Weapons Convention or BWC), was signed on April 10 and ratified by more than 140 nations to date
37.	1978 (August)	Vladimir Kostov, a Bulgarian state radio and television correspondent, and a defector to Paris, was shot in the back with a small pellet of ricin, a Centers for Disease Control category B biologic agent, on August 26. He was admitted to hospital for 12 days with a fever, from which he recovered. On September 26, exactly 1 month later, the offending metal pellet was removed from his back
38.	1978 (September)	Georgei Markov, a 49-year-old Bulgarian defector to the UK, was shot in the back of his right thigh on September 7, with a pellet of ricin. He died 4 days later on September 11. This is the first known case of successful assassination with ricin. Both Kostov and Markov had been close to Communist President Shivkov
39.	1979	In April and May, an outbreak of pulmonary anthrax occurred in the Soviet city of Sverdlovsk, now Yekaterinberg. It was widely believed to be due to accidental release of anthrax spores from a Russian biological weapons laboratory. The tightly regulated Communist Russian regime however continued maintaining that it was an outbreak of intestinal anthrax, resulting from contaminated black-market meat. After the dissolution of erstwhile Soviet Union, US and Russian scientists carried out a detailed study in 1992–1993 in Sverdlovsk, and found that it was indeed an outbreak of pulmonary anthrax due to the release of spores from a biological weapons laboratory. At least 68 civilians downwind of the release had died, and 15 farm animals had to be slaughtered. An undisclosed number of military casualties also occurred

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No.	Date	Event
40.	1974–1981	Mycotoxins were used as biological warfare agents in Southeast Asia and Afghanistan. The toxins were delivered by aerial spraying, and fell in large droplets much like rain. The color of the spray gave rise to the popular terminology ''yellow rain.'' In Laos alone, 6500 deaths were attributed to ''yellow rain''
41.	1984 (spring)	T-2 toxin (a mycotoxin) was recovered from Iranian soldiers attacked by Iraqi weapons
42.	1984	Members of a religious commune intentionally contaminated salad bars with *Salmonella typhimurium* in the Dalles, OR, USA. The idea was to keep members of the public at home, so that they couldn't come out to vote for Wasco county commissioners on November 6, 1984 (the outcome of the elections could have been against the interest of the commune). A total of 751 persons were affected
43.	1990 (June)	Nine people in Edinburgh, Scotland, were infected with *Giardia lamblia*, due to intentional contamination of water supply of their apartment building
44.	1990 (December)	Iraqis filled 100 R400 bombs with botulinum toxin, 50 with anthrax and 16 with aflatoxin. In addition, 13 SCUD warheads were filled with botulinum toxin, 10 with anthrax, and 2 with aflatoxin
45.	1991	In January, during the war with Kuwait, Iraq deployed R400 bombs and SCUD missiles loaded with biological agents to four locations. However they were never used during the war
46.	1992	Executives of the Aum Shinrikyo (Supreme Truth) cult in Japan, sent members to former Zaire ostensibly to treat Ebola victims, but their actual aim was to obtain Ebola virus for weapons development
47.	1995	Larry Wayne Harris (a resident of Lancaster, OH), a lab technician and a member of the American Society for Microbiology, ordered three vials of freeze-dried *Yersinia pestis* from the American Type Culture Collection (ATCC). He was found to be associated with extremist groups such as Aryan Nations and the Christian Identity Church. His intentions remain unclear to this day. Harris was convicted of wire fraud (for having lied to ATCC about being associated with a fictitious research laboratory), and received a 6-month suspended sentence
48.	1996 (October 29 to November 1)	An outbreak of shigellosis occurred in a medical center in Texas. Twelve laboratory workers experienced severe gastrointestinal illness after eating muffins and doughnuts anonymously left in their break room between the night and morning shifts of October 29. The eatables were contaminated with the medical center's own stock culture of *Shigella dysenteriae* type 2. The motive and method of contamination remain unknown
49.	1998	A report in January revealed that Iraq had sent approximately a dozen biological warfare researchers to Libya. The aim was to equip Libya with biological weapons also
50.	2001 (October to November)	After the September 11, 2001 attack on the World Trade Center and the Pentagon, anthrax spores were sent by mail to unsuspecting people. About 22 cases of anthrax were reported between October 4 and November 20, of which there were at least 5 deaths. The release caused such mass hysteria that at least 10 000 individuals were advised to undergo prophylaxis

