Nuclear War Prevention

Nuclear Bunker Busters:
The Medical Consequences

The Threat of Low-Yield Earth-Penetrating Nuclear Weapons to Civilian Populations: Nuclear "Bunker Busters" and Their Medical Consequences

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Abstract

Proponents of a new generation of low-yield nuclear earth-penetrating weapons (EPWs), such as modified versions of the B61-11 currently in the US stockpile, claim that such weapons could be used against deeply buried and hardened underground bunkers with "minimal collateral damage." Even a very low-yield nuclear EPW exploded in or near an urban environment will, however, cause radioactive dirt and debris and other radioactive material to fall out over several square kilometers. A nuclear EPW with a yield less than one-tenth of that of the nuclear weapon used on Hiroshima or Nagasaki could result in fatal doses of radiation to tens of thousands of victims. Biological and chemical agents stored in targeted bunkers may be dispersed into the atmosphere without being destroyed by an EPW, potentially injuring or killing unprotected civilians. The number of casualties from a nuclear EPW attack would depend on the location of the target, the density of the surrounding population, the extent of debris dispersal, and the possibility of escape or evacuation. In addition to the acute and long-term medical consequences, use of nuclear weapons would weaken existing restraints against further proliferation or use of nuclear weapons and would cross a threshold that has been maintained since 1945, when the United States detonated the first nuclear weapons over Hiroshima and Nagasaki.

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Introduction

The imminence of "pre-emptive" war against Iraq has raised concerns about the weapons that may be used to destroy underground command centers and alleged underground storage sites for chemical and biological weapons.[1] Such sites may be deeply buried and "hardened," protected by large amounts of steel-reinforced concrete designed to withstand the effects of aerial bombardment with conventional weapons. Earth-penetrating weapons – EPWs or "bunker busters" – are designed to hit the earth at high speed and to penetrate into the ground before exploding. Earth penetration increases the damage done to underground targets by "coupling" the energy of the explosion to the ground.

The United States currently deploys both conventional and nuclear EPWs. The largest and most effective conventional systems (the GBU-28 and the GBU-37) are designed to be dropped from an aircraft, have about 630 lbs of high explosive, and during tests have been able to penetrate up to 6 meters in concrete or 30 meters of earth. EPWs composed of conventional explosives are capable of destroying shallow-buried structures at depths less than 10 meters below the surface, but they are likely to be ineffective in the destruction of more deeply buried and hardened sites.

The United States also has about 50 nuclear-tipped EPWs (the "B61 modification 11") which are designed to be dropped from aircraft. Tests indicate the current design penetrates 2 - 3 meters in frozen soil. The yield of these warheads is reported to be between 0.3 kilotons and 340 kilotons. Production of a new generation of nuclear weapons designed as EPWs has been proposed and is being studied. A 1994 law currently prevents development of weapons with yields less than 5 kilotons (colloquially known as "mini-nukes"), but the House of Representatives, during this session of Congress, recommended that this restriction be eliminated.[2,3]

In January 2002 the Department of Defense and the Department of Energy released a new Nuclear Posture Review (NPR). These periodic reviews, required by Congress, describe the nuclear forces the Department of Defense deems necessary. The 2002 NPR added five new countries as potential targets for US nuclear weapons. In addition to Russia and China, the Democratic People's Republic of Korea (North Korea), Iraq, Iran, Syria, and Libya are specifically listed as potential threats. The NPR makes clear that the US nuclear arsenal could also be used to deter and respond to any use by those nations of nuclear, chemical, or biological weapons. Much of the new focus is on attacking "hardened deeply-buried targets" with nuclear EPWs. The 2003 DOE budget specifically requests funding for a "Robust Nuclear Earth Penetrator" (RNEP) that would be more effective than the existing modification of the B61. The debate about the RNEP has concentrated on a number of modifications to improve the B61 and new modifications on the B83, the largest nuclear warhead in the US arsenal. The modifications would include: developing new casings for the warheads so the speed at impact could be increased, thereby allowing the weapon to safely penetrate deeper; improving guidance systems for higher accuracy; better attitude controls at impact to ensure penetration at the right angle; and smarter fuses to control detonation at the proper time.

Some government and military officials have suggested that these low-yield earth-penetrating nuclear weapons could be used with "minimal collateral damage." A straightforward analysis[4] based on physical estimates and data from underground nuclear testing indicates, on the contrary, that even a very low yield nuclear weapon used in an urban environment would risk producing tens of thousands of civilian radiation casualties. Casualties of this magnitude would overwhelm even the most effective medical care system.

