TERRORISM

Contents

Medico-legal Aspects

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Introduction

Very few words today have more meanings than the word "terrorism." In a 1983 study Alex Schmid compiled all the definitions, and found there were a minimum of 109. It is believed that today more than 200 definitions of this word may exist (some representative definitions are given in Table 1). Notwithstanding the definition problem, most people think that they can recognize a terrorist act when they see one. The core meaning of the term is clear to most of us, even if its exact frontiers are not. If in the name of some political or ideological cause, a bomb goes off in an aircraft, a plane is hijacked, a parliament building is attacked, a suicide bomber blows himself up in a crowded area killing innocent citizens, or an airliner is rammed into a high-rise building, most people justifiably recognize it as terrorism. In the modern era, terrorist acts manifest in a number of ways such as torture, arson, robbery, kidnapping, hostage-taking, murder, bombings, aircraft sabotage, hijacking, and the use of weapons of mass destruction (WMD) such as chemical and biological agents. "Target Blue" ambush slayings of police officers may also be resorted to by some groups. Police officers may be selected at random, not because of who they are, but of what they represent. However the acts which are encountered most frequently, and those in which a forensic scientist/pathologist is involved in one way or the other are bombings, aircraft sabotage, and, to some extent, use of chemical and biological agents.

The term "antiterrorism" describes defensive measures that reduce the vulnerability of individuals and property to a terrorist incident. "Counterterrorism" is a proactive step describing offensive measures taken to prevent, deter, and respond to terrorism.

Torture

Torture as a weapon of terrorism is not often seen now, although at one time organizations such as the Irish Republican Army (IRA) resorted to this very frequently. Small groups may still want to resort to this simple but effective technique to make a political statement. Common methods of torture include beating, whipping, burning and scalding, sexual torture, electrical torture, and certain specialized procedures such as "falanga" (beating of the soles of feet with canes or rods), "knee-capping" (a technique developed by the IRA to cripple rather than kill informers; the victim is shot through the knees, from posteriorly generally), "submarining" (repeated dipping of the victim in foul liquid such as sewage or urine mixed with feces), and "telefono" (repeated slapping of the sides of the head with open palms; this ruptures the tympanic membranes and damages the inner ear). It is vital for forensic physicians and forensic pathologists to be able to distinguish signs of torture.

Terrorist Bombings

Bombing is undoubtedly the most common method employed by terrorists. Typically the bomb is left indoors in public places or placed in a vehicle ("blind date" bombings). From 1969 till 1983, there were at least 220 incidents of terrorist bombings worldwide, which killed 463 persons and injured an additional 2894. Since then incidents of bombings and resulting deaths have increased exponentially. In the USA, there was an increase by 400% in the bombing attempts from 1984 (803 bombing incidents) till 1993 (3163 bombings). A number of devices have been used by terrorists. These include improvised explosive devices (IED), napalm bombs, Molotov cocktails, and a number of other such devices. Napalm bombs and Molotov cocktails are basically incendiary bombs, which primarily cause burns rather than explosive effects. Napalm generates a temperature of 1100 °C (1800 °F), and consists of a combination of oil and gasoline in a jelly form. Phosphorus and magnesium are sometimes added to the mixture, which can raise the effective temperature as high as 2150 °C (3500 °F), or higher.

Table 1 Some representative definitions of terrorism and terrorist acts

1. Terrorism is premeditated, politically motivated violence perpetrated against noncombatant targets by subnational groups or clandestine state agents, usually intended to influence an audience. (US State Department)
2. Terrorism is the unlawful use of force or violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives. (FBI)
3. An action of violence is labeled ''terrorist'' when its psychological effects are out of proportion to its purely physical result. (Raymond Aron)
4. It is not possible to give a precise definition of terrorism or to lay down what constitutes terrorism. But ... it may be possible to describe it as use of violence when its most important result is not merely the physical and mental damage of the victim but the prolonged psychological effect it produces or has the potential of producing on the society as a whole ... If the object of the activity is to disturb harmony of the society or to terrorize people and the society, with a view to disturb the even tempo, tranquility of the society, and a sense of fear and insecurity is created in the minds of a section of the society or society at large, then it will, undoubtedly be held to be a terrorist act .... (Supreme Court of India, in *Mohd. Iqbal M. Sheikh* v. *State of Maharashtra* (1998) 4 SCC 494)
5. Terrorism is the use or threatened use of force designed to bring about political change. (Brian Jenkins)
6. Terrorism constitutes the illegitimate use of force to achieve a political objective when innocent people are targeted. (Walter Laqueur)
7. A terrorist act is an act done by using weapons and explosive substances or other methods in a manner as to cause or likely to cause death or injuries to any person or persons or loss or damage to property or disruption of essential supplies and services or by any other means necessary with intent to threaten the unity and integrity of India or to strike terror in any section of the people. (Prevention of Terrorism Act 2002 [India])
8. Terrorism is the premeditated, deliberate, systematic murder, mayhem, and threatening of the innocent to create fear and intimidation in order to gain a political or tactical advantage, usually to influence an audience. (James M. Poland)
9. Terrorism is the unlawful use or threat of violence against persons or property to further political or social objectives. It is usually intended to intimidate or coerce a government, individuals or groups, or to modify their behavior or politics. (US Vice-President Gore's Task Force, 1986)
10. Terrorist acts are acts where they are committed intentionally by individuals or groups against one or more countries or their institutions or population in order to threaten them and seriously undermine or even destroy their political, economic or social structures. (The European Commission, September 2001)
11. Terrorist acts are criminal acts intended or calculated to provoke a state of terror in the general public, a group of persons or particular persons for political purposes. These acts are in any circumstance unjustifiable, whatever the consideration of a political, philosophical, ideological, racial, ethnic, religious or other nature that may be invoked to justify them. (United Nations General Assembly, 1996 [GA Res. 51/210], commonly referred to as the ''GA 1996 definition of terrorism'')
12. The intentional use of violence – real or threatened – against one or more noncombatants and/or those services essential for or protective of their health, resulting in adverse health effects in those immediately affected and their community, ranging from a loss of well-being or security to injury, illness, or death. (A Proposed Universal Medical and Public Health Definition of Terrorism, proposed by 21 medical specialists from 16 different countries in *Prehospital and Disaster Medicine* 2003; 18(2): 47–52.)

The Molotov cocktail has been a favorite of guerillas and terrorists. It consists of a bottle full of gasoline and a rag which serves as a wick. The wick is lit and the bottle is thrown at the target. Various chemicals and acids may be added to this cocktail to increase its destructive potential.

Letter bombs are explosive devices sent through the mail in parcels. They consist of the detonating fuse, the explosive, the electronics for initiation and the energy source. They cause injuries – sometimes fatal – to the unsuspecting person who opens such parcels.

For a forensic pathologist investigating terrorist bombings, it is important to realize that terrorist explosions may kill or maim in a number of ways. Terrorist bombs typically are small. They are typically delivered either in suitcases or parcels, weigh in the range between 1 and 15 kg (2 and 30 lbs), or in vehicles (car bombs), weigh up to 200 kg (500 lbs). What makes them deadly is not their size, but the fact that (1) they can be hidden effectively, often at places where a large number of people congregate and (2) they are often charged with penetrating devices such as nuts, bolts, and nails which can fly about and cause injuries, much like missiles from a gun. Blast wave generation from the bomb can also cause damage, especially to air-containing organs such as lungs, ears, and intestines; since it is the gas–solid interphase where most of the blast energy is dissipated. A blast may also throw a victim about, causing him to strike surrounding objects. Conversely surrounding objects may also fly around and cause injuries to the victim.