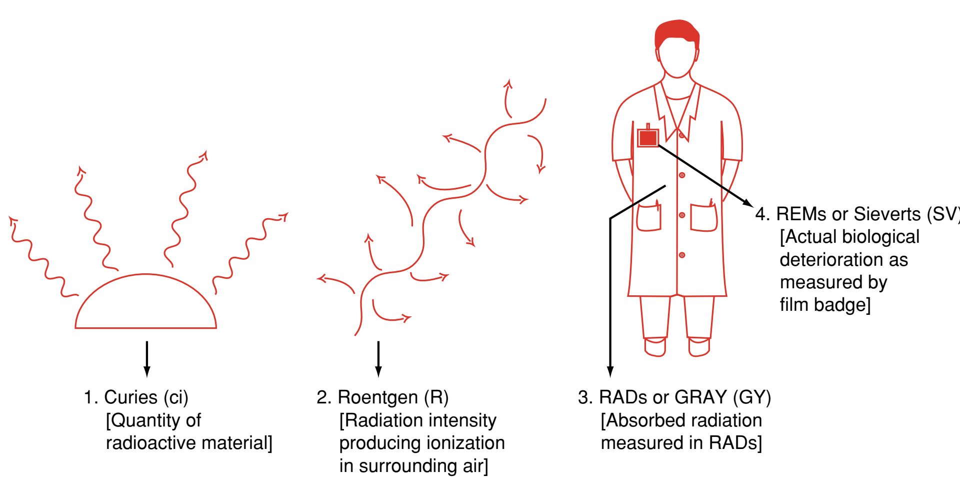

Figure 1 Interrelationships between various radiation units.

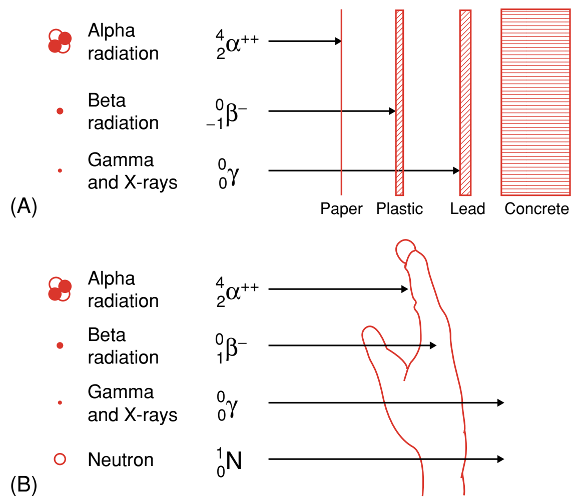

Figure 2 Penetrating distances of various radiations: (A) non-living matter; (B) living matter.

his right hand, both his hands received severe amounts of radiation. It has been estimated that his left hand, that had held the fallen brick, possibly received 5000–15 000 rem and the right hand, used to push the brick away, was exposed to a considerably higher dose, in the range of 20 000–40 000 rem. Daghlian suffered from acute radiation sickness and died on September 15, 1945, 26 days later. A similar accident occurred with another scientist, L Slotin (1910–1946), on May 21, 1946. He died 9 days later on May 30.

In general whole-body exposures are considered sublethal at <2 Gy (<200 rad), lethal at 2–10 Gy (200–1000 rad), and supralethal at >10 Gy (>1000 rad).

After acute exposure to radiation, most individuals suffer from acute radiation syndrome (ARS). Rapidly dividing cells are most prone to damage by radiation. These include those within the hemopoeitic system, lining cells of the gastrointestinal tract, cells within the reproductive system, and fetal cells.

