Acute Radiation Syndrome

Li-Wei Lin, MD; Tzong-Luen Wang, MD, PhD

Abstract

Acute radiation syndrome is an acute illness caused by irradiation of whole body or a significant portion of it from electromagnetic waves or accelerated atom particles. It is a sequence of phased syndrome: prodromal phase, latent period, clinical illness and one of recovery or death. The extent and duration of symptoms depend on individual radiation sensitivity, type of radiation, and radiation dose absorbed. Increasing radiation dose will heighten the severity of symptoms and shorten the duration of each phase. The three clinical forms of acute radiation syndrome depending on radiation dose are hematopoietic, gastrointestinal and neurovascular. Hematopoietic syndrome produces lymphopenia first then pancytopenia and increases the risk of infection and bleeding. Gastrointestinal syndrome is characterized by loss of the villus structure of intestine and then development of severe GI bleeding, diarrhea and abdominal pain along with hematopoietic syndrome. Neurovascular syndrome happened minutes after exposure with symptoms of vomiting, hypotension, ataxia, confusion, and seizures. Fatality is near 100%. Emergency physicians must recognize the manifestations of radiation syndrome, so we can provide optimal management for radiation victims. *(Ann Disaster Med. 2003;2 Suppl 1:S1-S7)*

Key words: Radiation Syndrome; Radiation Accident; Disaster Medicine

Introduction

Radiation incident is rare condition but worldwide, the number of radiation incidents has reached 403 since 1944.[1] They influenced with 133,617 victims, of which 2965 had significant exposures and 120 persons died. Most acute radiation injury is related to nuclear weapons, industrial accidents, nuclear power accidents and radiation therapy. After terrorist attacked on the World Trade Centers on September 11, 2001, the United States and all developed nation had increasing concern about the possibility of nuclear terrorism. The terrorist attack may include dispersal of radioactive substances with or without the use of conventional explosives, attacks on nuclear reactors and detonation of nuclear weapons.[2] In the United State nuclear attacks are thought easier to manage than bio-chemical terrorism because more then 10,000 persons deal with radiation daily at hospitals, universities, military units, national laboratories and government agencies. Geiger counters or dose-rate meter are available in more than 3,000 hospitals. Emergency

From: Department of Emergency Medicine, Shin-Kong Wu Ho-Su Memorial Hospital, Taipei, Taiwan
Address for reprints: Dr. Tzong-Luen Wang, Department of Emergency Medicine, Shin-Kong Wu Ho-Su Memorial Hospital, 95 Wen Chang Road, Taipei, Taiwan
Received: Sep 1 2003. Revised: Sep 18 2003. Accepted: Sep 30 2003.
TEL: 886-2-28332211 ext 2087 FAX: 886-2-28353547 E-mail: M002183@ms.skh.org.tw

personnel can carried these equipments to detect radioactive contamination and use a simple blood test, absolute lymphocyte counts and clinical manifestation of acute radiations symptoms to assess the severity of radiation injuries. In Taiwan we lack of the experience of management of radiation crisis so we required a thorough understanding of radiation syndromes for effective management of radiation casualties.

History

Most acute radiation injury is related to accidents or radiation therapy. Accidents are sporadic and usually effect small numbers of victims. The first large-scale exposure to radiation has been caused by the detonation of atomic bombs over Japan in World War II. One-hundred and twenty thousands individuals developed acute radiation syndrome. In the Marshall Islands 7, 266 natives were exposed to radiation due to errors in judging winds after a nuclear test in the South Pacific in 1954.[3] A radiation incident involving a medical Cs-137 source in Brazil resulted in 200 contaminated persons and 4 deaths.[4] A nuclear accident at the Chernobyl nuclear power station in Russia in 1986 had exposed more than 116,500 persons and resulted in 29 deaths from acute radiation syndrome.[5]

Epidemiology

Radiation is energy traveling through the space. Radiation includes electromagnetic emissions and particles.[6] Ionizing radiation means electromagnetic (X ray and gamma) or particulate (alpha, beta and neutron) radiation capable of producing ions or charged particles. Ionizing radiation comes from unstable atoms that had radioactivity to emit radiation spontaneously.

Gamma and X rays are electromagnetic radiation like light, radio waves and ultraviolet light but they have short-wave, high-frequency and more energy. Gamma and X rays travel many meters in air and several centimeters in human tissue. They penetrate most materials and is called penetrating radiation. Only dense materials like lead shied prevent penetrating radiation. A person exposed to penetrating radiation is not radioactive.

