

Radon in Medical Hydrology. An Update

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Received: 01-02-12

Accepted: 24-09-12

Abstract

Only a few therapeutic tools have been reported as having both, positive and negative action for human health, such as radon gas. The range of informed actions goes from a mild analgesic effect in patients with rheumatoid arthritis who inhale the gas, to lung cancer in miners (chronic exposition). European and Japanese communications, favors the radon inhalation therapy, while in the Saxon medical literature the therapeutic value of radon is literally ignored. In the '90s, begin to appear studies where the focus was proving that the inhalation of radon coming from mineral water, promotes complex systemic changes. Recently a meta-analysis confirm the beneficial effects of radon in chronic joint disease. Japanese researchers detected systematically, a number of actions occurring without immersion after a few days of breathing in a radon atmosphere. They confirmed that radon inhalation for few days, have an antioxidant action, modify the joint pain in osteoarthritis and rheumatoid arthritis. European authors confirm these findings en people exposed to radon in caverns.

In medical literature coming from North America, is only audible the lonely voice of Luckey, defending Hormesis Theory in the last 25 years. The paradigm of radiobiological science, has been for years "any radiation is dangerous", "there is a certain risk at each exposure to radiation". Hormesis theory describes and explains how - in defined situations- an agent usually lethal at high doses produce beneficial stimulation at low doses.

We review the medical literature generated last 25years about radon, concluding that coexist two opposite conclusions: a) any inhalation of radon is always dangerous and eventually, responsible for lung cancer; b) Inhalation of small doses of radon produces -through Hormesis phenomenon-, healthy and useful effects in certain clinical setting.

By some reason, nature has arranged that biological systems and natural radiation, must coexist in the same environmental space. It will be necessary further research and greater scientific rigor to know completely the action of radon gas inhaled from our hot springs and caverns.

Key words: Radon, Health Resort Medicine, Balneology, Spa, Hormesis

El radón en Hidrología Médica. Una actualización

Resumen

Sólo unas pocas herramientas terapéuticas como el gas radón han sido consideradas por tener acciones tanto positivas como negativas para la salud humana. La gama de acciones

informadas va desde un leve efecto analgésico en pacientes con artritis reumatoide que inhalan el gas, hasta el cáncer de pulmón en los mineros (exposición crónica). Comunicaciones europeas y japonesas, favorecen la terapia de inhalación de radón, mientras que en la literatura médica anglosajona el valor terapéutico de radón es literalmente ignorado. En los años 90, comienzan a aparecer estudios donde el foco de atención demuestra que la inhalación de radón procedente de agua mineral, promueve complejos cambios sistémicos. Recientemente, un meta-análisis ha confirmado los efectos beneficiosos del radón en la enfermedad crónica de las articulaciones. Los investigadores japoneses detectaron sistemáticamente, un número de acciones que ocurren sin inmersión después de unos días de respiración en un ambiente rico en radón. Confirmaron que la inhalación de radón durante unos días, tienen una acción antioxidante, modifica el dolor articular en la osteoartritis y la artritis reumatoide. Autores europeos confirman estos resultados en las personas expuestas al radón en cavernas.

En la literatura médica procedente de América del Norte, sólo se escuchará la voz solitaria de Luckey, defendiendo la teoría Hormesis en los últimos 25 años. El paradigma de la ciencia radiobiológica, ha sido durante años "ningún tipo de radiación es peligroso", "hay un cierto riesgo en cada exposición a la radiación". La teoría Hormesis describe y explica cómo -en determinadas situaciones- por lo general un agente letal en dosis altas producen la estimulación beneficiosa en dosis bajas.

Se revisa la literatura médica generada últimos 25 años sobre el radón, concluyendo que coexisten dos conclusiones opuestas: a) cualquier inhalación de radón es siempre peligroso y, finalmente, responsable del cáncer de pulmón; b) Inhalación de pequeñas dosis de radón produce a través del fenómeno Hormesis, efectos saludables y útiles en clínica determinada. Por alguna razón, la naturaleza ha dispuesto que los sistemas biológicos y de la radiación natural, deben coexistir en el mismo espacio ambiental. Será necesaria investigación adicional y un mayor rigor científico para conocer completamente la acción del gas radón inhalado de nuestros baños termales y cavernas.

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Palabras clave: Radón, Medicina Termal, Cura Balnearia, Balneario, Hormesis

REFERENCE STANDARD

Giacomino M, De Michele D. Radon in Medical Hydrology. An Update. *Anal Hidrol Med.* 2012, Vol. 5, Núm. 2, 147-159.

INTRODUCTION

Only a few therapeutic tools – such as radon gas- have been considered useful and dangerous to human health, at the same time.

