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HISTORY OF MEDICINE

# Twelve Decades of Using Radium in the Treatment of Deeper Localised Cancers

Goran Kolarević,[1, 2, 3] Oliver Arsovski,[1] Branko Predojević[3]

## Abstract

The end of the 19th and the beginning of the 20th century marked a period of fundamental discoveries in the physics of ionising radiation (X radiation and radioactivity). Isolating radium, a highly radioactive element, immediately opened the way to its application for medical therapeutic purposes. It turned out that the sources of ionising radiation are very effective for changes localised on the skin and at small depths under the skin but not for lesions at greater depths. Interestingly, the inventor of the modern telephone, Alexander Graham Bell, was the first to come up with the idea of placing radium sources in glass tubes and placing them directly in the pathologically changed tissues of the patients to be treated (at greater depths). That period marked the beginning of a highly successful era in radium therapy, involving the use of capsules and needles filled with radium, which eventually led to the development of modern brachytherapy. Unfortunately, for several decades people believed in the universally therapeutic properties of radium, so that (fortunately in smaller quantities) it was added to water, food, hygiene products, etc.

**Key words:** Radioactivity; Radium; Alexander Bell; Brachytherapy; Ionising radiation.

1. Centre for Radiation Therapy, International Medical Centres, Affidea, Banja Luka, the Republic of Srpska, Bosnia and Herzegovina.
2. Faculty of Medicine, University of Banja Luka, Banja Luka, the Republic of Srpska, Bosnia and Herzegovina.
3. Faculty of Natural Sciences and Mathematics, University of Banja Luka, Banja Luka, the Republic of Srpska, Bosnia and Herzegovina.

Correspondence:
GORAN KOLAREVIĆ
E: goran.kolarevic@affidea.com

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## Radioactivity and Radium

In February 1896, 3 months after the discovery of X-rays by Wilhelm Conrad Röntgen (1845-1923, Nobel Prize in Physics 1901), a strange phenomenon was observed by Henri Becquerel (1852-1908, Nobel Prize in Physics 1903),[1] uranium salt emits invisible and penetrating radiation similar X-rays. On March 2nd, Becquerel reported at the Academy of Sciences that this radiation arises without any stimulation by light. Names such as Becquerel rays, uranium rays and invisible fluorescence referred to the discovered phenomenon. Becquerel's discovery sparked interest in the scientific community, establishing more centres dedicated to studying this phenomenon. Without diminishing the significance of other centres, the most significant contributions in the early investigation of this phenomenon, particularly in experimental research, were made by research groups gathered around the Curies in Paris (Marie Sklodowska-Curie, Pierre Curie, Irene-Joliot Curie, Frederik Joliot), around Hahn and Meitner (Otto Hahn, Lise Meitner, Kaiser Wilhelm Institute Berlin) and Rutherford (Ernest Rutherford, McGill University in Montreal).

Several questions were formulated regarding Becquerel rays: a) which substances emit them, b) what is the nature of Becquerel rays, c) what processes lead to the emission of this radiation. These questions have determined the fundamental directions of further research. The


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most significant contribution in answering the first question in the early years of nuclear physics development was made by Marie and Pierre-Curie.

*Figure 1: Marie Skłodowska-Curie and Perie Curie*

Marie Sklodowska-Curie (1867-1934, Nobel Prize in Physics 1903 and Chemistry 1911), wife of physicist Pierre Curie (1859-1906, Nobel Prize in Physics 1903), was in Paris at the end of 1897 contemplating potential topics for her doctoral dissertation. The Curies (Figure 1) were very interested in radioactivity and began experiments with uranium. They concluded that radiation is a property of the atoms themselves.
In her report to the Paris Academy in April 1898, Marie Curie wrote: "Two uranium minerals: uranite (uranium oxide) and chalcolite (copper-uranium phosphate) are much more active than uranium itself. This fact is very significant and leads us to think that these minerals may contain some element that is much more active than uranium..."

Their stance was confirmed by publishing their work on the radioactivity of thorium, just days after Gerhard Schmidt.[2, 3] In the same year (1898), they managed to isolate two new elements, polonium[4] and radium,[5] the radiation of which is three million times more active than uranium.[6] Working on polonium, for the first time in the history of science, they used the word „radioactivity", a term that has remained in use to this day. Strictly speaking, the Curies did not obtain pure radium but radium chloride in their initial result. Radium as pure metal was isolated by Marie Curie and Andre Luis Debierne through the radium chloride ($RaCl_2$) electrolysis.[7]

Shortly after the discovery of radioactivity, in 1901, Pierre Curie recommended the use of radium to the French dermatologist Henri Alexandre Danlos for the treatment of skin changes. In the beginning, surface applicators were created for radium sources (for the treatment of surface-skin lesions) and we can say that surface brachytherapy was created (Figure 2).[8, 9] It was soon concluded that radium rays have the same biological properties as X-rays.