A blast is essentially an expanding hot sphere of gas generating from the high explosive contained within the bomb. It can have an initial pressure of approximately 6.895×10^{10} pascals (10 million PSI, 6.805×10^{5} atm). Human beings are endangered at 6.895×10^{5} pascals (100 PSI, 6.805 atm) or above. The destructive capacity of the blast is due to this force (known as blast loading). This pressure (or the blast load) dissipates rapidly into the surrounding medium causing in quick succession the following three phases: (1) a positive pressure phase, (2) a negative pressure phase (lasting about five to six times the duration of the positive pressure phase), and (3) the mass movement of wind (blast wind) (Figure 1). Most of the damage is due to the positive pressure component of the blast. The negative pressure component is always much weaker than the positive pressure component, and can never be greater than 15 psi, since this would produce a perfect vacuum. The positive pressure component however can theoretically rise to any value, depending on the amount of high explosive used.

Blast front is the term used to denote the leading edge of the blast wave; blast overpressure denotes the maximum positive pressure achieved during the positive pressure phase; and blast strength denotes the ratio of blast overpressure to the ambient atmospheric pressure. Blast front propagates at supersonic speeds ranging from 3000 to 8000 $m\,s^{-1}$ (speed of sound in air is 340 $m\,s^{-1}$), but it loses its pressure and velocity exponentially with the distance from the source. The pressure generated by explosions is inversely related to the cubed distance from the focus of detonation. This is the reason that terrorist bombs, even though small, are lethal at very short ranges (Tables 2 and 3).

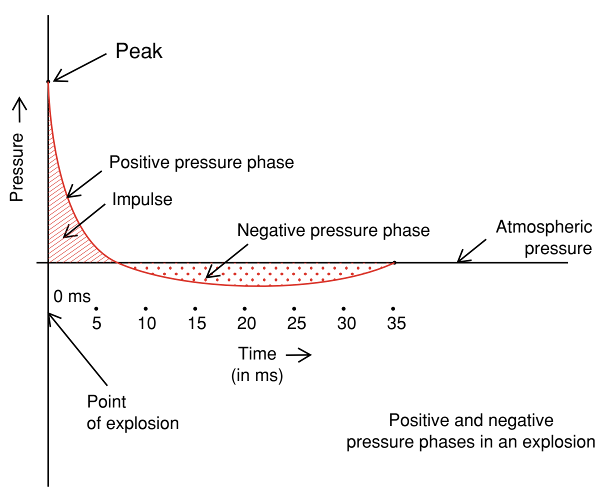

Figure 1 Dissipation of blast pressure into the surrounding medium.

Table 2 Exponential fall of pressure from the distance of the source of detonation (30 kg (70 lb) charge)

Distance (m (feet))	*Pressure (kg cm^{-2} (psi))*
4.20 (14)	7.48 (110)
5.4 (18)	4.08 (60)
9.0 (30)	1.02 (15)
15.0 (50)	0.40 (6)

Table 3 Some representative pressures in pounds per square inch (psi)[a]

• 1 psi	Breaks windows (1 psi is also the pressure below 2.3 feet of water)
• 1.55 psi	Normal diastolic blood pressure in man
• 2.32 psi	Normal systolic blood pressure in man
• 3 psi	Breaks walls
• 5 psi	Lowest pressure at which rupture of the human ear drum (most vulnerable organ to pressure) can occur
• 6 psi	Pressure produced by a 70 lb high explosive at a distance of 50 ft
• 15 psi	Pressure produced by a 70 lb high explosive at a distance of 30 ft
• 15 psi	Rupture of human ear drum occurs in 50% of the cases
• 30 psi	Pressure required in the tire of an average-sized car
• 60 psi	Pressure produced by a 70 lb high explosive at a distance of 18 ft
• 70 psi	Pulmonary damage seen in 50% of the victims
• 80 psi	Lethal in 50% of cases
• 100 psi	Endangers life of a human being in almost all cases
• 110 psi	Pressure produced by a 70 lb high explosive at a distance of 14 ft

[a]Normal atmospheric pressure at sea level is 14.7 psi (it decreases by 1 psi for every 2343 feet as we go up). All the units given above are in PSIG and not in PSIA. It is important to appreciate the difference between PSIG or ''pounds per square inch Gauge'' and PSIA ''pounds per square inch Absolute''. PSIA = PSIG + Normal atmospheric pressure. When we fill up our car tires at, say, 30 psi, the gauge used to measure the pressure ignores the normal atmospheric pressure. This is the PSIG, i.e. ''the pressure as measured by gauge''. This is also the pressure, as we normally understand it, in our day-to-day life. If we were to measure ''absolute pressure'' in our car tire, we would have to add normal atmospheric pressure (14.7 psi) to it. Thus a tire at 30 psi (PSIG), would be at 44.7 PSIA. Saying that a pressure of 15 psi causes rupture of the human drum, means that the ear drum is exposed to 15 psi of pressure ''over and above'' the normal 14.7 psi, to which it is always exposed.

Bomb Scene Management

The aim of a forensic scientist at the bomb scene is to gather and deduce as much information as possible. The police would be interested in raising several questions about the incident. Most frequently asked questions are:

1. What were the materials used to make the explosive device?
2. Where was the bomb placed?
3. What was the level of skill or expertise of the suspect?
4. What was the intended target of the bomb?
5. Who made the bomb and who placed it?
6. Was the explosion accidental or was there criminal intent?

7. How was the bomb detonated?
8. Who was the victim or intended victim?

Many of these questions can be successfully answered if certain foolproof protocols are employed, and evidence is collected diligently. It is frequently necessary to know if a low explosive or a high explosive was used. This information can often lead the investigation agencies to look for particular terrorist groups.

A low explosive such as gunpowder burns in a matter of milliseconds and generates a pressure of about 6000 atm. A high explosive such as nitroglycerine, on the other hand, burns in only microseconds and can generate pressures up to 275 000 atm. A low explosive functions by deflagration (very rapid burning), while a high explosive functions by detonation. The burning front in a low explosive moves relatively slowly – typically much slower than the speed of sound; in a high explosive, the burning front moves with supersonic speeds – typically from 900 to 7500 $m\,s^{-1}$ (3000 to 25000 $ft\,s^{-1}$). Low explosives typically need some sort of confinement to produce destructive effects as in a pipe bomb; high explosives do not need such kind of confinement. Destructive effects with high explosives are much worse. The difference between a low and a high explosive has been graphically described with this simile: "It is the difference between being bumped into by a pedal cyclist or being knocked for six by an express train."

The first response after a bombing incident should always be to call for emergency services. Their services include extinguishing fires, rescuing the survivors, administering first-aid, and transporting casualties to the nearest hospital. Next the bomb scene manager takes control and determines the seat of explosion, which usually can be identified by the presence of a deep crater. Fragments will be found scattered all around the seat of explosion. The distance of the farthest fragment is determined from the center of the crater. To this is added, one-half of distance, and this gives the radius of the inner cordon (Figure 2). The area inside the inner cordon may only be visited by bomb scene manager, exhibits officer, and the members of the forensic team. An outer cordon is placed outside this. The area between the inner and outer cordon is used by police teams, members of emergency services, press, etc. Falling debris, especially pieces of glass, can often pose dangers to the team working within the inner cordon, so it is essential to wear protective gear including helmets.

Collection of Physical Evidence

Physical evidence to be collected from the site of explosion includes power sources such as batteries (ranging in size from Polaroid film batteries to car batteries), timers (chemical, mechanical, and electronic), detonators and igniters, switches, circuitry (such as wires and printed circuit boards, etc.), adhesive tapes (used in the construction of several bombs; these usually survive the explosion), explosive device containers, and other bomb-making equipment such as rolls of tape, rubber gloves, and booby traps.