The range of informed effects goes from analgesic action in degenerative joint disease¹⁻²⁻³⁻⁴⁻⁵ to carcinogenic effects in chronically exposed population (lung cancer in miners⁶).

Several reports -coming especially from Germany, Austria, Eastern Europe and Japan- analyze radon inhalation effects, whilst in the English medical literature, radon is not only ignored, but also considered dangerous.

This paper presents a review of the medical literature upon radon until 2012 radon.

RADON

Radon and chronic joint disease

In a meta-analysis conducted in 2005, Falkenbach *et al* reviews five trials (three immersion and two speleotherapy studies) involving 338 patients and found differences in pain evolution compared with control groups 3 and 6 months after exposure. The population studied was diagnosed as osteoarthritis, ankylosing spondylitis and rheumatoid arthritis³.

Radon and Skin

After examining radon concentrations in 76 resorts in Poland, Olszewski reports that in most of establishments (75%), the monthly average radon concentration did not exceed 150 Bq/m³. However, in two cases the concentrations were more than 1000 Bq/m³ and therefore workers may have received an annual dose calculated over 6 mSv, which means that their exposure reached critical levels considering radiation protection standards⁷.

In 2010, an histologically confirmed case of solar lentigo affecting thighs and calves in a spa worker exposed to radon on a daily basis, was reported.

Unlike the classic solar lentigo - which typically develops on sun-damaged skin on the face, back of hands and forearms - this patient had more prominent lentigo in thighs and calves, unusual areas⁸.

The published case generated speculation over the relation between chronic exposure to radon and the onset of the injury, however it is difficult to exclude sun exposure as a causal factor, also present at this situation.

More recently, (2012) Wheeler in an ecological study covering 287 areas of southeast Britain examined the potential relationship between radon concentrations in homes with malignant skin lesions.

The author reported an increased incidence of squamous cell carcinoma in the population exposed to higher concentrations of radon. A relationship with other malignant skin lesions such as melanoma or basal cell carcinoma was not esta-

blished. His conclusion was that environmental radon exposure may be a risk factor for squamous cell carcinoma⁹.

It was reported in 2002 that after exposure to radon in caverns, there is a rise in activity in radon progeny in the hair and skin, which does not change after a shower¹⁰.

The same author, reports that after speleotherapy with radon inhalation, occurs a significative increase of activity of radon progeny in saliva¹¹ (maximum at 35 min) and sweat¹².

Little is known about absorption and excretion of gas radon.

It was recently suggested that the human body absorbs radon through the lungs and skin and eliminated through the lungs and excretory organs.

To test this theory, Kávási (2010) compared radon concentrations in urine samples before and after balneotherapy in radioactive waters. Radon was recovered in all urine samples, confirming some urinary excretion which was previously unknown¹³.

Radon and countries

In the U.S., medical use of radon is almost no reported. The few existing are more likely related with government environmental protection agencies. Papers published in Russian and indexed in MEDLINE database, are almost untraceable and abstracts in English extremely brief or non-existent.

North American studies continually reaffirms that radon is the second leading cause of lung cancer after smoking¹⁴⁻¹⁵.

There are detailed accounts in the medical literature on the concept of "risk perception" for general public on matters concerning to radioactivity that has spread to radon¹⁶.

"Radiophobia" -as result from the fear of nuclear explosion- moved away from the field of health topics radon related.

The attitude of governments in relation to the recommendations in central countries, is varied.

While some countries do not set regulations, others indicate very accurately the possible effects of radon as its concentration in the atmosphere.

They are in the literature references to "alert levels" and "top levels" accepted.

Netherlands, for example -a country with low levels of radon- set 20 Bq/m³ as acceptable in homes, while Finland, Belgium and Switzerland use minor acceptable levels¹⁷.

It's almost impossible to get a book or a publication that mentions radon as a valuable therapeutic agent in the English literature.

Medical Hydrology is not considered as a medical specialty in the United States. The only graduate program that deals the topic in the continent is held in Argentina¹⁸.

The Environmental Protection Agency BEIR VI study (Biologic Effects of Ionizing Radiation) states that "... the radon is one of the most widely investigated carcinogens" and "the carcinogenicity of radon is convincingly documented in epidemiological studies of miners"¹⁹.

EPA considers that people exposed to radon integrate a defined risk group for lung cancer.

On the other hand, public concern about the presence of radon in the atmosphere could be ranged from absolute indifference to the requirement of dosages in the rooms of a property before buying, as verified in certain U.S. states ("*All homes should be tested for radon*" in EPA Guide for the buyer and seller of homes)²⁰.