Signs and symptoms of ARS occur in four distinct phases, the duration and onset of which depend on the exposure dose.

Prodromal Phase

Depending on the exposure, this can commence from a few minutes to a few hours after exposure. The symptoms include nausea, vomiting, and anorexia. At higher doses, additional symptoms such as fever, prostration, respiratory problems, erythema, conjunctivitis, and increased excitability are common.

Latent Phase

With doses of 200–300 rad, the symptoms will regress within 2–4 days, to be followed by a latent period lasting 2–3 weeks. The latent phase may be absent if the dose is high. During the latent phase, critical cell populations such as leukocytes and platelets begin to decrease.

Illness Phase

Overt symptoms such as nausea and vomiting return. Bleeding may be particularly troublesome.

Recovery or Death Phase

Recovery occurs if the dose is less than 500 rad. The probability of recovery is less if the dose was higher. A dose higher than 1000 rad would cause death in most cases.

Considerations of the Dead

In any nuclear scenario involving terrorism, the forensic pathologist would have to handle a number of bodies that are contaminated with radioactive nuclides. This calls for special considerations. Contaminated bodies may not be kept in a hospital morgue, because various pathology facilities could become contaminated. A temporary morgue must be set up. A mobile chilling unit, as used in the food industry, placed strategically on the hospital grounds, may be the ideal solution. It is important to note that the requirement is a chilling unit, not a freezing unit. With freezing, some forensic evidence can be lost.

Autopsy on Radioactive Bodies

Opening up the dead body would necessarily release radionuclides that had been inhaled or ingested. Shielding of the pathologist is a concern; this could be achieved by wearing a radiology lead apron (0.5 mm lead or equivalent thickness). Long-handled instruments may be helpful in keeping the extremities away from the radioactive organs. Double gloves, hair and foot covers, splashguards, and fluid-resistant long-sleeved jump suits should be used to minimize radiation risk. A problem of special concern is a cut produced during autopsy. The wound should be debrided and rinsed thoroughly to remove as much radioactivity as possible. Placing plastic-backed paper on the floor around the autopsy table would facilitate decontamination. For similar reasons autopsy instruments must be wrapped in plastic.

Processing of Radioactive Tissues

If tissues are preserved for histology, it must be kept in mind that they may be radioactive. Storage of such tissues may require leaded containers, which may be available from the radiation safety officer. During processing of such tissues, usual precautions such as minimal handling time, double-gloving, wearing of protective apparel, and use of long-handled instruments would apply.

Embalming of Radioactive Bodies

If the deceased has to be transported to a distant location (such as, for example, to a different country), the body would need to be embalmed, and this would pose special challenges to the embalmer. Fluids should be removed by means of a trocar and tubing in such a manner that the embalmer is not required to hold either item or be close to the body while the fluid is draining. Urine, pleural, and ascitic fluid may be radioactive and may be drained directly into the sewage system, but only after consultation with the radiation safety officer.

Decontamination of Instruments

After the autopsy, the instruments and clothing must be cleaned and decontaminated by repeated soaking in water with detergents. Sometimes an item may need to be kept aside for radioactivity to minimize by the usual decay process. Such items must be stored in a plastic bag with proper labels (including the date the item became contaminated and level of activity), and the bag stored in a remote location.

Disposal of Radioactive Bodies

Contaminated bodies must not be cremated, because nuclear material cannot be destroyed by fire. Cremating such bodies can actually disseminate radioactive material in the environment along with the fumes. In internally contaminated bodies (where radionuclides have entered the body through inhalation or ingestion), cremation may facilitate dispersal of radioactive nuclides in the environment. In addition, cremation would produce contaminated ash, which will again pose problems of disposal. Burial may be the ideal solution, but can cause problems if the religion of the deceased does not allow this. Counseling of a deceased's relatives and of the relevant religious heads must be attempted.