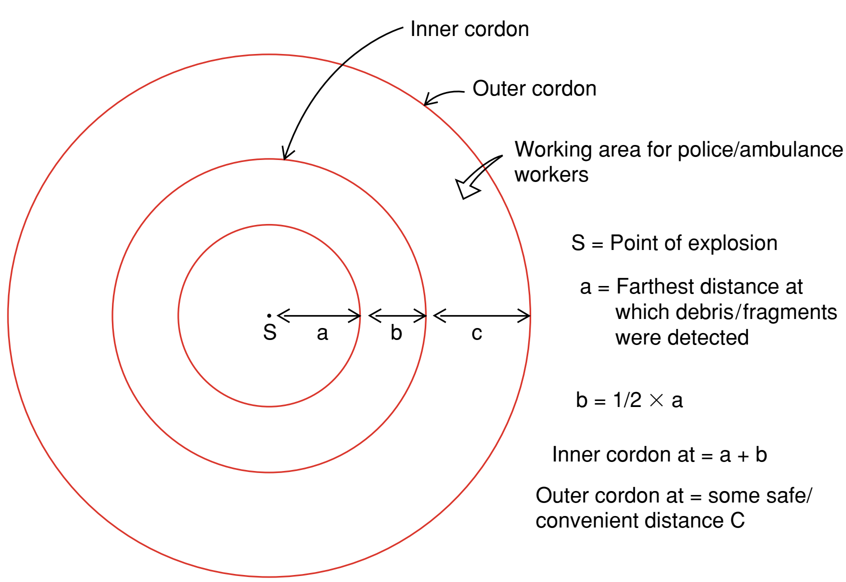

Figure 2 Sketch of explosion site with inner and outer cordons marked.

A careful examination of all this evidence would often lead the investigators towards a particular terrorist group or groups. Additionally, matching of tool marks on one or more of these objects with the tools recovered from suspect's possession can greatly strengthen the prosecution's case.

Collection of Explosive Residues

Particles of explosives recovered from the bomb scene may provide valuable clues. They can often provide clues regarding probable manufacturer and the brand of explosive. If a suspect is later found, the particles recovered from the crime scene may be compared with those found in his/her possession or on the body. Low-explosive residues are best collected by mechanical vacuuming. Collection of high-explosive residues is a more complex task. This is because they burn more completely, leaving only traces, and also because of the availability of a vast variety of different formulations and physical forms. Additionally since a high explosive is likely to involve a much wider crime scene, there is much greater "dilution" of residues than can be expected in the case of low-explosive blasts.

Vapors at the crime scene may be sampled by passing the air through adsorbent materials such as Tenax®. Alternatively a portable pump may be used in conjunction with charcoal. Explosive detectors developed for aviation safety are also very useful. One of the best known is the EGIS explosives detector, a "field portable" instrument which can detect many high-explosive residues such as those of TNT (trinitrotoluene), RDX (Research Department Explosive), PETN (pentaerythritol tetranitrate), NG (nitroglycerine), and EGDN (ethylene glycol dinitrate). An EGIS (Equipment Gesellschaft für Internat Systeme GmbH) explosives detector was used in the Oklahoma City bombing investigation. Basically this instrument uses high-speed gas chromatography, coupled with highly specific chemiluminescent detection, to identify explosive compounds.

When a suspect is later apprehended, there could be traces of the explosive on his person and/or on the vehicle that was used to transport the bomb. Hand swabs and fingernail scrapings are taken in the same way as of that from a shooting suspect. Isopropanol is a suitable solvent. Many high explosives such as RDX are absorbed by the skin and may be detected up to 1 week after the incident. Clothing may also present traces of explosives. Suspects' premises may also contain material which may match that recovered from the scene of the bombing.

Detection of Bomber's Signature

Often a terrorist group can be identified by some definitive design feature or a unique choice of materials for making bombs. This is usually referred to as the "bomber's signature." The unique feature could be the design of the firing circuit, an improvised explosive, a combination of components, or a particular type of target. Sometimes the identifier can be quite unique. The "Unabomber" in the USA always included the initials "FC" on an internal component of his devices. The initials were deliberately placed so that they would survive the blast and fall into the hands of the investigators. Advanced psychological profiling techniques can now help in charting the personality of the bomber.

Dealing with Human Bodies

Human bodies lying around must be handled with great care. Life may still be present in people presenting an outward appearance of death. All such persons must be examined by medical personnel. Only when death is confirmed by medical personnel, should the work of transporting the bodies to the mortuary begin.

Dead bodies lying at the scene may belong to the terrorists. Hands, feet and head may have been severed from the body due to the explosion. To preserve all possible evidence – and to avoid contamination – both hands, feet, and head of such bodies are bagged separately in nylon bags and sealed with tape. The bodies are then transported to the mortuary.

Autopsy

The postmortem examination in terrorist deaths can conveniently be divided into five important phases, each having a distinct and specific role. These are: (1) identification of bodies and preparation of a correct total body count, (2) radiological examination, (3) collection of surface evidence, (4) collection of internal samples, and (5) documentation of injuries.

Identification of individual bodies may not only be necessary for insurance claim purposes, but also to identify possible suspects among them. A proper reconstruction of the face may aid in facial identification. Clothing and other personal possessions are also useful in several cases. In addition, standard identification protocols such as hair and eye color, scars, tattoos, dactylography, odontology, anthropology, osteology, and DNA-profiling techniques aid in the correct identification. A correct body count may be done by physical matching of body parts. Sometimes just a single unaccounted body part may indicate an additional body. Finding of tissues like testis, prostate, and uterus will indicate the sex of the individuals. In badly mangled bodies the presence or absence of Barr bodies and Davidson's bodies in the cell nuclei can indicate true sex. Cases that cannot be resolved by any means may be resolved by means of DNA profiling.

Radiological examination will enable the pathologist to correctly locate and retrieve various shreds of the original explosive device which might have been lodged in the body. This can help in identifying the bombing devices and often "bomber's signatures." A bullet may sometimes be found in the body, which may confound the uninitiated. But it could indicate that the victim was tortured and murdered before the explosion occurred.

Collection of surface evidence includes collection of traces of powder, bomb fragments, and bomb chemicals from the bodies and body fragments using standard protocols. Materials from hands should be collected by standard wiping techniques. Finding stronger concentration of bomb chemicals on the hands than on rest of the body may indicate that the person had handled the bomb just before the explosion and might have been a perpetrator of the incident rather than an innocent victim. Many bomb chemicals tend to stick to clothes for long durations, and an examination of clothing can be very rewarding.

Collection of internal samples includes collection of blood, urine, vitreous humor, bile, stomach and intestinal contents for toxicology, and hair and blood for DNA profiling. Findings of street drugs like cocaine and heroin in the blood may be significant.

Finally the proper documentation of injuries is a vital task of the pathologist. Not only will it establish the cause of death, but also the manner of death and the position of the victim at the time of explosion. Two factors make the deduction of the position of explosion victims possible. Firstly, the explosive force declines exponentially with distance, and is very directional. As observed earlier, the explosive force declines as the cube of the distance. Since injuries are directly proportional to the explosive force, it effectively means that the injuries sustained are inversely proportional to the victim's distance from the seat of explosion. Secondly, if the seat of explosion is on, for example, the right side of a victim, because of the unidirectionality of the explosive force, his right side would be badly mutilated.