Radon is ubiquitous, on fact; the most important source of natural radioactivity contributing to the total dose received by the human is coming from radon²¹⁻²² (almost 50% of the total daily dose).

Radon in Argentina

As far as we know, there is no systematic experiences with human exposure to radon in caves in Argentina.

Nuclear Regulatory Authority report that the average radon concentrations in different cities of Argentina are between 25.7 and 49.6 Bq/m³ (nationwide average of 36.3 Bq/m³)²³.

The measurements correspond to levels of indoors radon or radon in the air.

This concentration implies an average annual effective dose of about 0.9 mSv.

These are acceptable values for the general population, carrying no significant radiological hazard.

An annual average radon concentration of 400 Bq/m³ or more requires engineering solutions to air environments and reduce the emission of gas²⁴.

Europe recommends for new housing no more than 200 Bq/m³ of air radon levels and the United States lowered to 148 Bq/m³.

Ubogui *et al* reported in 2007 that radon levels in mineral water of Copahue, Argentina was 9000 ± 2000 Bq/l²⁵, which allows water classified as radioactive²⁶.

De Michele *et al* reported low radioactivity levels in 9 balneary facilities in the province of Entre Ríos (Argentina). Highest radon levels in the region (6300 ± 1314 Bq/m³), were detected in Concepción del Uruguay, lagging below the standard required to consider radioactive the mineral water²⁷.

Radon and housing

In 2000, UN study "*Effects of Atomic Radiation*" reports that the average concentration inside homes in different countries ranges from 8.7 Bq/m³ (Australia) and 40 Bq/m³ for the group of countries included in the study²⁸.

WHO concerned about this situation, designed in 2005 *International Radon Project* (IRP) and a year later presented the final report of its conclusions²⁹.

One of productions of IRP was the *WHO Handbook of radon indoors*. The compiled material focuses the debate on public exposure to radon in homes promoting risk reduction policies, prevention and mitigation of exposure. The manual reflects epidemiological evidence that indoor radon is responsible for a substantial number of lung cancers in the general population³⁰.

Radon, physiology and pathology

Japanese researchers report that in cultured rat cells exposed to radon, remarkable activity of the enzyme superoxide dismutase (SOD) is detected. SOD is considered a free radical scavenging and these findings suggest that an atmosphere of radon in vitro promotes anti-oxidation³¹.

Almost 20 years ago, the same group of researchers confirmed in rabbits that radon inhalation induces changes in cell membrane fluidity, levels of lipid peroxide-ses (TBARS) and brain levels of superoxide reductases³².

Recently, Kataoka (2011) provides valuable data on the behavior of superoxide reductase in small animals underwent to inhalation of different concentrations of radon³³.

In 1996, the same group reported radon vasoactive action and a probable influence of inhalation on blood pressure. Analgesic morphine type action was also informed.

In the latter study, Yamaoka was unable to detect effects of radon on human physiology separating them from those induced by immersion³⁴.

Generating closed atmospheres with different concentrations of radon, before and after inhalation, pain levels, vessel caliber, anti-oxidation levels and changes in immunity cells were compared.

The findings emerged from methodical studies, suggest that in fact, following radon inhalation, some complex systemic effects are detected. These effects seem to explain the level of oxido-reduction modifications after a 10 days exposure.

They also suggest that immune phenomena, oxidation and production of pain can be altered by inhalation of radon gas.

It is thought that the proper amount of active oxygen produced by the inhaled radon, is responsible for pain relief in diseases redox reaction related, as osteoarthritis³⁵.

On the other hand, Canadian authors reported in 2011 that radon alpha particles induces deregulation of pro-inflammatory cytokine system and DNA damage³⁶.

HORMESIS THEORY

The whole theory that explains the damage caused by ionizing radiation to biological systems holds in the axiom of the *linear no-threshold model* (LNT).

The concept of the linear no-threshold model, was introduced by Gofman.

It is a model trying to explain the damage caused by ionizing radiation, particularly the increased risk of cancer. This model suggests that the risk of injury is long-term predictable, cumulative and increases with exposure to the radiation source.

Gofman suggested that “*the only safe dose, is the dose zero*”³⁷.

In 1943 and Erlich Southam noted that despite the high concentrations of oak bark extract inhibit the growth of fungi, low doses of this agent stimulate it.

For over 30 years, several researchers call attention to the health effect of small doses of radiation on human physiology³⁸⁻³⁹.

In the '80s and '90s Luckey published a series of papers in line with other authors, suggesting that small doses of ionizing radiation are beneficial for life, growth, fertility, health and longevity⁴⁰⁻⁴¹⁻⁴²⁻⁴³⁻⁴⁴.