Alpha radiation has 4 neutron masses and +2 charges. It travels only a few centimeters in air and cannot penetrate skin. It can be hazard from inhaled, swallowed, or absorbed through open wounds with alpha-emitting materials. Paper and keratin layer of skin provide protection against for most alpha radiation.

Beta radiation is thru electrons and travels meters in air and up to 8 millimeters into skin. It may be harmful if beta-emitting materials deposited on skin or internally. Beta radiation can be prevented by clothing and turnout gear.

Neutrons possess a large range of energy and variable penetrating ability. The major source of neutrons comes from critical accidents around nuclear power production facilities or nuclear weapons. It had a unique property that a stable atom may absorb a neutron and then become an unstable atom. Metallic object worn or implanted in the affected person and sodium in human body will become radioactive.

Ionizing radiation produces free radicals from water and then disrupts chemical bonds. This causes damage of cellular biochemical systems and DNA. Cellular replication and protein synthesis are further disrupted. If higher radiation dose absorbed damage will overcome the ability of repair. In general rapid replicating

cells are vulnerable to radiation, e.g. blood, gut, epithelium, and reproductive cells. Clinically young patients, men and debilitated patients are more susceptible from radiation.

Radiation Measuring

Variable methods were developed for measuring radiation. The dose and amount of radiation absorbed by the exposure person determinate the toxicity of radiation injury. The units of radiation measure are listed in Table.[1] Common radiation-monitoring equipments include dosimeters and survey meters.

Dosimeters were worn on the upper torso to record the cumulative dose of beta, X and gamma rays. Two types are thermoluminescent dosimeter or film badge and pocket dosimeter. But these devices need processing. Some self-reading pocket dosimeters may be read immediately. Measurement is typically recorded in milliroentgen (mR).

Geiger counter and ionization chamber are types of survey meters for recording exposure rate of radiation. Geiger counter is used for detecting low exposure of X, gamma and beta radiation. With special instrument GM counter can detect alpha radiation. Ionization chamber is for high exposure of X and gamma rays. Estimates are typically recorded in cpm and mR/h. 2500 cpm is equal to 1 mR/h.

Clinical Acute Radiation Syndrome

Acute radiation syndrome has somewhat predictable clinical courses.[7] During prodromal phase nausea, vomiting and fatigue happen. According to absorbed dose its onset begins from 3-6 hours to minutes and last from 24 to 48 hours. Latent phase follows prodromal phase and last up to 2 weeks. In the period bone marrow suppression and gastrointestinal system destruction occur insidiously but the victim is asymptomatic. Clinical illness develops after affected systems loss its function. Depending on absorbed radiation dose it divides to hematopoietic, gastrointestinal and neurovascular syndrome. Death or recovery follows the critical period.

Whole body irradiation dose at < 2 Gy is

Table. Units of Radiation Measure

Unit name	Tradition Unit	SI Unit	Conversion	Description
Activity	Curie (Ci)	Becquerel (Bq)	$1Bq=2.7\times10^{-11}Ci$ $1Ci=3.7\times10^{10}Bq$	A measure of the amount of radioactivity present in disintegrations per seconds. 1Bq= 1 dps
Exposure	Roentgen (R)	coul/Kg	$1R=2.58\times10^{-4}$ C/kg	A quantity used to indicate the amount of ionization in air produced by x- or gamma ray radiation
Absorbed Dose	rad (r)	gray (Gy)	1 rad=0.01 Gy 1 Gy=100 rad	A measure of absorbed dose can be applied to any type of radiation and reflects the energy imparted to matter
Dose Equivalent	rem	sievert (Sv)	1 rem=0.01 Sv 1 Sv=100 rem	A measure of radiation dose related to biological effect by multiplying the absorbed dose of radiation by modifying factors that take into account the different biological effect of different radiation types

considered subclinically.[1,2,6-8] No symptoms develop when exposure to < 0.75-1 Gy. At 1-2 Gy nausea and vomiting occur 3-6 hours later after events and last shorter than 24 hours. Under this exposure radiation victims have no disease.