*Figure 2: Treatment of skin lesions with radium, Melbourne, Australia (1905)*

In June 1903, Marie Curie presented her doctoral thesis at the Sorbonne University and became *Docteur es Sciences* (PhD) and in December received the Nobel Prize. Pierre Curie was appointed as a professor and head of the Physics Department at Sorbonne University in October 1904, while Marie Curie became head of his laboratory. On April 19th, 1906 (age 47), Pierre Curie was killed by a horse-drawn carriage crossing Dauphine Street in Paris (Marie was 39 years old). Sorbonne University appointed Marie as a professor and she became the first female full professor at a French University (November 1906). The unit for measuring the activity of radioactive material (1910) was named „curie" (Ci) and defined as the activity of radium mass 1 g.[10]

## Dr Alexander Graham Bell - Radium Pioneer

Alexander Graham Bell (1847-1922) patented the modern telephone as his invention. His life was made miserable by a lengthy court process due to circumstances where Elisha Gray reported the same invention to the US Patent Office just two hours after his lawyer (February 14th, 1876).

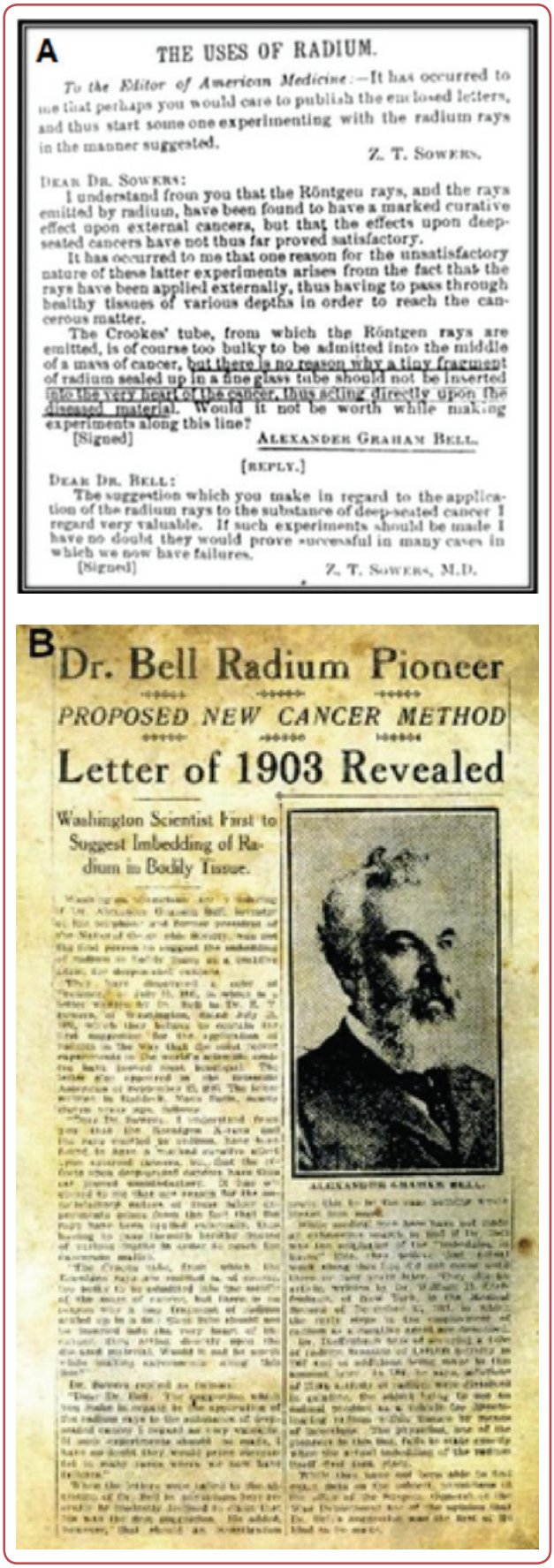


*Figure 3: A) Radium and Cancer (Letter to Dr ZT Sowers). Science, July 31st, 1903, B) Medical record, New York, December 13th, 1913*

Because of those two hours, Gray lost millions.[11] The letter, dated July 21st, 1903, in which Bell addresses doctor Sowers from Washington, is considered to contain the first proposal for the application of radium in the way that the latest experiments in the world's scientific centres showed to be the most useful at that time.[12] The letter was published in the Scientific American magazine on September 12th, the same year (Figure 3A) and read:

„Dear Dr. Sowers. I understand from you that the Roentgen X-rays and the rays emitted by radium have been found to have a marked curative effect on external cancers but that the effects upon deep-seated cancers have thus far proved unsatisfactory.

