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REGULAR ARTICLE

The potential use of biogas producing microorganisms in radiation protection

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Hypothesis

Abstract Radiation induced injury is a limiting factor in radiation related approaches from earth to space. Inductions of a wide spectrum of damages in radiotherapy patients due to unwanted normal tissues irradiation and space radiation related diseases in astronauts have been caused many limitations in cancer treatment and space missions. There are many radiation protection/mitigation approaches including: physical, chemical, biological and physiological methods. Radiation protection using these methods is expensive and also has many problems including acute toxicities and difficulties in their targeting to normal tissues. Based on experimental and hypothetical data, showing that medical/biological gases have many protective effects such as antioxidant, anti-inflammatory, anti-apoptotic, and induction of radioresistance, we hypothesize that similar gases which have been produced by microorganisms (biogases) have those properties and may be used as radiation mitigators/protectors in radiation related approaches such as radiotherapy, radiation accidents and in space missions. Isolation microorganism in safe laboratory conditions in enough amounts, finding non-toxic dose of microorganisms that provide highest radioprotection percent, dose reduction factor (DRF) calculation to compare the radioprotective efficacy of the microorganisms, finding the best targeting techniques to deliver those microorganisms into normal tissues, genetically manipulations of microorganism to achieve the highest amount of biogases with lowest side effects can be done for testing the hypothesis.

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Introduction

Radiation injuries and radioprotectors

Radiation induced injury is a limiting factor in radiation related approaches from earth to space. Inductions of a wide spectrum of damages in radiotherapy patients due to unwanted normal tissues irradiation and space radiation related diseases in astronauts have been caused many limitations in cancer treatment and space missions [1–4]. Developments of radiation related damages have led to the conclusion that radiation can result in diminished quality of life and carries the potential for severe debilitating disease.

In radiotherapy, the mechanism of normal tissues injury is very complex and based on dose, manifestation time, volume of irradiated tissue and radiosensitivity can be categorized as acute and late injuries. Speaking generally, interaction of low LET ionizing radiation with normal tissues results in formation of free radicals such as reactive oxygen/nitrogen species (ROS/RNS) that cause oxidative stress and activation of some transcription factors, pro-inflammatory molecules and cytotoxicity by inducing DNA damage, alteration of cell function/phenotype, resulting in chronic inflammation, organ dysfunction, and ultimate fibrosis and/or necrosis [5,6] (Fig. 1).

In the other hand, radiation environment in space is very unique and complex and has three components including: galactic cosmic radiation (GCR), solar particle events (SPE) and trapped energetic particles (TEP). The high LET/charge/energy particles such as protons and Helium from GCR can cause more complex biological effects. In addition to cardiovascular, CNS, hematopoietic and many other diseases, recent evidence show, GCR leads to cognitive impairment and increased Aβ plaque accumulation and so Alzheimer's disease [7–9].

There are different radiation protection/mitigation approaches including: physical, chemical, biological and physiological based methods. The physical approaches such as shielding and technological enhanced radiation delivery is more prominent and new radiotherapy devices and techniques have been developed to have less normal tissue injuries, but those techniques are expensive and have their own problems. In space also, GCR and SPE can penetrate into the shielding material of planet and produce secondary radiation, including neutrons, gamma rays and other radiations. So, additional shielding is required.

In the other hand, many biological and chemical radiation protection/mitigation were suggested. Radioadaptive response by ionizing and non-ionizing radiofrequency radiation [10–12], natural radioprotector agents [13,14], antioxidants materials [15,16], immunomodulatory agents [17,18] and many others were tested and hypothesized as useful radiation counterbalancing tricks [19–23].

In recent years, there has been a hypothetical focus on medical gases as radiation protection agents. In an interesting paper, Schoenfeld et al hypothesized that "hydrogen administration to the astronauts by either inhalation or drinking hydrogen-rich water may potentially yield a novel and feasible preventative/therapeutic strategy to prevent radiation-induced adverse events" [24]. Liu et al also hypothesized that hydrogen therapy may be an effective and specific novel treatment for acute radiation syndrome [25]. The main proposed mechanisms of hydrogen are increase in antioxidant enzymes and reducing free radicals.

In continuing to their hypothetical works, Schoenfeld et al, by reviewing the radiolysis properties of water, biological effects of gas, and radiobiological mechanisms, suggested a systems biology approach that proposed medical gases including CO, H_2, NO, and H_2S as chemical radioprotectors for radical scavenging and as biological signaling molecules for management of the body's response to exposure [26]. According to this paper, medical gases have many beneficial properties such as: radical scavenging, anti-apoptotic, anti-inflammatory and they also can decrease radiosensitivity. We showed the main radiation protection mechanisms of these gases in Fig. 2 briefly.

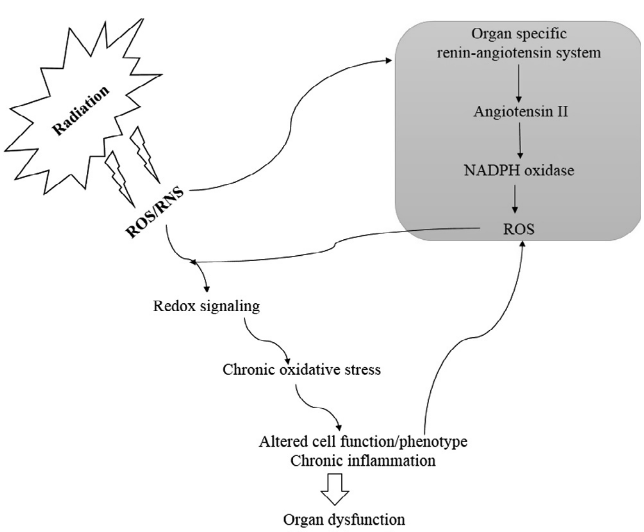

Fig. 1 Putative pathways of chronic oxidative stress resulting in the radiation-induced late effects. Adapted from Zhao et al. with permission (Ref [5]).

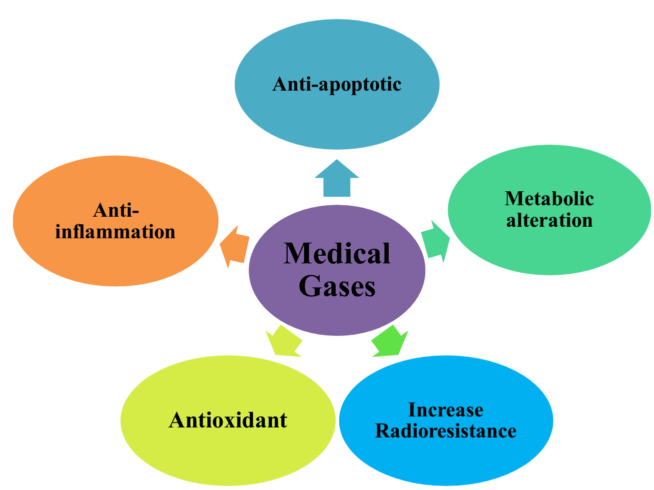

Fig. 2 The main radiation protection mechanisms of medical gases.