Hematopoietic syndrome

When exposure dose is greater than 2 Gy, acute nausea and vomiting (50-100%) happen within 3 hours and last 24-48 hours depending on lower or higher dose. Latent phase follow from 2 days to 2 weeks. Acute leukocytosis present after irradiation and then lymphocyte falls. Thrombocytopoenia, neutropenia and anemia follow in sequence. The maximum effect on bone marrow suppression occurs at 3 weeks after radiation exposure. Infection and bleeding developed due to neutropenia and thrombocytopoenia. During this clinical phase infection and sepsis, especially with Gram-negative bacteria are leading causes of mortality. Death rate is 0-90% depending on dose received and treatment.

Gastrointestinal syndrome

Over 10 Gy exposure gastrointestinal syndrome occur but also may occur at lower dose such 5 Gy. LD 50 for human without treatment is about 325 rads. Nausea and vomiting happened within 1 hour after exposure. Nausea, vomiting and diarrhea are more profuse than hematopoietic syndrome. Villus structures are destroyed and massive amount of plasma are shift to the intestine. Severe gastrointestinal symptoms recur within 1-3 days with diarrhea, gastrointestinal bleeding and abdominal cramping. These induce fluid loss, electrolyte imbalance, dehydration, septicemia and shock. Hematopoietic syndrome follows soon later. Mortality is usually caused by bleeding and Gram-negative sepsis. Survivals are usually complicated late by bone marrow suppression. With treatment death rate is 90-100%.

Neurovascular syndrome

Neurovascular syndrome is the most dangerous condition of radiation injury associated with exposure to radiation dose greater to 30 Gy. Nausea, vomiting, and prostration occur within minutes. Tremor, ataxia, confusion, convulsion, hypotension and hyperpyrexia develop within hours. Patients who receive more than 50 Gy usually die within 24 to 48 hours. Fatality is near 100%.

Diagnosis

Acute radiation syndrome is clinically suspected by history of exposure, clinical symptoms and laboratory tests.

(1) Patients develop a predicable pattern of acute radiation syndrome after a history of radiation exposure

(2) Specific symptoms with a 2-3 week prior history of unexplained nausea and vomiting, are
   - Thermal burn lesion without heat or chemical exposure
   - A tendency to bleed (epistaxis, gingival bleeding, petechiae)
   - Infection with bone marrow suppression (neutropenia, lymphopenia and thrombocytopoenia)
   - Epilation

(3) Obtain complete blood count with differential immediately post event. Repeat every 6 hours for 48 hours. Absolute lymphocyte count at 48 hours predicts the

exposure radiation dose.[2]

- Over 1500= trivial or no exposure, 0-0.4 Gy, Excellent prognosis
- Over 1000= moderate injury, 0.5-1.9 Gy, survival without treatment
- 500-1000= severe injury, 2.0-3.9 Gy, survival with treatment
- 100-500= very severe injury, 4.0-7.9 Gy, death without bone marrow transplant
- Under 100= lethal injury, >8.0 Gy, certain death

(4) Swabs from body orifices and wounds if external contamination is suspected. Collect 24 hours urine and stool if internal contamination is possible.

Treatment

Medical management for radiation emergency includes triage, emergency care, and definitive care. During triage we focus on immediately life-threatening problems and priority. Emergency care includes decontamination, therapy and diagnosis of radiation and combined injuries. Definitive care provide final disposition and stand care for patients.

Antiemetics

Nausea and vomiting was prodromal symptoms after radiation exposure. Use serotonin 5-HT3 receptor blockages, such as garanisetron (Kytril ®) or ondansetron (Zofran ®) will diminish nausea and vomiting.[7] But these drugs will not change the clinical course of radiation injury.

Infection prophylaxis and control

Sepsis is the primary enemy of radiation victims. Prevention of infection need reverse isolation, avoidance of invasive procedure, such as CVP, NG and Foley, insertion, prophylactic antibiotics and stimulation of hemataopoiesis. Antibiotics are used only when afebrile patients with absolute neutrophil count<100 cells/μl or febrile patient with absolute neutrophil <500 cells/μl. Gram-negative bacterial infections are the most concern such as other patients received chemotherapy with neutropenia and fever.[9] Life-threatening gram-positive bacterial infections also would happen. Empire anitibiotics must cover broadly against gram-negative bacteria and be continued least 7 days after defervescenece.

