Antidotal Treatment for Radioactive Materials

Dr. Man-li TSE

FHKAM(Emerg Med), FHKCEM, FRCSEd(Emerg Med), MRCP(UK), MBChB
Consultant and Deputy Director,
Hong Kong Poison Information Centre, Hospital Authority

Introduction

Internal contamination occurs when radioactive materials get into a patient’s body. Possible routes are inhalation, ingestion, percutaneous absorption and penetration. Focusing on the recent scenario of this nuclear power plant leakage, the radioactive materials of concern are radionuclides, atoms with unstable nuclei which emit radiation. They get into the human body through inhalation of the contaminated air or ingestion of the contaminated food products. When the absorbed concentration of these radionuclides exceed certain levels, antidote treatment should be considered by a multidisciplinary team that includes radiation specialists, clinical toxicologists and medical doctors from other specialties.

Pharmacological Principles

Strictly speaking, there exists no antidote for radiation injuries. However the term is still borrowed from its toxicological context for the ease of understanding. Decorporation is the more used term which literally means removal (of radioactive materials) from the patient’s body. As the radionuclides possess the same pharmacological properties as their non-radioactive counterparts, (for example, radioactive caesium-137 is handled pharmacokinetically by our body in the same way as the usual non-radioactive caesium-133) therefore they are amenable to the same treatment measures as in caesium-133 poisoning.

The principles of decorporation treatment include the following:

1. Gastrointestinal decontamination: gastric lavage, laxative and even whole bowel irrigation may be applied in acute ingestion of a significant dose of radioactive materials that presents early.
2. Reduced gastrointestinal absorption by saturating the gastrointestinal tract with a physiologically similar chemical.
3. Enhanced elimination by physiological manipulation, e.g. increasing urine output, blood acidification and urinary alkalisation.
4. Blockage of end organ absorption.
5. Enhanced elimination by chelation therapies.
6. Transformation of radionuclides into less chemically toxic substances to reduce their specific chemical toxicities.

Indication

Indication of decorporation treatment, like most if not all other medical treatments is based on risk-benefit consideration. The first rule-of-thumb is that any medical and surgical emergencies should take the first priority, decorporation should not delay or impede the emergency treatment of such conditions. The second priority is external decontamination if needed in order to prevent secondary contamination as well any possible ongoing internalisation of the radionuclides on the body surface. After clearance of these two, the decision of decorporation treatment should be considered. It should be balanced among the estimated harm from the internalised radiation, the potential adverse effects from the treatment and the medical resources available in a crisis situation. The radiation dose needs to be assessed by a radiation specialist who should be able to advise on...
the type and dose of radionuclides being internalised so that the potential harm to the patient can be estimated. There is no well established threshold radiation level for decorporation. One conservative approach is to use the Annual Limit of Intake (ALI) established for nuclear plant workers as the threshold dose. However at risk groups like pregnant women and children would need special consideration.

Radionuclide-specific Treatment

In the scenario of leakage from a damaged nuclear power plant not in the very close proximity, several radionuclides species are usually released in large amounts. They include the radioactive isotopes of iodine, strontium, caesium, plutonium and uranium. The specific decorporation treatment of each radionuclide will be discussed.

**Iodine-131**

As form of iodine, iodine-131 is absorbed and concentrated in the thyroid gland for the production of thyroxines making the thyroid gland most vulnerable to its carcinogenic effect. In order to stop the absorption, non-radioactive iodine supplement at high dose in the form of potassium iodide can be used to saturate the thyroid gland. The unabsorbed iodine-131 will then be excreted in the urine. This treatment is most effective if administered shortly before radionuclide exposure. Its effect wanes over hours and is considered useless 12 hours after radioactive iodine internalisation. The usual adult dose is 130mg orally once daily. The dose is reduced to 65mg daily for a 4 to 18 year old, 32.5mg daily for a 1 month to 3 year old and 16.25mg daily for those younger than 1 month old. For patients older than 40 year old, as the risk of radiation-induced thyroid cancers in their expected life span being low, a higher threshold radiation dose is recommended for their treatment. The treatment should be continued when the air and food are free of significant iodine-131 or the patient has been removed to a protected place with uncontaminated food supply. Contraindications for potassium iodide are iodine hypersensitivity, dermatitis herpetiformis and hypocomplementemtic vasculitis.