The same author reports that ionizing radiation promotes growth of protozoa in the laboratory⁴⁵ and that the overall rate of cancer is reduced in people with chronic low exposure⁴⁶.

A clear example of radiation hormesis is the finding of Yonezawa in 1996.

This research proved that pre-irradiated mice with low doses of X-rays showed increased survival when they were subjected to subsequent lethal radiation dose⁴⁷.

Miller *et al* (1989) followed a cohort of 31,710 women by previous diagnosis of tuberculosis, had been repeatedly examined with fluoroscopy⁴⁸.

The population studied was women who had received a dose estimated at 10 cGy or more, considered risky for breast cancer. He compared the breast cancer deaths with another group that received less than 10 cGy. It concludes that the risk of breast cancer associated with radiation, decreases when higher the age at which exposure began.

CHRONIC EXPOSURE TO IONIZING RADIATION AND RADIATION HORMESIS

Shimizu *et al.* studied the risk for cancer and death from cancer in survivors of the Hiroshima and Nagasaki atomic explosions (86,520 people)⁴⁹.

This author reports that cancer mortality in the population of slightly irradiated survivors is somewhat lower than the average mortality in the region.

In 1993 Cohen found a negative relationship between home radon levels and lung cancer.

The results of Cohen study agree with those Hayes in England⁵⁰.

The study BEIR VII (2005) finally approached the human risk to low doses of ionizing radiation.

The definition of low doses include values between 0 and 100 mSv or less than 0.1 mGy/min every month of life. There is evidence in humans of exposure to that range of radiation, since 60% of the atomic bomb survivors received less than 100 mSv.

The levels of regulation proposed, should be as low as cancer or mutations not be statistically significant.

The study adds a conclusion absent in the BEIR VI; it was informed that scientific evidence is consistent with the linear no-threshold model to explain the risk of cancer by ionizing radiation, but clarifies at small doses of radiation, cancer and risk mutations will be very small⁵¹.

CONCLUSIONS

The medical literature on therapeutic uses of radon in the last 20 years comes preferably from Central Europe (especially Austria, Germany), Eastern Europe and Japan.

In the '90s, begin to appear studies where the focus was proving that the inhalation of radon coming from mineral water, promotes complex systemic changes.

From these publications stand out and highlight healthy actions of inhaled radon from mineral hot springs, especially in chronic degenerative rheumatic diseases⁵²⁻⁵³⁻⁵⁴⁻⁵⁵⁻⁵⁶⁻⁵⁷⁻⁵⁸.

Working with atmospheres of different radon concentration, has been separated actions attributable to the immersion and the specific actions attributable to the inhalation of the gas.

Japanese researchers (Yamaoka *et al*) were able to detect and quantify a number of actions that occurred without immersion, which were attributed to inhalation of known concentration of radon from a particular atmosphere.

Following this method, it is confirmed that inhalation of radon for few days, has an antioxidant action, modifies peripheral resistance and diminishes the joint pain in osteoarthritis and rheumatoid arthritis.

In addition, other researchers reported accentuation of incidence of lung cancer only in certain populations.

From Saxon literature, appears the lone voice of Luckey, defending the *Hormesis Theory* in the last 30 years, and criticizing U.S. authorities and other governments who deny it⁵⁹⁻⁶⁰⁻⁶¹⁻⁶²⁻⁶³⁻⁶⁴.

The radiobiological science paradigm seems to be is "*all radiation is dangerous*".

In fact, the radiation damage model proposed by non-threshold linear theory, suggests that the greater the exposure, the greater the risk.

The threshold indicates no matter how small the risk if exposure exists.

Since 1979, National Committee for Radiation Protection (NCRP) defined another dogma in radiobiology; "...there is a certain risk in each exposure to radiation." This approach has remained unchanged to the present.

Preeminence of this radiobiological dogma is evident in Saxon medical journals.

After 30 years of preaching, Luckey Hormesis Theory has been not completely accepted by science and states in Saxon countries.

Criticism of the theory of radiation hormesis explains the indifference of the health press on the subject of the medical use of radon in Saxon countries.

The BEIR VII Phase 2 study has addressed for the first time, issues of the effects of exposure to low doses of ionizing radiation, opening a small gap in the controversy between the theory of hormesis and the linear no-threshold model.

It is likely that this trend will continue, so further research and greater rigour are needed for explaining why nature has provided that every day, we coexist in harmony with natural radiation.

When somebody speaks of radon as a health curse, it has forgotten that the gas is part of many natural environments where human intervention is not recorded.

This polarization in the focus on the action of radon, puts the matter mentioned in the middle of an ongoing controversy.

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