Forensic Considerations

Clues that could be suggestive of possible radiological or nuclear activity include the presence of unusual material that seems to emit heat with no sign of any external heat source and the presence of glowing or luminescent material or particles. Understandably the most important forensic question in such scenarios would be, "who did this act?" In nuclear detonations, this may not be easy or possible, since it would cause widespread destruction of the scene. In other scenarios, such as placing of radioactive materials at public places , usual crime-scene and forensic protocols must be employed.

Bioterrorism

Bioterrorism is defined as the illegal and illegitimate use of biological organisms (e.g., animals, plants, and microorganisms, including bacteria and viruses), dead or alive, in their natural state or after genetic modification, and/or their products (e.g., blood, toxins, a physiologically active protein or peptide), to produce fear, alarm, or dread in the general public with or without illness or death.

The Lure of Bioterrorism

Why would terrorists choose bioterrorism at all? Primarily, because it is cheap. Only about \$10 000 worth of equipment and a 5×5 m room are needed. Furthermore, to produce mass casualties (killing greater than 50% of people in an area), terrorists would need to spend \$2000 per km^2 if they used conventional weapons, \$800 if they used nuclear weapons, \$600 if they used chemical weapons, and just \$1 if they used biological weapons. Alternatively, using the same monetary resources, terrorists could inflict mass casualties in an area 2000 times larger if they chose to use biological weapons instead of conventional weapons such as bombs. Another lure of bioterrorism is that its onset is very insidious, and it can often be confused with a natural event. A chemical or a nuclear calamity would automatically imply an intentional attack by someone, most probably a terrorist group, but a sudden onset of, say, plague may not arouse any suspicion for quite some time. In addition, a bioterrorism event could be self-perpetuating because of contagiousness (Table 6).

Bioterrorism Agents

It fairly soon became obvious to nations engaged in biowarfare research that, of the thousands of microbial agents found in nature, only 20 could survive long enough in the environment to be inhaled by their unsuspecting victims. These 20 agents were the most likely agents to be used in biowarfare programs. The Centers for Disease Control and Prevention (CDC) at Atlanta classifies the potential bioterrorism agents into three categories – A, B, and C – depending on several key factors (Table 7, Figure 3).

Category A Agents

Category A organisms are the most dangerous bioterrorism agents, as can be seen in Table 8. They can be deadly in extremely low doses (Figures 4–6).

Category B and Category C Agents

These are less likely to be used by terrorists in view of their lower mortality rates. They are also less easy to disseminate. A listing of these agents is given in Table 7.

Forensic Considerations

It is very important to tell a bioterrorism event from a natural disease outbreak. Some indications that may arouse suspicion are: (1) the presence of an

Table 6 Why bioterrorism is an attractive option for terrorists

1. Cheaper, per casualty. Has been called the ''poor man's atomic bomb''
2. More effective, delivery methods simpler
3. High mortality (in Ebola, as high as 90%)
4. Deployment silent, insidious onset, incubation periods make perpetrators difficult to identify
5. Contagious, exponential spread by asymptomatic and undiagnosed carriers, casualties may multiply rapidly if prompt action not taken
6. Humans no more immunized against some agents such as smallpox
7. Genetic manipulation of microorganisms can create novel forms, which could be virtually invincible
8. Mere mention of certain diseases such as smallpox, anthrax or plague cause terror in people

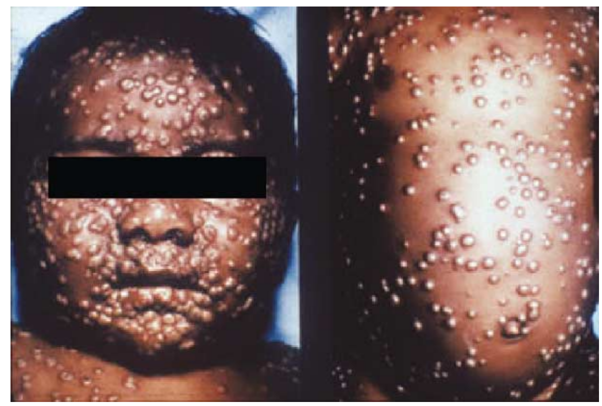

Figure 3 Rash on the face and body in smallpox. Courtesy of WHO.