The medical consequences of use of nuclear weapons in the kiloton range (such as the bombs with explosive force approximately equivalent to 15 thousand tons of TNT used on Hiroshima and Nagasaki in 1945) and in the megaton range (such as weapons with explosive force as high as 20 million tons of TNT equivalent that have been tested by the United States and the Soviet Union) have been extensively analyzed.[5-8]

Characteristics of Nuclear Weapons Explosions

Analyses of the effects of the use of nuclear weapons of greater power have distinguished between the effects of their detonation as an air burst or as a ground burst. Detonation of a nuclear weapon in the air thousands of feet above the ground – as was the case for the bombs used on Hiroshima and Nagasaki – results in an extensive area of blast and heat damage, much greater than the area damaged by a weapon detonated at ground level. Air bursts also expose those on the ground to radiation injury from the initial flux of neutrons and gamma rays produced by the nuclear reaction and also by subsequent fallout from radioactive particles lofted into the atmosphere by the explosion.

A surface or shallow-buried ground burst, in contrast, results in a smaller area of blast and heat damage and less injury from the prompt gamma radiation. However, a large crater open to the atmosphere is almost certain to be formed at the surface by the explosion. For a one-kiloton weapon, nearly a million tons of dirt and debris excavated by the ground burst would be spread over a wide area surrounding the epicenter of the blast. In addition to the fission products from the bomb itself, this excavated material is made radioactive by the initial burst of neutrons from the nuclear explosion and will be deposited as fallout.

Characteristics of Nuclear EPWs

Because EPWs are intended to detonate below ground and have substantially lower yields than other warheads in the US stockpile, proponents of the development and use of such weapons have suggested that nuclear EPWs could be used even near densely populated areas with "minimal collateral damage." As one Pentagon official put it to the *Washington Post* in June 2000, "What's needed now is something that can threaten a bunker tunneled under 300 meters of granite without killing the surrounding civilian population."[9]

An analysis by one of us (RWN) has demonstrated that EPWs simply cannot penetrate deeply enough to contain, below the ground surface, the nuclear explosion and the radiation it produces.[4] As tests at the Nevada Nuclear Test site have shown, a 1-kiloton explosion must be buried and carefully sealed more than 300 feet (100 meters) below the surface to fully contain the radioactive products. Yet a missile made of the hardest steels cannot survive severe ground impact stresses at velocities greater than about 900 meters per second without destroying itself. This limits the maximum possible penetration depth of the missile into reinforced concrete to about four times the missile length—approximately 12 meters for a missile three meters long. Even for the strongest of materials, impact velocities much greater than one kilometer per second will crumple and destroy the penetrator and its warhead. At this relatively shallow depth, the explosion will inevitably breach the ground surface and throw out radioactive dirt and debris. The resulting base surge of radioactive fallout will extend over an area of several square kilometer. Anyone remaining in this area for more than a few hours would receive a fatal dose of radiation and shorter exposure would cause significant injury, as will be noted in detail below.[4]

Dissemination of Chemical and Biological Agents

In addition to the risk of radiation exposure, analysis of the effects of EPWs used on underground storage sites indicates that all the hazardous stored materials are unlikely to be incinerated by an EPW. Instead, some may be disseminated to the ground surface and to the atmosphere.[10] Contemporary bunkers in which such materials are stored typically contain long and complex tunnel systems with multiple storage rooms. This configuration would attenuate the blast and thermal energy of the underground explosion. There is a high probability that some storage tanks would be ruptured by the blast, but that the agents themselves would not be destroyed.

Evidence from the 1991 Persian Gulf War and other examples of the destruction of storage sites indicates the potential for dissemination of the agents by detonation of explosives.[11] In a memo to US Senators in September, 2002, Mello, Nelson, and von Hippel stated: “A nuclear attack would be much more likely to release than to destroy any biological or chemical agent present. Thus, the most likely outcome . . . would be to disperse lethal agents into the atmosphere, potentially killing unprotected civilian populations in a large area downwind. Military forces would be more likely to have protection.”[12]

Effects of Ionizing Radiation

In previous analyses of the medical consequences of the use of nuclear weapons, consideration of injury from ionizing radiation included (1) the effects of radiation injury from the initial burst of radiation from the nuclear detonation on people who survived the blast and heat; and (2) the effects of radiation injury from fallout of the radionuclides produced by the nuclear detonation. One example of the first type of injury is a person who was in an underground shelter in Hiroshima at the time of the detonation and thus escaped the effects of blast and heat, but died of radiation illness. Other survivors of blast and heat in Hiroshima and Nagasaki suffered injury from the neutrons and gamma rays in the initial radiation flux. Neutron and gamma rays are capable of penetrating shielding and therefore causing radiation injuries at considerable distances from their source. Doses of radiation greater than a few sieverts (hundred rems) can cause radiation sickness characterized by serious illness, disability, or even death. Smaller doses of neutron and gamma radiation may lead to subsequent cancers, as documented by the Atomic Bomb Casualty Commission and its successor, the Radiation Effects Research Foundation, in long term follow-up studies of the survivors of the nuclear bombing of Hiroshima and Nagasaki.[13,14]

In addition to direct exposure to gamma rays and neutrons produced by the detonation, people may ingest or inhale radionuclides from fallout either locally or at a great distance from the epicenter of the detonation. Inhaled or ingested radionuclides that emit alpha or beta radiation can seriously injure tissues close to their location in the body. The National Cancer Institute has published information estimating the number of thyroid cancers in the United States produced by the absorption of short-lived radioactive iodine-131 from atmospheric nuclear tests conducted by the US and the Soviet Union.[15] The fallout of radionuclides was one of the reasons for the banning of nuclear tests in the atmosphere by the 1963 Limited Nuclear Test Ban Treaty.

