SPECIAL ARTICLE

Evolving Societal Risks and Necessary Precautions in the Age of Nuclear Power and Therapeutic Radiation: An American Perspective

Martin H. Pham[1], Cheng Yu[1,3], Mairead Rusch[4], Charles Holloway[5], Eric Chang[2], Michael L. J. Apuzzo[1]

Key words
- Dirty bomb
- Gamma Knife
- Nuclear weapon
- Radiation dispersion device
- Radiosurgery
- Terrorism

Abbreviations and Acronyms
BWR: Boiling water reactor
CFR: Code of Federal Regulations
NRC: Nuclear Regulatory Commission
RDD: Radiation dispersion device

From the Departments of [1]Neurosurgery and [2]Radiation Oncology, Keck School of Medicine, Los Angeles; and [3]Department of Radiation Physics, [4]Gamma Unit, and [5]Security Operations, Keck Hospital of USC, Los Angeles, California, USA

To whom correspondence should be addressed: Martin H. Pham, M.D. [E-mail: martin.pham@usc.edu]

Citation: World Neurosurg. (2014) 82, 6:1060-1070. http://dx.doi.org/10.1016/j.wneu.2014.09.007

Supplementary digital content available online.

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

1878-8750/$ - see front matter Published by Elsevier Inc.

Terrorism involving nuclear or radiologic weapons can devastate populations, city infrastructures, and entire sociopolitical systems. In our age of nuclear medicine and therapeutic radiation delivery, the unauthorized and illegal acquisition of radioactive materials needed for such an attack is always a possibility and risk. Physicians handling high-energy isotopes for medical radiotherapy must be aware of the basic security requirements as outlined by the Nuclear Regulation Commission, which include background checks and authorized access, physical protection during radionuclide use, and physical protection during its transit. The Leksell Gamma Knife and its Category 1 cobalt-60 radioactive source are discussed because of their significant potential for deployment in a weaponized device. Although this article presents a perspective relating to American rules and regulations, these precautions are applicable anywhere that similar situations exist. Understanding these materials and the security they require is essential to preventing the disastrous outcomes should these isotopes fall into terrorists' hands.

INTRODUCTION

The terrorist attacks on September 11, 2001, in the United States have generated a national climate of heightened awareness to the ever-present risk of violence against large civilian populations. Deliberate attacks by terrorist organizations using chemical, biologic, radiologic, or nuclear agents can terrify and disrupt large portions of society, which renders these agents tremendously more dangerous than conventional weaponry. In our age of nuclear therapeutics, the acquisition of radioactive materials with the intention to perpetrate radiologic or nuclear terrorism is a constant possibility. This fact is underscored in light of the death of a Russian spy in London from polonium-210 as well as 2 radiation exposure devices left in Moscow in the mid-1990s (14). Many iterations of radiologic and nuclear terrorism exist with the possession of radioactive material, and awareness of the potential use of these radioactive sources is an essential first step toward protection and prevention. A successfully executed attack in the United States would have far-ranging consequences across the social, political, economic, and medical landscapes.

As yet, there have been no major radiologic attacks in the United States. However, the threat of hazard remains. This article discusses terrorism involving nuclear and radiologic weapons in the context of our current ubiquitous use and access to nuclear therapeutics. Special focus is placed on cobalt-60 and the Leksell Gamma Knife (Elekta AB, Stockholm, Sweden) because of its high potential for use in a weaponized radiologic device. Although many of the rules and regulations discussed are requirements regarding radiation safety, security, and protection in the United States, the potential dangers inherent with using high-energy radioisotopes are present worldwide.

RADIATION

Much of the terror from a radiologic or nuclear device detonation comes from the harmful radiation exposure and area contamination from radioactive fallout. Harmful radiation injures cells through both somatic and genetic effects. Immediate somatic effects involve damage and destruction to enzymes, structural proteins, and other organelles and molecules required for cellular function. This is typically a consequence of high-radiation exposure and results in cell damage, tissue injury, and organ failure. Genetic effects are typically delayed and can result from both low-radiation and high-radiation doses. These effects are largely due to radiation injury on cellular DNA, which render it susceptible to mutation and carcinogenesis (34). Harmful radiation can be in the form of particles (alpha particles, beta particles, neutrons) or energy in the form of electromagnetic radiation (ultraviolet, x-ray, and gamma rays). Table 1 summarizes the different types of radiation that are commonly encountered in everyday life and in the medical and commercial industries.