When the treatment window has passed before potassium iodide is available, propylthiouracil can be considered. It is a drug commonly used in the treatment of thyrotoxicosis. It also inhibits the absorption of iodine by the thyroid gland. The usual adult dose is 130mg orally once daily. The dose is increased up to 12gm daily and for a longer duration. Prussian blue is usually well tolerated with constipation increased up to 12gm daily and for a longer duration.

**Caesium-137**

Caesium is handled by the body similar to potassium, once inside the body, it will be transported inside cells by the sodium-potassium pump on cell membranes. Insoluble Prussian blue has been successfully used in the treatment for radioactive caesium contamination as well as in non-radioactive caesium poisoning. It significantly reduces the plasma half life of caesium through a several fold increase in the faecal elimination of caesium. The usual dose is 1gm orally thrice daily for three weeks. In severe exposure cases, its dose may be increased up to 12gm daily and for a longer duration. Prussian blue is usually well tolerated with constipation as the commonest reported adverse effect.

**Strontium-90**

Radioactive strontium once absorbed will be concentrated in bones due to its pharmacological resemblance to calcium and therefore it increases the risks of bone cancer and leukaemia. Its similarity to calcium is utilised as a principle of treatment. Blood and urine acidification together with calcium supplement is recommended as the decorporation treatment of choice. The usual regime is ammonium chloride 1-2 gm orally four times daily, together with 50ml of 10% calcium gluconate in 500ml dextrose solution via intravenous infusion over 4 hours daily for 6 days. Monitoring of the blood pH, calcium and other electrolyte concentrations are needed. In a case of acute radioactive strontium ingestion which presents early, gastrointestinal decontamination with sodium alginate powder 10gm in water or a big dose of calcium carbonate (5 gm two to four hourly) can reduce strontium absorption.

**Plutonium-239**

The metal chelator DTPA (diethylene triamine pentaacetic acid) is recommended for the decorporation of radioactive plutonium. Treatment regime starts with calcium DTPA for one to a few doses daily followed by a dose of zinc DTPA daily for several days are usually used. Such a mixed regime is based on the fact that calcium DTPA is more effective than zinc DTPA as least in the first 24 hours after exposure but it also depletes the essential metals in the body like zinc, magnesium and manganese. Both types of DTPA are given as 1gm in 250ml dextrose solution intravenously over 1 hour, once daily. Zinc DTPA is more preferable in the treatment of pregnant women because of the reported higher reproductive outcome risk associated with calcium DTPA. However in case of heavy internal contamination by plutonium, the reproductive risk has to be balanced against calcium DTPA’s better effectiveness. Nebulised forms of the two antidotes may also be used for inhalation-only exposures to plutonium within 24 hours. DTPAs should be used cautiously in haemochromatosis, asthma and renal failure as well after repeated dosings.

**Uranium-238**

Apart from its radioactivity, uranium is also renal toxic. Alkaline urine promotes the formation of the less renal toxic uranium bicarbonate. Urinealkalisation can be achieved by giving 50 to 100 ml 8.4% sodium bicarbonate intravenously in the first half to one hour, then titrate the subsequent infusion rate aiming at a urine pH of 7.5 to 8. Blood pH and potassium need to be monitored. Urine alkalisation by oral intake of sodium bicarbonate is also possible.

**Conclusion**

The treatment of radioactive material contamination requires the collaboration of a multidisciplinary team of specialists. Treatment decision should be based on risk-benefit considerations. Type of radionuclides, the dose, the route of body entry and the time of exposure are all essential information needed in deciding on the appropriate antidote regime.

**References**

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