Table 7 The critical bioterrorism agents according to CDC, Atlanta (http://www.bt.cdc.gov/agent/agentlist–category.asp)

Category	Description	Agents
Category A	These are the high-priority agents and include organisms that pose a risk to national security because they: 1. can be easily disseminated or transmitted from person to person; 2. result in high mortality rates and have the potential for major public health impact; 3. might cause public panic and social disruption; and 4. require special action for public health preparedness	1. Variola major (smallpox) 2. Bacillus anthracis (anthrax) 3. Yersinia pestis (plague) 4. Clostridium botulinum neurotoxins (botulism) 5. Francisella tularensis (tularemia) 6. Viral hemorrhagic fevers (filoviruses [e.g., Ebola, Marburg] and arenaviruses [e.g., Lassa, Machupo])
Category B	The second-highest priority agents include agents that: 1. are moderately easy to disseminate; 2. result in moderate morbidity rates and low mortality rates; and 3. require specific enhancements of CDC's diagnostic capacity and enhanced disease surveillance	1. Coxiella burnetti (Q-fever) 2. Brucella spp. (brucellosis) 3. Burkholderia mallei (glanders) 4. Burkholderia pseudomallei (Melioidosis) 5. Chlamydia psittaci (Psittacosis) 6. Rickettsia prowazekii (Typhus fever) 7. Alphaviruses: VEE, EEE, WEE (Venezuelan, Eastern, and Western encephalitis) 8. Food safety threats (e.g., Salmonella species, Escherichia coli O157:H7, Shigella) 9. Water safety threats (e.g., Vibrio cholerae, Cryptosporidium parvum) 10. Ricin toxin from Ricinus communis (castor beans) 11. Epsilon toxin from Clostridium perfringens 12. Staphylococcal enterotoxin B
Category C	Emerging pathogens that could be engineered for mass dissemination in the future because of: 1. Availability; 2. Ease of production and dissemination; and 3. Potential for high morbidity and mortality and major public health impact	1. Nipah virus 2. Hantaviruses 3. Tick borne hemorrhagic fever viruses 4. Tick borne encephalitis viruses 5. Yellow fever virus 6. Multidrug-resistant Mycobacterium tuberculosis

Table 8 Category A bioterrorism agents and their infectivity

S. no.	Microorganism	Illness caused	Estimated infective dose (as in an aerosol)	Incubation period	Major symptoms	Fatality rate
1.	Variola major	Smallpox	10–100 organisms	Classically described as between 7–17 days. Could be upto 19 days or possibly longer	Illness begins with 2–3 days of high fever. Pox lesions, which are initially macular, but go on to become papular and then pustular. Scabs form in 8–9 days, and separate in 14 days, leaving a permanent hypopigmented scar	30%
2.	Bacillus anthracis	Anthrax	8000–50 000 spores	1–5 days	Three main forms: 1. **Cutaneous anthrax**: Most common form, representing 95% of all cases. Skin shows the classic leathery, depressed, painless black eschar that falls off within 1–2 wk 2. **Gastrointestinal anthrax**: Nausea, vomiting, fever, severe abdominal pain, hematemesis, hematochezia, melena, and/or ascites 3. **Inhalational anthrax**: Dyspnea, chest pain, nonspecific influenza-like symptoms such as fever, chills, diaphoresis and headache	80–90%
3.	Yersinia pestis	Plague	100–500 organisms	2–3 days	Three main forms: 1. **Bubonic plague** accounting for over 75% of cases show tender lymph nodes (buboes) 2. **Septicaemic plague** shows hypotension and multiorgan dysfunction 3. **Pneumonic plague** shows predominantly respiratory symptoms such as cough, hemoptysis and chest pain	Without antibiotic treatment, very high
4.	Clostridium botulinum	Botulism	0.001 microgram/ kg of body weight	1–5 days	Weakness, dry mouth, hypotension, gastrointestinal distress, paraesthesias	Without antibiotic treatment, very high
5.	Francisella tularensis	Tularemia	10–50 microorganisms	2–10 days	Mainly six clinical forms: pulmonary, glandular, ulceroglandular, oculoglandular, oropharyngeal, and typhoidal. However, the most important clinical manifestation of intentionally released tularemia is the appearance of pneumonia	Variable
6.	Hemorrhagic fever viruses	Hemorrhagic fevers (viral)	1–10 organisms	4–21 days	Fever, rash, jaundice, shock	Variable