The position of the victim at the time of explosion can often indicate if he was indeed the perpetrator of the crime. For instance in one case of explosion that occurred in a car, the driver had the left part of his body totally destroyed, and his colleague (co-passenger) the right part of his body. From these facts, it could be deduced that the bomb was lying between them at the front seat, and they were probably carrying it to some predestined location. This fact immediately pointed to the fact that they could be terrorists rather than innocent victims in whose vehicle the bomb had surreptitiously been placed. In another case, when a terrorist was bending over a bomb, it went off prematurely killing him instantaneously. In such cases, although chest, abdomen, and face showed severe injuries, the umbilicus was completely spared, because during bending forward, it gets trapped in folds of skin.

Six types of injuries (listed below) are seen in explosion victims.

Primary Blast Injuries

These are the injuries that occur as a result of the direct pressure effects of the blast wave on the victim. These are more severe when the blast occurs in a confined space, primarily due to repeated reflection of the blast wave. Organs most likely to suffer damage due to this are those that contain air, for example, auditory apparatus, respiratory system, and gastrointestinal system. Blast waves tend to get reflected at the air–fluid interphase, and since these organs contain such a boundary, they are more liable to be injured. Three mechanisms serving to augment blast injuries are spallation, implosion, and inertial effects. The tendency for a boundary between two different density media to be disrupted when a compression wave in the denser medium is reflected at the interphase is known as spallation. Implosion refers to a violent collapse inward (as of a highly evacuated glass vessel) and is usually applied to the inward collapse of a building that is being demolished in a controlled manner. In the context of primary blast injuries, implosion refers to the forceful compression of a bubble of gas by a shock wave passing through a liquid. This compression causes the bubble to implode, the pressure within the bubble rising up to the levels of shock pressure. When the shock wave passes, this pressure is suddenly released, and the bubble explodes outwards, severely damaging the local tissue. When two adjacent objects of different densities are acted upon by the same force, they may be accelerated differently, causing them to slide against each other. This inertial effect is the classic mechanism responsible for injuries such as retinal detachments seen in terrorist bombings.

The organ most sensitive to blast effects is the ear. Classic injuries seen in terrorist bombings are rupture of the tympanic membrane and damage to the

Eustachian tube, the ossicular chain, and to the organ of Corti within the cochlea.

While the ear is the most sensitive organ to blast effects, injuries to the lungs are the greatest cause of mortality. Lungs would often reveal the fatal lesion in cases of deaths. There is some controversy as to whether the shock wave passes to the lungs directly through the chest wall, or through the air via oronasal orifices. Quite probably both mechanisms work together to produce injuries. Main injuries seen are

Table 4 Some significant major terrorist acts in history

Date/Year	*Event*	*Deaths*
1585	Antwerp, Belgium[a]	1000
1925	Bombing of Cathedral in Sofia, Bulgaria	160
1946	Nakam attack in Germany	100s (?)
1969	Cu Chi, Vietnam	15
1970s	IRA bombings, UK	100s
1970s	PLO in Israel	100s
May 30, 1972	Tel Aviv airport shootings	27
Sep. 5, 1972	Terrorist attack in Olympic village in Munich, Germany	17
Jun. 27, 1976; Jul. 4, 1976	Hijacking of an Air France jetliner from Tel Aviv to Entebbe Airport in Uganda	10
1979	Arson attack on a cinema in Abadan, Iran	477
Aug. 1, 1980	Bologna train station, Italy	84
Oct. 23, 1983	Bombing of the US Marine Barracks in Beirut, Lebanon	241
1983	In-flight bomb explosion in Gulf Air airliner, Bahrain	112
Jun. 22–23, 1985	Bombing of Air India passenger airliner over the Irish Sea	329
1986	Paris bombings	20
1987	Bombing of South Korean airliner near the Thailand–Burma border	117
1987	Car bomb in bus station, Sri Lanka	113
Dec. 21, 1988	Bombing of Pan Am flight 103 over Lockerbie, Scotland	278
1989	Bombing of French UTA airliner over Niger	171
1989	In-flight bombing of Colombian Avianca aircraft, near Bogota	107
Feb. 23, 1993	Bomb detonated at the underground parking garage of World Trade Center, New York	6
Mar. 12, 1993	Bombings in Mumbai, India (10 explosions in less than 3 h)	235
Jul. 18, 1994	AMIA (Asociación Mutual Israelita Argentina), Buenos Aires	89
Mar. 20, 1995	Tokyo subway sarin gas attack by Aum Shinri Kyo cult	12
Apr. 19, 1995	Bombing of federal building in Oklahoma City, Oklahoma	168
1997	Car bomb in Kenya, attributed to Bin Laden	213
1998	Massacre in Algeria's Relizane province, attributed to GIA	412
Sep. 11, 2001	Airliners flown into World Trade Center and Pentagon buildings	About 5000
May 14, 2002	Indiscriminate shooting at Kaluchak, India	31
Oct. 12, 2002	A massive explosion from a car bomb destroys a night club at the Kuta beach resort on the tourist island of Bali in Indonesia (most probably connected to the first anniversary of the beginning of the US air strikes in Afghanistan on Oct. 7)	202
Oct. 26, 2002	Chechnyan rebels seize a Moscow theatre, holding 750-plus hostages	118
Sep. 24, 2002	Indiscriminate shooting at Akshardham temple, Gujrat, India	28
Aug. 5, 2003	Car bomb explodes outside Marriott Hotel	13
Aug. 25, 2003	On this Black Monday, two bombs exploded in Mumbai, India. The first one at about 1 PM at the Gateway of India, and the second shortly thereafter at Zaveri Bazaar	52. Injured about 150
Dec. 5, 2003 (Friday)	A female suicide bomber detonates herself inside a crowded train in Southern Russia (near the war-torn region of Chechnya). The morning train from Mineralnye Vody to Essentuki was crowded with students, workers and shoppers headed for a local market at 8 AM. The explosives were packed in a waist-belt	42 (36 died on first day)
Mar. 11, 2004	A series of explosions at three Madrid railway stations. Ostensibly because Spain supported US during its Iraq war. Worst terrorist event in Spain	200
Sep. 1–3, 2004	On the morning of September 1 (Wednesday), a group of militants seize some 1200 people in the main school of the city of Beslan in Russia's Caucasus Republic of North Ossetia. The hostages include students, parents and teachers. Russian forces storm the school on September 3 ending the siege	Over 300 dead, half of them children. More than twice that number are injured

[a]The first recorded case of terrorist bombing. Seven tons of gunpowder were detonated to destroy a bridge on the River Schelt, reportedly killing 1000 soldiers.

Sources: (1) Falkenrath RA, Newman RD and Thayer BA (2001). *America's Achille's Heel: Nuclear, Biological, and Chemical Terrorism and Covert Attack, p. 47. Boston: MIT Press.* (2) Frykberg ER (2002) Medical management of disasters and mass casualties from terrorist bombings: how can we cope? *Journal of Trauma* 53: 201–212.

widespread alveolar damage, tears in the visceral pleura, pulmonary hemorrhage, atelectasis, pneumothorax, hemothorax, pneumomediastinum, and traumatic lung cysts. Air emboli are common, which can be due to traumatic alveolar–venous fistulae. Subcutaneous emphysema and chest wall damage, including injuries to the ribs, are also seen.

The blast wave causes rapid expansion of the hollow organs within the abdomen such as stomach and intestines. This can cause gastrointestinal hemorrhage, especially in the lower small intestines or the cecum where gas content is greater. Other abdominal injuries are intestinal perforation, especially at the ileocecal junction, retroperitoneal hemorrhage, and injuries to solid organs.

Injuries to the cardiovascular system include myocardial contusion, myocardial laceration, coronary artery air embolism, and hemorrhage. Injuries to the central nervous system include concussion and various forms of intracerebral hemorrhage.