It has occurred to me that one reason for the unsatisfactory nature of these latter experiments arises from the fact that the rays have been applied externally, thus having to pass through healthy tissues of various depths in order to reach the cancerous matter.

The Crooks tube, from which the Roentgen rays are emitted, is of course too bulky to be admitted into the middle of the mass of cancer, but there is no reason why a tiny fragment of radium sealed up in a fine glass tube should not be inserted into the very heart of the cancer, thus acting directly upon the diseased material. Would it not be worthwhile making experiments along this line?"

Dr Sowers replied as follows:
„Dear Dr. Bell. The suggestion which you make in regard to the application of the radium rays to the substance of deep-seated cancer I regard as very valuable. If such experiments should be made I have no doubt they would prove successful in many cases where we now have failures".[13]

Today, Dr Alexander Graham Bell, inventor of the telephone and former president of the National Geographic Society, is believed to have been the first person to propose the implementation of radium into body tissue as a cure for deep-located cancers.

The article by Dr Williams Dieffenbach, in the Medical Record of December 13th, 1913 (Figure 3B), described the first steps in using radium as medicine. He talks about a solution of radium in gelatine, which was injected into a patient in 1906.

# Radium Applicators – Radium Therapy

Nineteen twenties, radium salts are inserted into tubes and thin needles with the help of jewellery experts. In Paris, platinum tubes containing 10 mg of radium and needles of various lengths were made. The platinum wall absorbed alpha, beta and gamma rays of low energy.[10]

Brachytherapy (term of Greek origin introduced in 1931) is defined as a short-distance treatment of malignant disease with radiation from encapsulated sources. The sources are placed directly (or in the immediate vicinity) into the tumour.[12] Radium ($^{226}$Ra, half-life 1622 years, $E_\gamma$ = 0.8 MeV)[14] was an ideal choice for brachytherapy because it emitted high-energy radiation that could effectively destroy tumour tissue.

Intracavitary radium therapy is performed by insertion of the suitable applicators in the body cavities-gynaecologic cancers or rectal cancers.

Radium salts (powder) are packed in metal tubes (Figure 4A) or cylinder capsules (Figure 4B) designed for endocavitary application in the rectum or vagina/cervix (Figure 5); the thinner ones could be placed in the uterus or cervix.[15]

Cancer was treated more successfully by applying the radium by the intracavitary technique of treating the cervix. The so-called Paris system, consisting of a uterine tube containing 33.3 mg of radium and two vaginal cylindrical plugs connected by a movable spring and containing 13.3 mg of radium each, was used for continuous irradiation for 120 hours (Figure 5).[10]

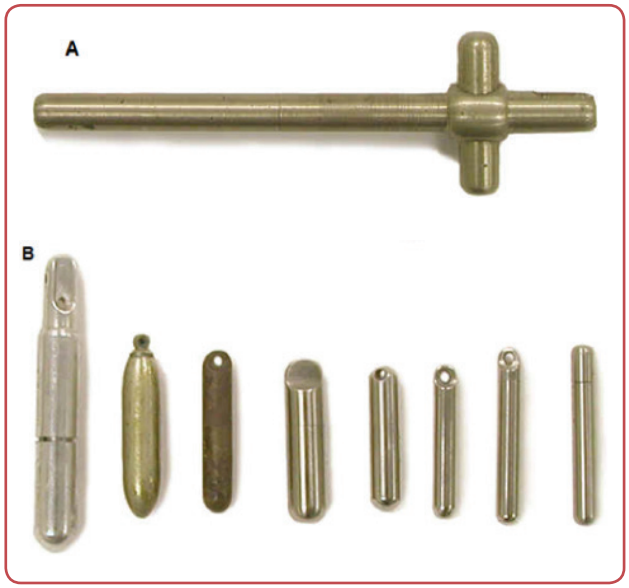


*Figure 4: A) Cervical-uterine radium applicator (1930-1970), made from brass which is chrome plated, activities 50-100 mCi; B) Radium capsules*