The ground radioactivity after a 1-kiloton shallow-buried explosion would be distributed over a few square kilometers in high concentration. About 60% of the radioactivity is deposited locally at high dose rates, and more than half the radioactivity will descend in the first 24 hours. Meanwhile, the winds will determine the distance that the fallout will carry, with debris likely distributed over a wide area.

Figure 1 shows the approximate radiation

isodose contours due to fallout from a 0.43 KT underground nuclear test.[16] The buried depth of 34 meters reduced the total radioactivity released, but people within the innermost contour would nonetheless have received a radiation dose of 1,000 rads per hour or more, and those within the second contour would have received a radiation dose of 100 rads per hour. A dose of 1,000 rads per hour would cause radiation sickness in the majority of victims in about 10 minutes and fatal injury in about 45 minutes. A dose of 100 rads per hour would be likely to produce radiation sickness in one to two hours and fatal injury in four to five hours. Those exposed would have to leave the area of exposure — or be evacuated from it — as quickly as possible. Of course, victims may be injured or trapped by the debris produced by the heat and blast, or will be busy attempting to rescue others. Since radiation is invisible and its detection requires radiation-sensitive badges or other monitors, such victims may be totally unaware of their exposure to radiation and its magnitude. Once such people have made it out of the area, their clothing and other repositories of radioactive material would have to be removed and taken to a safe distance so as to avoid additional radiation exposure to the victims or to others. The victims would also need access to showers – with protected drainage – that could remove particulate radioactive matter from skin and hair. (An isodose contour map such as the one shown, overlaid on a metropolitan map of Baghdad, Pyongyang, Damascus, Teheran, or any other potentially targeted urban area, would permit a rough quantitative estimation of the large number of civilian casualties that would result from nuclear EPW use.)

Medical Consequences of Radiation Exposure

Radiation injury affects multiple organ systems; the range, intensity, progression, and duration of symptoms are functions both of the exposure dose and the type of exposure – gamma rays or neutrons, or radionuclides that affect specific tissues in which they are concentrated, such as strontium-90 in bone and I-131 in the thyroid gland. These exposures may result in cancers that become apparent years after the exposure.

With regard to acute radiation sickness, cells in mitosis and those with higher levels of metabolic activity are more radiosensitive than others. Hence, rapidly proliferating cells such as lymphocytes, erythroblasts, and intestinal crypt cells are affected more extensively than highly differentiated muscle and nerve cells. Since epithelial cells are particularly vulnerable, first symptoms often reflect damage to the gastrointestinal tract, with protracted vomiting, diarrhea, and fluid and electrolyte loss. Bone marrow (white cells) and other immunological defenses are also vulnerable, and profound anemia, hemorrhaging, and secondary infection are common phenomena. For those exposed to lethal doses, death may take several days to a week or more to occur.

It is the damage to the blood-forming tissues and the gastrointestinal tract that largely determines the fate of individuals exposed to moderately large doses of total body radiation. When the dose is over 2 sieverts (200 rem), nausea and vomiting are virtually immediate symptoms, accompanied by a loss of appetite and diarrhea in about a third of those exposed.

After the early symptoms – the so-called "prodromal" syndrome -- the lethal response is characterized by three modes of death. At doses of 20 to 150 sieverts, the terminus is a matter of hours to days, from neurological and cardiovascular breakdown. At levels of 5-12 sieverts, the gastrointestinal syndrome produces progressive deterioration over a period of days to weeks Even at a lower dose, on the order of 2-4 sieverts, death may occur several weeks after exposure as a result of bone marrow failure.[17]

The immediate reaction is not accompanied by a change in the white count in the first few days. With the destruction of the precursor cells or stem cells, there is a decreasing quantity of available red cells, white cells, and platelets. But the real evidence of radiation sickness becomes apparent when the circulating cells are depleted and the replacements are not forthcoming from an inactive marrow. At this point, a few weeks after the exposure, fever, chills, oropharyngeal ulcers, and anemia develop as a consequence of infection and marrow depression.[18]

Infants, children, the elderly, the chronically ill, and women of reproductive age are especially vulnerable. These populations may be already vulnerable due to disease or malnutrition. In Iraq infection and malnutrition may be a consequence of the effect on water and food supplies and the destruction of the medical and sanitation infrastructure by the 1991 bombing and as a consequence of food shortages because of United Nations sanctions and the response of the Iraqi government. Radiation injury accompanied by exposure to blast or burn has a synergistic effect. Other synergistic effects may be caused by the deleterious combination of suppression of immune response by radiation and dissemination of infectious agents.