Secondary Blast Injuries

These are the injuries produced by flying objects produced by the explosion. These injuries resemble classic ballistic wounds, except that the entrance wound is very irregular. Small flying objects striking the body produce the classic triad of abrasions, bruises, and puncture lacerations. This triad is very characteristic of bombings.

Tertiary and Quaternary Blast Injuries

These are produced either when the victim is actually lifted up and thrown around by the blast wind, or when some heavy piece of masonry breaks and falls upon the victim (the latter have often been called quaternary blast injuries). These injuries resemble classic blunt force injuries.

Burns

The characteristic burns seen in explosions are flash burns. They are not due to flames, but rather due to extremely hot gases which strike the victim. Since the duration of exposure is infinitesimally small, these injuries are superficial in nature. Since the heat applied is the same, they are of uniform depth. If an object was in between the seat of explosion and the victim, it would cast its "shadow," just as it would if there were a flash of lightning. Contours of the body also tend to cast their "shadow" over the burnt area. Areas protected by clothing are safe.

Explosive Injury

Typical injury seen in this category is the "dust tattooing," which occurs due to small particles of dust entering the subcutaneous tissues.

Complete Disruption

If the victim is seated over or in very close proximity to the explosive device, his body would be completely disrupted. The individual body parts are thrown wide apart. These are the bodies that are the most difficult to identify.

Current Trends

Although terrorist bombings still remain the most common form of terrorism, new forms of terrorism have emerged in the twenty-first century. The beginnings of this century saw airplanes being used as missiles against tall buildings. Bioterrorism, nuclear terrorism, hijacking, and aircraft sabotage are other forms which forensic pathologists may have to face in the future. Finally, Table 4 lists some of the major terrorist acts recorded to date.

See Also

Ballistic Trauma, Overview and Statistics; **Crime-scene Investigation and Examination:** Collection and Chain of Evidence; Major Incident Scene Management; **Identification:** Prints, Finger and Palm; **Injury, Fatal and Nonfatal:** Explosive Injury; **Mass Disasters:** Principles of Identification; **Torture:** Physical Findings

Further Reading

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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

Continued

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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

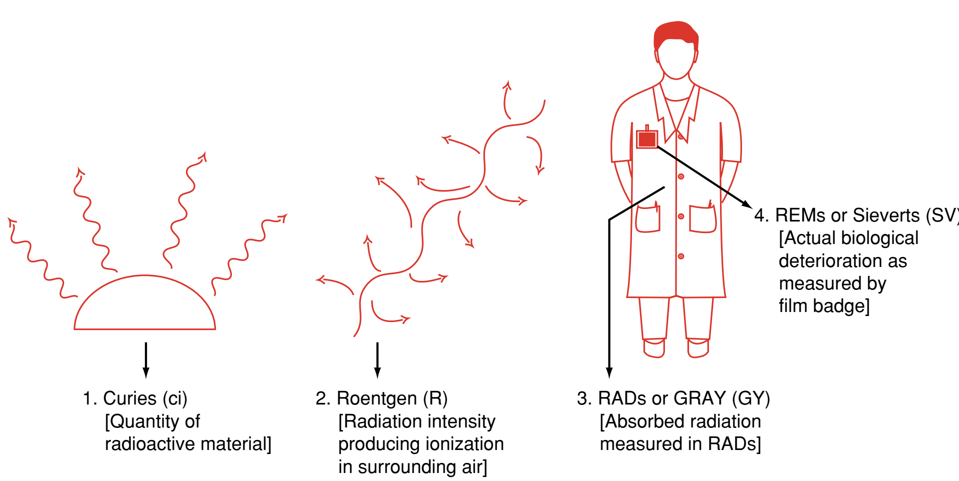

Figure 1 Interrelationships between various radiation units.

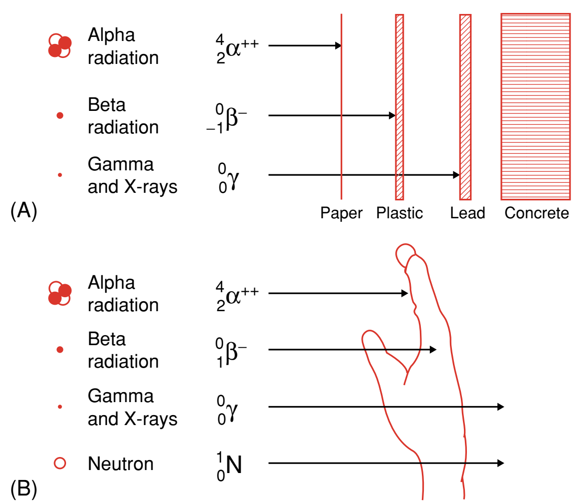

Figure 2 Penetrating distances of various radiations: (A) non-living matter; (B) living matter.

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

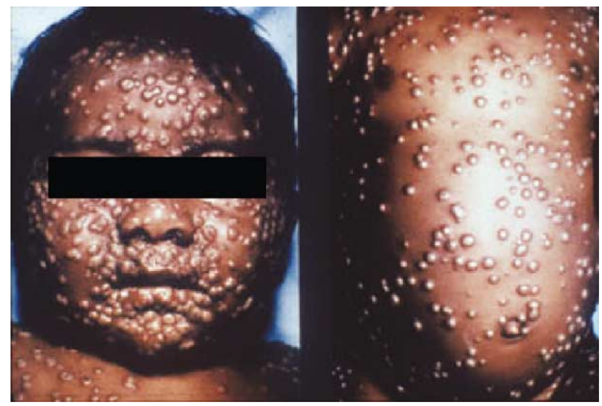

Figure 3 Rash on the face and body in smallpox. Courtesy of WHO.

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.

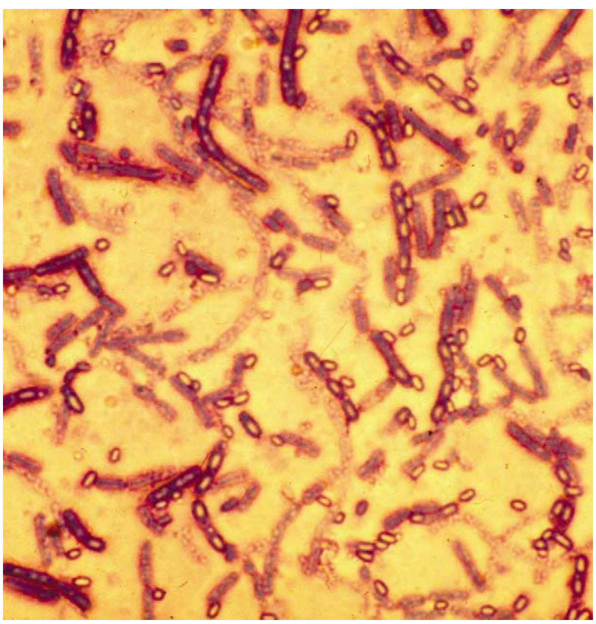

Figure 5 Microscope photograph of spores and vegetative cells of anthrax bacterium Bacillus anthracis. Courtesy of WHO, © Eric Miller.