NUCLEAR MEDICINE AND MEDICAL RADIATION THERAPEUTICS

With regard to nuclear therapeutics, a difference exists between radioactivity

Table 1. Types of Radiation

	UV Rays	X-Rays	Gamma Rays	Neutrons	Beta Particles	Alpha Particles
Ionizing energy	Low	High	High	Very high	Very high	Very high
Body penetration	Superficial	Deep	Deep	Deep	Moderate	Superficial
Potential for harm	Moderate	Moderate	Moderate	High	High	Moderate
Common source	Sun, welding	Medical imaging	Cosmic radiation, radioactive decay	Cosmic radiation, radioactive decay	Cosmic radiation, radioactive decay	Cosmic radiation, radioactive decay
Materials that block	Sunscreen, UV eye protection, anything blocking visible light	Lead and other metals	Thick metal such as lead, tungsten, steel	Paraffin, water	Thick aluminum, plastic glass	Paper, clothes, water, skin

The types of electromagnetic and particle radiation commonly encountered either in daily life or in the medical and commercial sectors are compared. Different radiation types have different energies, abilities to penetrate the body, and potential for harm. Common sources of these types of radiation and routine blocking materials are compared as well.
UV, ultraviolet.
From Yamamoto LG: Risks and management of radiation exposure. Pediatr Emerg Care 29:1016-1026 [quiz 1027-1029], 2013 (34).

and radiation. A radioactive substance continuously decays and emits ionizing radiation secondary to an inherent instability of its atomic structure. Cobalt-60, iridium-192, and cesium-137 are examples of radioactive isotopes used for therapeutic radiotherapy. Conversely, a radiation device such as an x-ray machine or linear accelerator are sources of radiation when turned on, but because they are not radioactive substances, they do not emit ionizing radiation when they are off (34). **Table 2** lists several radioactive isotopes that are commonly used in nuclear imaging and medical radiotherapy.

Radioactive sources typically used by the military and nuclear power plant industry are known as the "military 4" (tritium, uranium-235, plutonium-239, and americium-241) and are well guarded with sophisticated security systems (24, 34). University research hospitals as well as commercial industry are typically associated with a different set of radioactive sources termed the "university 7" (tritium, carbon-14, phosphorus-32, cobalt-60, iodine-125, iodine-131, and californium-252) and the "industrial 3" (iridium-192, cesium-137, and cobalt-60) (24, 34). All 3 industry-associated radionuclides are also used in therapeutic radiation delivery and are often found in the hospital or university setting as well. This grouping lies in the relatively lower security protocols associated with these latter isotopes, which means there is an increased risk of their acquisition by terrorist organizations for destructive purposes.

NUCLEAR WEAPONS AND RADIATION DEVICES

The method of a terrorist attack using radioactive material can take the form of both nuclear and radiologic weapons. Nuclear fission bombs (also known as atomic bombs) use either uranium or plutonium to create a chain reaction

Table 2. Characteristics of Various Diagnostic and Therapeutic Medical Isotopes

Radioactive Substance	Half-Life	Medical Use	Disintegration Radiation Release
Cesium-137	30 years	Medical radiotherapy	Beta, gamma
Cobalt-57	272 days	Schilling test for vitamin B_{12} excretion	Beta, gamma
Cobalt-60	5.3 years	Stereotactic radiotherapy, sterilization of equipment	Beta, gamma
Gallium-67	3 days	Nuclear medicine imaging	Gamma
Technetium-99m	6 hours	Nuclear medicine imaging	Beta, gamma
Indium-11	3 days	Nuclear medicine imaging for white blood cell scans	Gamma
Iodine-123	13 hours	Nuclear medicine imaging for thyroid scans	Gamma
Iodine-131	8 days	Thyroid radiation ablation treatment	Beta, gamma
Iridium-192	74 days	Brachytherapy	Beta, gamma
Radium-223	11 days	Bone metastasis treatment	Alpha, beta, gamma
Strontium-89	51 days	Bone metastasis treatment	Beta, gamma
Strontium-90	29 years	Bone metastasis treatment	Beta
Xenon-133	5 days	Ventilation/perfusion lung scan	Beta, gamma
Thallium-201	3 days	Cardiac stress test	Gamma

Radionuclides used in medical radiotherapy and radiosurgery are listed with half-lives, typical medical uses, and type of radiation decay.
From Yamamoto LG: Risks and management of radiation exposure. Pediatr Emerg Care 29:1016-1026 [quiz 1027-1029], 2013 (34).

Download English Version:

https://daneshyari.com/en/article/6045588

Download Persian Version:

https://daneshyari.com/article/6045588

Daneshyari.com