Figure 4 Man infected by Bacillus anthracis. Courtesy of WHO, © Eric Miller.

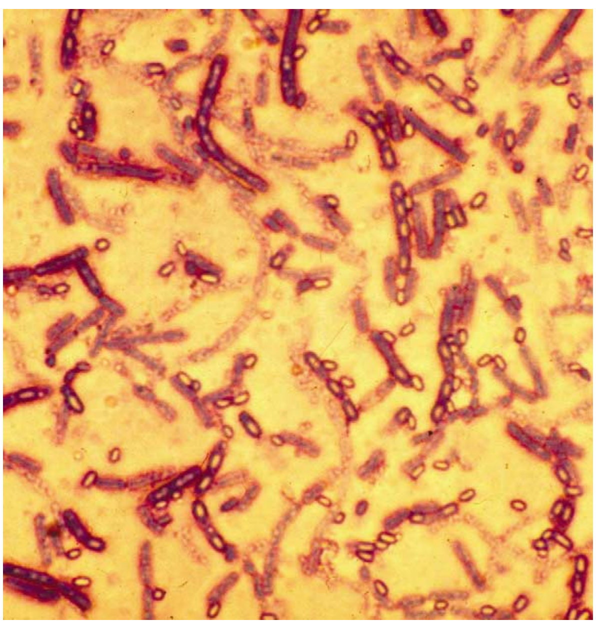

Figure 5 Microscope photograph of spores and vegetative cells of anthrax bacterium Bacillus anthracis. Courtesy of WHO, © Eric Miller.