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);

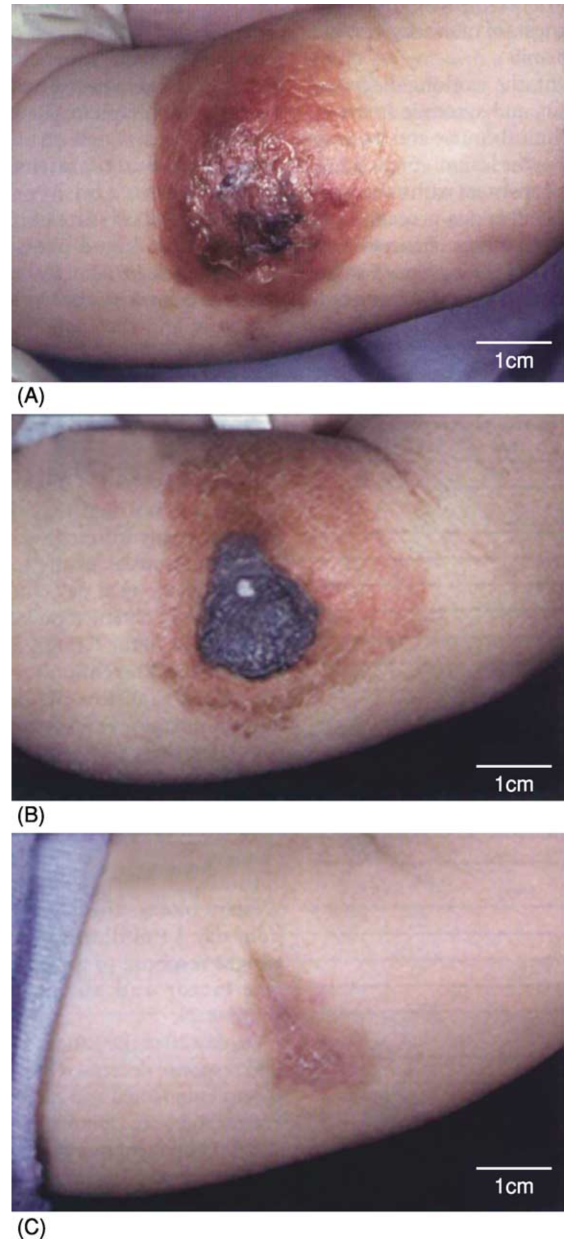

Figure 6 The lesion of cutaneous anthrax: (A) hospital day 5; (B) hospital day 12; and (C) 2 months after discharge. Courtesy of Journal of American Medical Association and W. Bockowsky (2002) 287: 869–874.

(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 human bomb" (SHB). When he/she drives an explosive-laden vehicle into crowds, it is termed a "vehicular human bomb" (VHB).

This article focuses on suicidal and suicidal-homicidal (terrorist) bombings. Among these, it is usually the latter situation, which merits more public attention. However, investigative procedures at the scene of explosion as well as autopsy findings are comparable. While in suicidal bombings, circumstantial findings reveal much information (e.g., death of a single person, isolated spot chosen, previous history of suicidal intention, or earlier suicide attempts), it is the suicidal-homicidal bombing that stretches the forensic pathologist's and crime investigator's skills to its maximum. In such cases, the forensic pathologist or medical examiner, as well as other investigative authorities involved must identify: the actual suicidal bomber among the casualties, the type and source of explosive devices and ignition systems used, the affiliation of the suicidal bomber to a particular terrorist group, and several other similar questions. Above all, the forensic pathologist and investigator teams may be required to reconstruct the sequence of events.

Principles of the Design of Explosive Devices Used by Suicide-Homicide (Terrorist) Bombers

Explosives used by suicidal as well as suicidal-homicidal (terrorist) bombers are substances or devices capable of a sudden expansion of gas, which upon release of its potential energy creates a pressure wave. Based on the mechanism of energy release, explosives can be classified as chemical, mechanical, or nuclear. Chemical explosives, volatile or nonvolatile, decompose into gases upon detonation.

In order to conduct a more effective investigation of a bombing incident, the forensic pathologist should at least be familiar with the basic design of bombs used by terrorists. Devices are generally concealed within an article of clothing worn close to the body such as a vest, belt, or jacket. Most bombing devices used by different terrorist organizations worldwide are mainly constructed based on similar principles, although there may be subtle differences. In general, such bombing devices consist of a simple push-button toggle switch for the ignition of the charge and the electric circuit is completed by using a simple battery. These ignition devices are relatively small in order to reduce the chances of discovery. The main explosive charge may consist of a military-grade plasticized explosive or homemade explosive mixtures. Most often used as the latter are chemical explosives such as 2,4,6-trinitrotoluene (TNT), black powder (potassium nitrate, sulfur, charcoal), liquid gasoline, or natural gas. The potential energy release of chemical explosives depends on the rate of decomposition, which in turn is determined by the chemical compounds used for the explosive; for example black powder has a lower rate of decomposition than TNT, which detonates at much higher speeds. Dispersed fragmentation is the mechanism primarily intended to kill persons in the vicinity of the explosion epicenter. Small metal objects, such as nails, screws, balls, or bearings, also form an integral part of the explosive device. With the blast wave (a radially propagating shock wave resulting from the explosion), these "missiles" scatter all over the surrounding environment and act like a spray of bullets. Many devices have a backup trigger system, such as an electronic timer, pager, or booby-trap type switch. If the attacker is killed, apprehended, or has to abort the attack by any other reason, a secondary trigger system then provides an alternative ignition.

Scene Investigation

In explosion-related fatalities, it is important to conduct inquiry by a team consisting of police investigators, bomb experts, and forensic pathologists. A terrorist attack should be initially suspected in each case of suicide involving explosives.

Apart from death scene investigation, autopsy findings, and technical reconstruction of the explosive device, and the analysis of explosive residues using gas chromatography–mass spectrometry, scanning electron microscopy, and stereomicroscopy, the history of the victim may give additional hints about the the mode of death – suicide or homicide without a terrorist background. The determination whether the manner of death is suicide, homicide, or accident in such cases can present a difficult task to the investigative authorities, especially within the first ten hours following the incident.

It is usually the intention of a terrorist bomber to cause as many casualties as possible, so a crowded place – confined or open space – is normally chosen for detonation of the explosive. Thus, the scene of suicide-homicide bombing is usually characterized by massive destruction (Figure 1). It must be kept in mind that when an initial attack has occurred, it may be followed by a (sometimes even more) powerful follow-on attack shortly thereafter, a tactic utilized in the terrorist bombing which killed over 200 in Bali, Indonesia in 2002. This second attack is timed to inflict the maximum number of casualties against the responding police, fire and emergency medical

Figure 1 Scene of suicidal-homicidal bombing with three victims lying on the floor in a totally destroyed courtroom. Massive destruction of walls, ceiling, and windows as well as debris scattered all over the floor. Bloodstains can be seen on the walls in the lower parts. Courtesy of Professor B. Madea, Institute of Legal Medicine, University of Bonn, Germany.

Figure 2 Posterior view of a bombing victim with deep lacerations and interspersed foreign body fragments on neck (A) and occiput (B). Courtesy of Professor F. Longauer, Institute of Legal Medicine, Pavol-Jozef-Šafárik-University, Košice, Slovak Republic.

service (EMS) responders, and gathering crowds. Thus, while EMS responders may arrive at the scene immediately to rescue the surviving injured persons, all other responding personnel and vehicles should stay clear of the immediate attack site. Gathering crowds and media personnel should be kept clear of the site. The crime scene investigators must try to locate the debris furthest from the object bombed. An inner cordon should then be placed at one-and-a-half times this distance, and an outer cordon at some convenient distance outside of that. The area between the inner and outer cordon is used by police teams, members of emergency services, press, etc., while the area inside the inner cordon can only be visited by the bomb scene manager, exhibits officers, and the members of the forensic pathologist's team.

As mentioned above, dispersed fragmentation is the primary killing mechanism in individual suicide bombing attacks. Fragmented components of the explosive device such as nails, or other smaller metal pieces, must therefore be looked for at the scene and on the outside as well as inside the bombing victims' bodies. This will be occasionally helpful in identifying a particular terrorist group, or a particular explosives manufacturer or dealer.