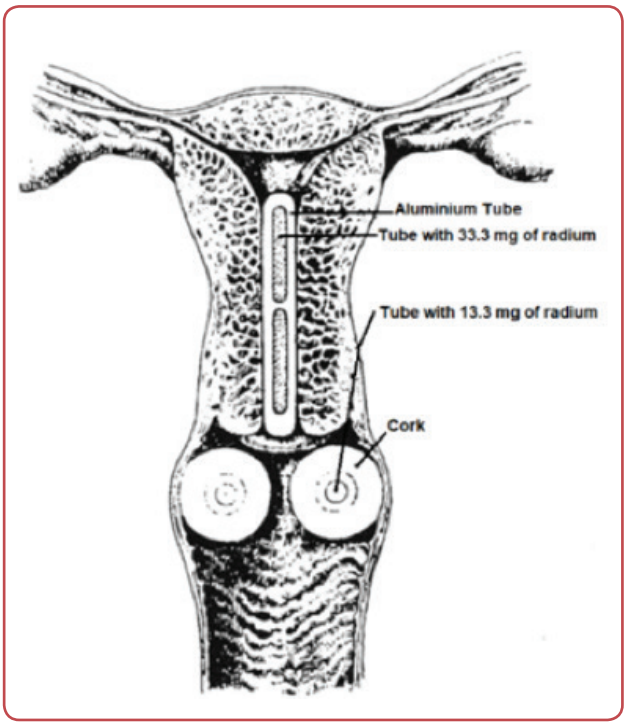


*Figure 5: Intracavitary radium treatment for cancer of cervix*

Interstitial radium therapy is performed by insertion of the applicators directly in the tumour tissue-head and neck cancers or prostate cancers.

One of the key advantages of using radium needles (Figure 6) in brachytherapy was the possibility of targeted tumour treatment. Radium needles were placed directly into the tumour or its surroundings, allowing focused radiation to the diseased area. This approach had an advantage over external radiotherapy (X-radiation) because it allowed a higher dose of radiation to the tumour while at the same time protecting healthy tissue from excessive radiation. Indeed these radium insertions could be considered as the first three-dimensional radiotherapy treatments.

During the 1920s, interstitial radium therapy (needles) was commonly used to treat tumours of the head and neck (Figure 7), breast, bladder, prostate and cervix (through the abdominal route).[10]

Over time, the harmful effects of radiation became better understood. Workers involved in producing radium needles and medical professionals

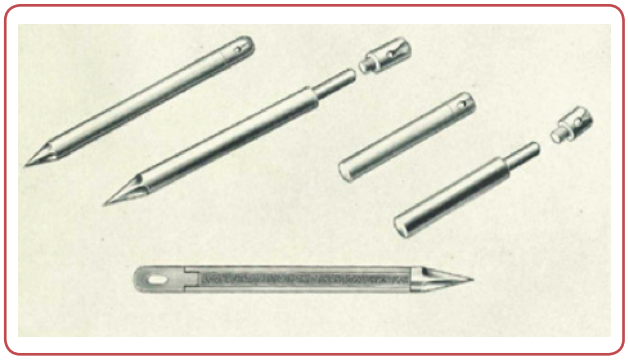

*Figure 6: European-type radium needles and tubes*[16]

who used them were at high risk of radiation over-exposure. Thus, using radium needles in brachytherapy became controversial during the 20th century. Although this therapy was very effective in treating tumours, the radioactivity of radium caused serious consequences for the health of medical personnel who came into contact with it. Many have also developed various forms of cancer. As a result, the use of radium in medicine became less and less popular and later it was replaced by other radioactive materials ($^{60}$Co, $^{192}$Ir, $^{125}$I or $^{137}$Cs).

Although the use of radium needles/capsules in brachytherapy is rare today, their importance in the history of medicine cannot be ignored. These needles represented a turning point in cancer treatment, paving the way for developing more advanced brachytherapy methods that have been successfully applied in modern oncology. The use of radium for medical purposes is definitively prohibited by law in France on October, 1976.[10]

*Figure 7: Loaded radium needles were inserted into malignant tumours (head and neck)*

## The World's Delusion

Medicine's belief in the universal therapeutic properties of radium (a cure for all diseases) lasted several decades. This had an impact on the general population and numerous consequences in medicine. The entire public was misled about the magic of radium in treating pathological changes, pain relief, regulation of physiological functions and maintenance of good health. The radioactive content of mineral waters was emphasised as an indicator of their quality as water for drinking or bathing as a prevention against all diseases. People were offered radioactive ointments and poultices to relieve pain and to treat ulcers and burns, radioactive powder for digestive problems, bathtubs made of radioactive materials, radioactive bedding, radioactive soap and cosmetic cream to prevent skin aging (Figure 8). Fortunately, all this was not too dangerous for the customers since the radioactivity of the product was minimal.[15]


*Figure 8: Advertisements for „radium“ enriched products*

Thomas Edison, William J Morton and Nikola Tesla were among the first to point out possible unwanted harmful effects on the human body, inappropriate exposure to radium and X-radiation.[17]

## Conclusion

The discovery of radioactivity and radium is a significant event in the history of physics. Some applications have led to progress in many areas of technique and sciences, including medicine. Brachytherapy is one such case. Radium needles/capsules were crucial in developing brachytherapy and cancer treatment. Their use ensured targeted irradiation of tumours and technological progress led to the creation of more efficient and safer methods.

## Acknowledgement

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## Conflict of interest

None.

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