The degree and duration neutropenia increases the risk of infection increases. Use hematopoietic growth factors, such as G-CSF or GM-CSF has important role for severely exposure patients. It shorten the time of neutrophil recovery and decrease the risk of infection. Recommendations for uses of cytokines are Filgrastim (G-CSF) 2.5-5 μg/kg/QD SC, Pegfilgrastim (pegG-CSF) 6mg QD SC and Sargramostim (GM-CSF) 5-10 μg /kg/QD SC.[7]

Transfusion support

Transfusion of packed red blood cells and platelets is necessary for symptomatic anemia and severe thrombocytopoenia (platelets< 20, 000) or bleeding.[10]

Bone marrow transplant

Bone marrow transplantation or peripheral blood transplantation is indicated when whole body irradiation more than 5 Gy. [11]Above this level bone marrow suppression would be irreversible or prolonged. In Chernobyl nuclear reactor accident 13 persons exposure greater than 5 Gy received bone marrow transplanta-

tion and only 2 persons survived.

Summary

Acute radiation syndrome has a predicable pattern of disease progression. Absorbed dose can be simple calculated by the fall of absolute lymphocyte count and dosimeters. Understand the absorbed radiation dose physicians can estimate outcome and provide proper intervention for radiation causalties. The probability of radiation accidents is rare but real. Emergency health workers must have the knowledge of radiation injury and the skill of decontamination for this challenge.

Reference

1. Radiation Emergency Assistance Center/Training Site (REAC/TS). Available at: URL: http://www.orau.gov/reacts
2. Mettler FA, Voelz GL. Current concepts: major radiation exposure-what to expect and how to respond. N Engl J Med 2002; 346:1554-61
3. Hamilton TE, van Belle G, LoGerfo JP. Thyroid neoplasia in Marshall islanders exposed to nuclear fallout. JAMA 1987;258: 629-36
4. Gal RP. Treatment of radiation victims in Brazil. Science 1988;22:335
5. Linnemann RE. Soviet medical response to the Chernobyl nuclear accident. JAMA 1987;258;637-43
6. Hogan DE, Kellison T. Nuclear terrorism. Am J Med Sci 2002;323:341-49
7. Jarrett D, ed. Medical management of radiation casualties: handbook. AFRRI special publication 03-1. Bethesda, Md.: Armed Forces Radiobiology Research Institute, 2003 (Also available at http://www.afrri.usuhs.mil.)
8. Finch SC. Acute radiation syndrome. JAMA 1987;258:664-7
9. Conklin JJ, Walker RI, Hirsch EF. Current concepts in the management of radiation injuries and associated trauma. Surg Gynecol Obstect 1983;156:809-29
10. Gale P. Immediate medical consequences of nuclear accidents. JAMA 1987; 258: 625-8
11. Geiger HJ. The accident at Chernobyl and the medical response. JAMA 1986;256: 609-12

急性輻射症候群

林立偉　王宗倫

摘要

急性幅射症候群是全身或大部份身體受到電磁波或加速的原子粒子幅射產生的急性疾患。它是一個有連續階段的症候群：前驅期，潛伏期，臨床期和恢復期或是死亡。症狀的程度和時間根據個人對輻射的感受性，輻射的型式和吸收的輻射計量而有所不同。輻射計量的增量將提高症狀的嚴重度和縮短每個時期的時間。依據輻射計量的多寡急性幅射症候群有三種臨床的型態分別為血液、腸胃及神經血管症候群。血液症候群一開始造成淋巴球減少然後產生全血球減少及增加感染和出血的危險。腸胃症候的特色在於失去腸子絨毛結構而後伴隨著血液症候群形成嚴重腸胃道出血，腹瀉及腹絞痛。神經血管症候群在暴露後幾分鐘內產生嘔吐，低血壓，運動失調，混亂及抽筋等症狀。死亡率接近100%。急診醫師必須能辨別輻射症候群的表現才能給輻射傷害的病患最佳的處置。（*Ann Disaster Med. 2003;2 Suppl 1:S1-S7*）

關鍵詞：輻射症候群；輻射意外；災難醫學

財團法人新光吳火獅紀念醫院急診科
抽印本索取：王宗倫　台北市士林區文昌路95號　財團法人新光吳火獅紀念醫院急診科
收件：92年9月1日　修正：92年9月18日　接受刊載：92年9月30日
電話：(02)28332211 分機 2087　傳真：(02)28353547　E-mail：M002183@ms.skh.org.tw