As with the location of burn injuries and splinter penetration (Figure 2), the location of damage to clothing is helpful in establishing the body posture of a victim (or the attacker) at the time of the explosion. In addition, in suicidal bombings involving just one person (the suicidal), the pattern of bloodstains at the scene of explosion gives additional hints towards the reconstruction of events.

It must be remembered that the scene of bombing may still contain undetonated explosives. Until the arrival of the bomb squad, no object should be touched as it may contain unexploded devices. Potential concealment areas for bombs include parked vehicles at the scene of bombing.

Autopsy Findings

Explosions in confined spaces are associated with more and a higher extent of severe injuries and a higher mortality rate compared with explosions that occur in open spaces, because the blast wave reflects back from the walls and the ceilings of buildings. It is usually impossible to draw any realistic conclusions from injuries sustained by the victims concerning the size of the explosive charge. Proof of air embolism is essential when the body surface is intact since air embolism is a major cause of death in blast victims. If the autopsy is not performed within a few hours after death, the differentiation between air and decomposition gases should be made with the pyrogallol test.

Gross Pathology

Appearance of external injuries based on the definition of blast injuries Instantly with the explosion, compression of air in front of the pressure wave that heats and accelerates air leads to a sudden increase in atmospheric pressue (overpressure) and temperature transmitted into the surrounding environment creating the blast wave.

According to their etiology, injuries caused by explosions are traditionally classified into four categories: primary, secondary, tertiary, and quaternary blast injuries (Table 1).

Primary blast injuries Injuries directly inflicted on the human body by the sudden increase in air pressure after an explosion are referred to as primary blast injuries and involve almost exclusively gas-containing internal organs such as the lungs, middle ear, and gastrointestinal tract, the organs most vulnerable to overpressure. Primary blast injuries on the external surface of the body are: scattered dermal abrasions and contusions, gross lacerations of the skin (Figure 3) that may be interspersed with foreign body material, mutilations or amputations of limbs, opening of body cavities (Figure 4), decapitation, near-total disruption of the body (Figure 5), or even complete body destruction. Primary blast injuries are estimated to contribute to 86% of fatal injuries in explosion victims.

Secondary blast injuries Secondary blast injuries result from blast-energized bomb fragments and other displaced objects at the site of explosion such as glass, casing, and masonry causing splinter-induced penetrating trauma.

Tertiary blast injuries Tertiary blast injuries occur when the body is accelerated from the blast wave initially and is then abruptly decelerated on rigid objects, thus resulting in a combination of blunt force and penetrating trauma.

Quaternary blast injuries Quaternary blast injuries are defined as those derived due to the collapse of a

Table 1 Classification of blast injuries caused by explosions according to etiology and types of injury

Category	*Etiology*	*Type of injury*
Primary blast injuries	(Direct) blast wave exposure	Disruption of the body, traumatic amputation, gaping lacerations of the skin, rupture of gas-containing organs (e.g., ear, lungs, gastrointestinal tract), perforation of hollow organs
Secondary blast injuries	Blast-energized bomb fragments and other debris (shrapnel)	Penetrating trauma
Tertiary blast injuries	Abrupt deceleration of the body on rigid objects following acceleration due to (indirect) blast wave effect	Blunt force trauma, penetrating trauma
Quaternary blast injuries	Collapse of a building or falling down of parts of a building where the explosion took place	Miscellaneous; for the most part blunt force trauma

Figure 3 Gross laceration of the skin due to the suicidal explosion of an industrial explosive (Gelamindonarit) with superficial abrasions and bruising seen adjacent to the wound's margin.

Figure 5 Explosive-induced trauma of the upper posterior part of the trunk with decapitation and gaping lacerations of the superior parts of both thoracic cavities in a suicidal-homicidal bombing victim who was located in the immediate vicinity to the epicenter of the explosive device consisting of TNT.

Figure 4 Opening of the abdominal body cavity following the (probably accidental) explosion of a homemade pipe bomb containing black powder. Note peppering, bruising, and abrasions seen on and adjacent to the wound's margin.

Figure 6 Superficial flash burn injuries upon the skin of the anterior side of the lower parts of the trunk and more severe burns of the superior parts of the body deriving from local ignition of clothing following an accidental gas explosion.

building or parts of a building where the explosion took place.

Burns Superficial flash burn injuries, together with singeing of head hair and eyebrows, derive from the enormous heat generated by the explosion (direct burns). More severe burns usually represent indirect burns that derive from local ignition of clothing. They can be differentiated from burns that result from a secondary fire at the scene of explosion by their restriction to areas of clothing of the victim (Figure 6). The clothes of the victims are possibly torn for the most part (Figure 7), depending mainly on the vicinity of the victim to the epicenter of explosion (the loss of clothing may also take place simply due to ignition). The location of burn injuries and splinter penetration is helpful in determining the body posture of a victim (or the attacker) at the time of the explosion.

Internal injuries Since, as explained above, external injuries inflicted on the human body by explosions are mediated by miscellaneous underlying mechanisms, victims usually suffer from a combination of primary-blast effects to gas-containing organs, blunt-force injuries, penetrating trauma, and burns.

Internal injuries in explosion-related fatalities comprise perforation of hollow organs, such as the ear, gastrointestinal tract, and urinary bladder, in the absence of penetrating cranial or abdominal trauma. The gut may be torn off from the mesenterium.

Figure 7 Suicidal-homicidal bombing. The perpetrator is lying in a lateral position within glass, casing, and masonry displaced by the explosion. Clothing is torn off and lacerations and tissue loss of the limbs are seen. Courtesy of Professor B. Madea, Institute of Legal Medicine, University of Bonn, Germany.

Solid abdominal organs, such as the liver, kidneys, spleen, and pancreas, less frequently incur injury in the form of contusions or lacerations. In general, damage to the liver and spleen is only seen when the abdominal wall has been opened by the blast wave or secondary to penetrating trauma.

In the lungs, unilateral or bilateral pneumothorax may be seen. Usually, the lungs show severe overdistension. Grossly visible lesions of the lungs are circumscribed or more confluent petechiae as well as contusion zones seen under the pleural surfaces or within the parenchyma on cut sections through the organ. These contusions may be focal, multifocal, or diffuse and are most often seen shining through the pleural surfaces adjacent to the diaphragm, medially next to the heart, and especially corresponding to protruding parts of the rib cage. Where fire fumes were inhaled, deposits of soot particles will be seen in the trachea and bronchi. Edema, mucosal bleeding, and patchy or vesicular detachment of the mucosa in the nose, mouth, pharynx, larynx, trachea, and bronchi are often indicative of an inhalation of hot gases. The nasopharynx, larynx, and trachea, comprising the upper respiratory tract, are usually involved in blast injury. Emphysematous bullae under the mucosa of the upper respiratory tract are another frequent finding in blast victims (Figure 8).

Cardiac contusions, grossly manifesting as hemorrhages in the form of petechiae and hemorrhages are commonly located in the epicardium along the posterior surface of the heart next to the diaphragm and in the endocardium of the left ventricle. Myocardial ischemia may be caused by air emboli in survivors.

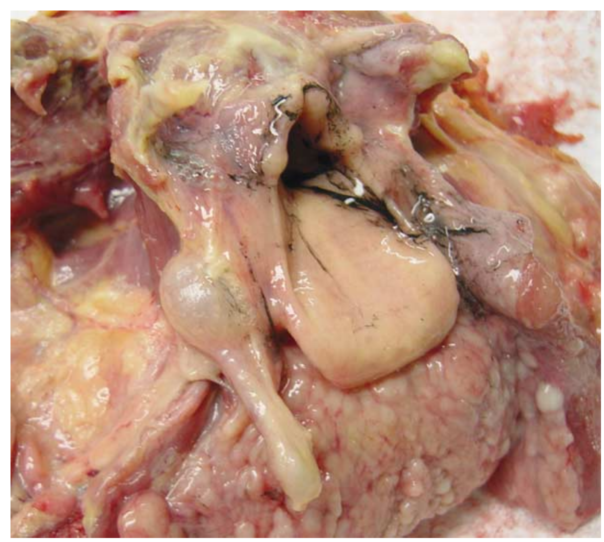

Figure 8 Emphysematous bullae under the mucosa of the pharynx and larynx and aspiration of soot upon the mucosa of the epiglottis and larynx in an explosion-related fatality.