There are no specific therapies for acute radiation injury; supportive treatment (intravenous fluids, blood transfusions, antibiotics) is all that can be offered. Even with available modern antibiotic therapy – and the appropriate drugs are not always at hand – infection is an important cause of death. For those sub-lethally exposed, such measures may be crucial in permitting survival through acute illness and lead to eventual recovery. Even in such cases, longer term effects may occur subsequently. In most cases, there will be no way for physicians to determine the level and type of radiation exposure in any individual patient. Effective triage, separating those who are certain to die from those for whom recovery is a possibility, will therefore be impossible. Unless hospitals, clinics, and other sources of medical care have adequate decontamination facilities, physicians, nurses, and other health workers will themselves be at risk for radiation exposure from patients' contaminated clothing.

Given the time course of radiation injury and illness, the effects of even a single exposure of the type most likely to result after the explosion of a nuclear EPW as described above will occur over a period of weeks, rather than as an acute, self-limiting event. If the treatment resources are available, the central problems of infection and hemorrhage may be managed successfully in a significant number of patients.

Synergistic Effects and Medical Responses

It is important to note that the use of nuclear EPWs targeted on underground bunkers in or near urban areas is likely to be accompanied by other military actions – simultaneous conventional air strikes, helicopter gunship assaults, or infantry combat. These combinations are likely to increase panic, prevent any semblance of orderly evacuation, and vastly increase civilian casualties.[19] As a consequence, traumatic injuries – in addition to the effects of radiation exposure – will make the demand for medical care overwhelming. The availability of medical care facilities, personnel, supplies and equipment, and the functional status of the entire medical care system, are likely to be affected. Blood and fluid supplies , including whole blood, packed red blood cells, platelets, plasma, albumin, and Ringer's lactate, as well as bandages, intravenous solutions and injection sets, antibiotics, and anesthetics may be needed. Hospitals may be crippled by interruption of water and sewage pumping, disruption of telephone and other communication systems, destruction of electrical power grids, and damage to transportation systems, as they were during the 1991 Persian Gulf War.

Escape and Evacuation

Analysis of the possibility and speed of escape and of evacuation depend on a number of factors: (1) mobility of the victims; (2) availability of transport; and (3) barriers to flight or evacuation caused by physical damage to victims or to transport systems or by panic. Most of the total radiation dose received from fallout occurs in the first few hours after the detonation. In New York City, for example, a low-yield nuclear EPW detonated at the southern end of Central Park during a weekday would require the rapid evacuation of millions of people. In Baghdad, which has a population density greater than that of New York City, even more people would have to be evacuated from any affected area.

Extensive analyses of the problems of escape and evacuation were conducted during the 1950s and 1960s when it was alleged that "civil defense" could be an effective response to the use of nuclear weapons.[20] Among the findings of those analyses was the prediction that much of the "evacuation" would be spontaneous and uncontrolled. Uncontrolled evacuation from the site of a nuclear EPW explosion could not only lead to confusion, congestion, and long delays, but, in cases where "bunker busters" were used against underground biological weapons facilities, could possibly lead to the exposure of more people to biologic agents capable of person-to-person transmission.

Weakening of the Restraints Against the Use of Nuclear Weapons and of Other Weapons of Indiscriminate Mass Destruction

The effort by nuclear advocates to introduce new low-yield nuclear weapons into the US arsenal is part of a growing trend to lower the nuclear threshold and make the use of nuclear weapons more acceptable. Proponents have argued that small nuclear weapons could be used in otherwise conventional conflicts because they minimize collateral damage. Our analysis shows that this is not true.

Furthermore, the use of low-yield nuclear weapons may lead to weakening the restraints against the use of nuclear weapons of greater yield and in other environments, such as in the air, underwater, and in space. Further development of new nuclear weapons such as EPWs by the United States may require renewed underground nuclear testing, breaking the current world moratorium and destroying prospects for eventual universal accession to the Comprehensive Test Ban Treaty (CTBT). It would almost certainly fuel a new cycle of global nuclear weapons proliferation as other nations respond with their own new weapons.

The US currently enjoys overwhelming conventional military superiority and remains the world's unchallenged superpower. Nuclear weapons still have the capability to threaten large numbers of the US population. The CTBT and other treaties intended to limit the proliferation of nuclear weapons to other states greatly increases US security. The development of new nuclear weapons, with new designs that have to be tested, would ultimately undermine not only US national security but global security as well.

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