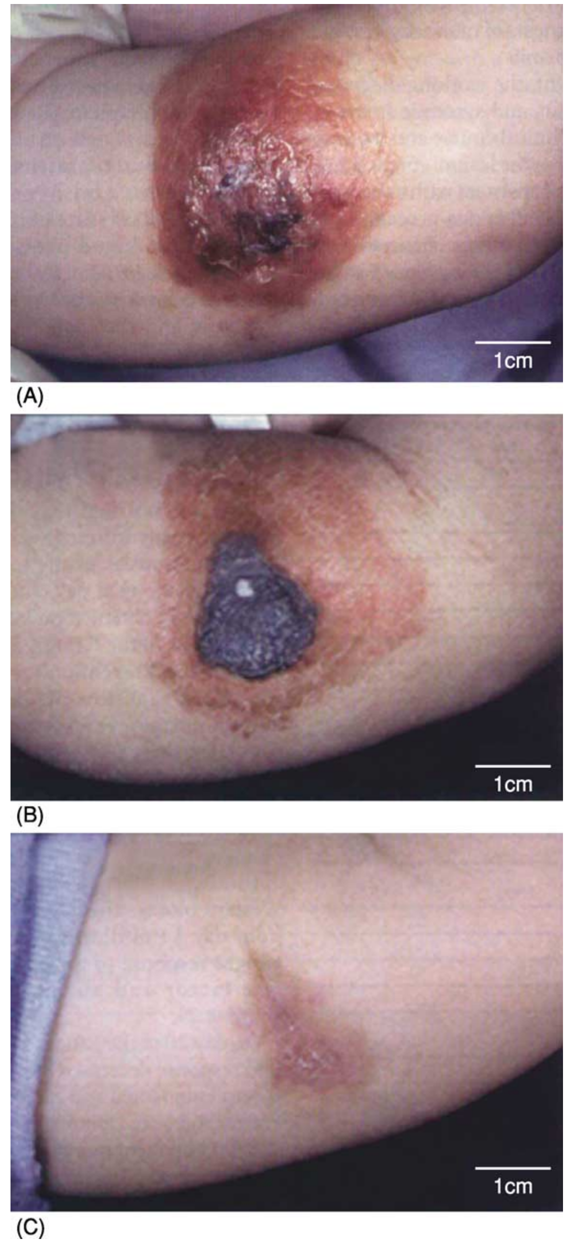

Figure 6 The lesion of cutaneous anthrax: (A) hospital day 5; (B) hospital day 12; and (C) 2 months after discharge. Courtesy of Journal of American Medical Association and W. Bockowsky (2002) 287: 869–874.

unusual number or cluster of illnesses; (2) abandoned spray devices; (3) atypical clinical presentation (e.g., a case of inhalational anthrax when cutaneous anthrax would be much more common); (4) confinement of an illness to a limited geographical area; (5) presence of dead fish or birds, which cannot be otherwise accounted for; (6) occurrence of a disease in an unusual season (e.g., Q fever usually occurs in the spring when sheep are born; a case of Q fever in winter should arouse suspicion); (7) incidents being concurrent with other terrorist activities (the occurrence of anthrax attacks immediately after the US World Trade Center attacks, for example); (8) illnesses with predominantly respiratory symptoms, fever, or gastrointestinal complaints; (9) unusual swarms of insects; and (10) unusual antibiotic resistance patterns.

Conclusion

The capacity to wage nuclear or biowarfare terrorism is available to nations and to others wishing to misuse them. The need for vigilance and an understanding of the theoretical issues behind them and the practical implication of such modes of attack has never been higher.

See Also

Terrorism: Medico-legal Aspects; Suicide Bombing, Investigation

Further Reading

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Suicide Bombing, Investigation

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Introduction

Injuries or deaths from explosions due to bombing have generally only been occasionally encountered in clinical and forensic pathological practice. However, with the recent rise in militant terrorism, there has been an increase in the incidence of terrorist bombings, and the forensic pathologist or medical examiner is likely to be confronted with such cases.

Suicidal terrorism in one form or other has existed for years. It has been used by the Jewish sect of Zealots in Roman-occupied Judaea and by the Islamic Order of Assassins (hashashin) during the early Christian crusades. During World War II, the Japanese crashed explosive-laden warplanes on American ships, popularly known as "kamikaze" (divine wind). About 2000 of these suicide bombers rammed fully fueled fighter planes into more than 300 American ships in April 1945, in the Battle of Okinawa. About 5000 Americans were killed in those suicidal attacks. This has been the most costly naval battle in US history. More recently, suicidal bombing has been used increasingly to make a political statement e.g., on 21 May 1991, Rajiv Gandhi, former Prime Minister of India, and 16 others were killed by a female suicide bomber at Sriperumbudur, near Chennai.

In general, deaths by bombings can be classified as (1) suicidal, (2) homicidal, (3) accidental, and (4) suicidal-homicidal (terrorist).

In suicidal bombings, the main intention of the bomber is to kill himself or herself. The bomber takes care to choose an isolated spot, such as the interior of his/her own house, as he/she is not interested in injuring anyone else. Homicidal bombing is represented by cases where vehicles loaded with explosives are left at crowded places. Accidental explosions can occur in several situations such as bursting of gas tanks or when fire is kindled in areas where explosives are stored. Finally, suicidal-homicidal (terrorist) bombings are those where an individual either straps explosives on his/her body and detonates it in crowded places, or rams an explosive-laden vehicle into a crowd of people or into a building. An individual who straps explosives on his/her body may be referred to as a "strapped