The brain may undergo direct injury, such as cerebral contusion, or indirect injury such as cerebral infarction from air emboli in those victims who survive the incident.

Histopathology of Blast Lung Injury

Of the gas-containing organs, the lung is the most susceptible to primary blast effects and the extent

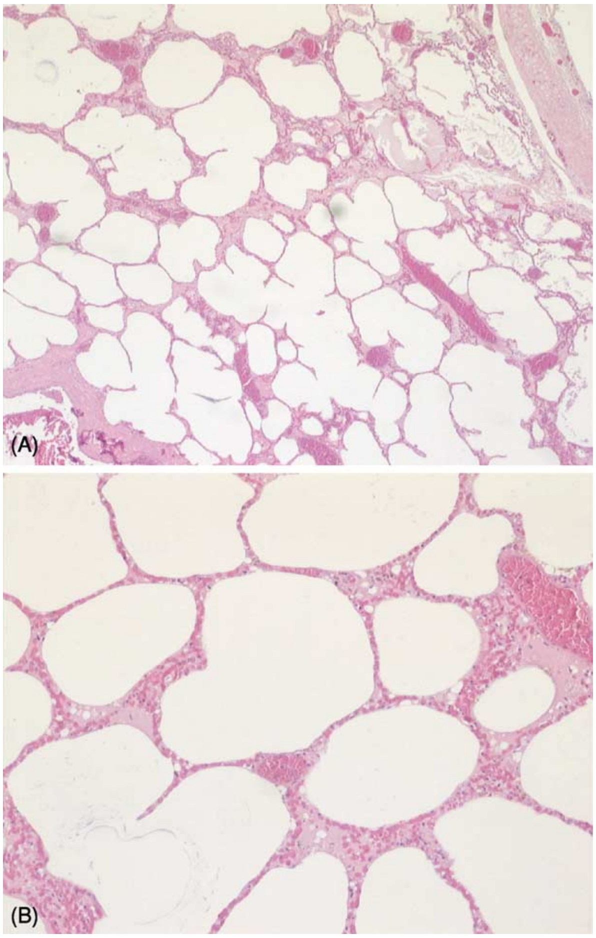

Figure 9 Blast lung injury. (A) Panoramic view of severe alveolar overdistension, enlargement of alveolar spaces, ruptures, and thinning of alveolar septae (×25). (B) Close-up view of ruptures and thinning of alveolar septae (×100).

of lung injury is the decisive parameter defining mortality in victims of explosions who survive in the first place. Alveolar ruptures, thinning of alveolar septae, and enlargement of alveolar spaces (Figure 9) as well as circumscribed subpleural, intraalveolar, and perivascular hemorrhages, the latter showing a cufflike pattern in the interstitial spaces around larger and smaller pulmonary vessels (Figure 10), are the main histopathologic findings in blast lung injury. Aspiration of soot is often seen in the bronchi. In addition, venous air embolism, bone marrow embolism, and pulmonary fat embolism are frequent findings. Leukostasis, an intense alveolar and interstitial edema, as well as interstitial inflammatory infiltrates can be observed in blast victims who survived the incident for a few hours.

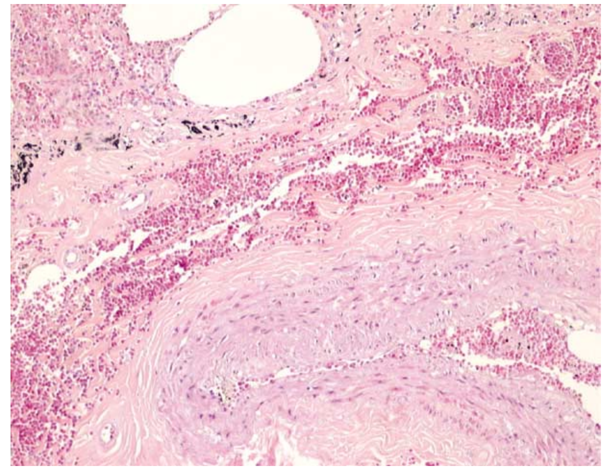

Figure 10 Interstitial perivascular hemorrhage showing a cufflike pattern around a larger pulmonary in human blast lung injury (×25).

Recovery of Evidence from the Body

Before undertaking the autopsy, it is essential to radiograph the whole body. This can reveal several radio-opaque and radiolucent bomb parts. Radio-opaque parts usually recovered from within the body include various metallic missiles, portions of trigger mechanisms, such as screws, wires, gears, springs, and batteries. Wires may be among the most important evidences to recover, because they can often indicate the specific manufacturer. Removal of this evidence is most essential; this can sometimes be so intricately lodged in the tissue that it may even require tissue maceration.

Radiolucent material may include fragments of the explosive wrapper, fragments of paraffin-coated paper (explosive cover), and other elements such as cloth, wood, cardboard, plastic, etc., used to conceal the bomb.

It is essential to radiograph the survivors also, since some explosive device fragments may be lodged in their bodies. If they are operated on surgically, and some surgical specimen such as a badly mutilated limb is removed, it should also be radiographed for similar reasons. The examination of survivors should be undertaken at the earliest stage possible by individuals with forensic medical training. Finally, after all fragments have been removed, it is recommended to carry out radiography again in order to ensure that the fragments have been completely removed.

Traces of explosives (burnt and unburnt) may be adhering to the body and should be recovered using a suitable solvent. Isopropranol is usually employed to recover explosive residues, but methanol and ethanol can also be used. In some countries, certain special substances known as "taggants" are required by law to be added to all explosives. These taggants are small magnetic or fluorescent chips, which contain color-coded information. These taggants do not burn with the explosive, but are scattered at the scene. These can be recovered by a magnet (if they are magnetic), or by fluorescence. They can provide information regarding the manufacturer of the explosive, the year, month, and day of the manufacture, and also the batch number of the explosive.

Identification

In multiple deaths, identification of the deceased is an important task and even more important is to identify the person responsible for the attack. Usually, the body of the suicide bomber will be the worst damaged or perhaps completely disrupted. If isolated limbs are recovered, an unusually high concentration of explosive residues on hands would indicate that the person handled explosives. DNA sticking to clothes, belts, etc., may help reveal the identity of the suicide bomber. Rajiv Gandhi was assassinated by an LTTE (Liberation Tigers of Tamil Eelam) female bomber called Dhanu. In this case, the Special Investigation Team visited the scene of crime where they found parts of Dhanu's dress, strips of the vest, and the belt-bomb she wore with pieces of flesh attached, two toggle switches, wires used in the bomb, and a half-burnt 9-V battery. DNA profiling of the pieces of flesh found at the spot was done, as also that found sticking to the belt. The flesh piece attached to the belt matched with the portion of the woman's body found. That established convincingly the theory of the assassin being a human bomb.

See Also

Crime-scene Investigation and Examination: Collection and Chain of Evidence; Recovery of Human Remains; **Mass Disasters:** Principles of Identification; **Terrorism:** Medico-legal Aspects; Nuclear and Biological; **War Crimes:** Pathological Investigation

Further Reading

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