Evolution trends of radiation oncology: technologies and principles of applied nuclear physics

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Radiation oncology is the set of techniques used to treat diseases with ionizing radiation, taking advantage of their biological effects, particularly the selective destruction of tissues (WHO - IAEA, 1972). The principles of nuclear physics that permit the use of these specific techniques in the medical field developed in the twentieth century with the studies and experimental observations of W.K. Röntgen. As known, in the laboratories of the Institute of Nuclear Physics in Würzburg in Germany, in 1895 he obtained the first X-ray diagnostic image. The following year the french physicist H. Bequerel discovered natural radioactivity. Other studies conducted by the Curies led to a great knowledge about the properties of radioactive elements. In the following years other scientists such as E. Rutherford and J.J. Thompson led nuclear tests on natural and artificial radioactivity, cataloging and baptizing using greek letters (Alpha, Beta and Gamma) the measured radiations. The study of such phenomena became more widespread and systematic with an ever increasing use, especially with regard to medical applications. In this context, the use of ionizing radiation is various: in addition to a very wide use for diagnostic purposes, the specific mode of interaction with the human body make it possible therapeutic use, especially in oncology.
Nowadays, for the oncologic applications of ionizing radiations is possible to define the following function/machine overview report:
- **Cobalt unit**: the gamma rays from a ^{60}Co source (energy of 1.3 MeV) inserted in a shielding head with an adjustable nozzle are used to obtain a beam with which radiate the anatomical site of disease.
- **Linear accelerator**: a megavoltage X-ray tube produces a beam shaped, by means of a collimator, on the tumor size. Linear accelerator can be used for a wide range of treatments: *two-dimensional treatments*, in which the dose calculation is manual, based on radiographic images of the patient and beam features; *three-dimensional conformal treatments*, in which the dose distribution is calculated, using a specific software, on tomographic images (axial view) of the patient. Moreover the treatment beam is shaped using multi-leaf collimator to better match the area of disease. Also *intensity-modulated treatments* (Intensity Modulated Radiation Therapy, IMRT), are available with linear accelerators. In this tecnique the beam is differentially modulated in his primary fluence, according to the clinical target, providing an even greater dose conformation to the tumor, thus limiting toxicity to healthy involved organs. Finally *stereotactic radiosurgery treatments*, i.e. delivery of large radiation doses in a single fraction, can be made with linear accelerators. Stereotactic treatments are typically used for inoperable, very small tumors requiring high accuracy and therefore additional accessories for the accelerator, such as specific beam collimators and rigid immobilization systems for the patient. Additional accessories can be mounted on the linear accelerator to allow *images-guided treatments* (Image Guided Radiation Therapy IGRT). These systems provide three-dimensional images of the patient immediately before dose delivery, which can be real-time compared with planning images to optimize the positioning accuracy.
- **Accelerator for intraoperative radiation oncology**: consists of a compact moving megavoltage X-ray tube, which can be positioned in the operating room for the irradiation of the tumor bed during the surgical event, with remarkable preservation of healthy tissue and better disease local control.

- **Gammaknyfe**: a header containing more than 200 ^{60}Co sources fitted with conical collimators of variable diameter and customizable to the patient helmets, specifically designed for brain tumors.
- **Cyberknyfe**: a compact linear accelerator mounted on a robotic arm with six degrees of freedom able to "follow" the tumor during patient's physiological movements. Allows high dosages of diseases also very close to sensitive organs, and very moving (i.e. lungs) with great precision and safety.
- **Tomotherapy**: a complete and compact system for radiation oncology, IMRT, IGRT: very similar to a computerized tomography gantry, uses the same rotating X-ray tube for image acquisition and treatment synchronized with the treatment couch. Each therapy fraction is preceded by the acquisition of high resolution axial images based on which the software automatically provides the couch shifts for best patient positioning, allowing a submillimetric accuracy.
- **Hadrontherapy**: Hadrons (heavy charged particles) interaction with matter is very different with respect to X-rays. The "Bragg peak" characterizes hadrons dose delivered curves and suggests an high utilization within radiation oncology. However the complexity of the installations and the high energy required may affect the development of this technology. From a structural point of view, an accelerator of charged particles requires considerable space, in addition to more devices in terms of users safety. Anyway the treatment room, where the beam reaches the patient, is not so different with respect to a linear accelerator's bunker: analogue systems for patient positioning and immobilization are required.

The particular complexity of installation, management, use of these sources of radiation for medical purposes is developed in the context and objectives "Good use of health technologies" and "Ensuring the quality of services" as recommended by WHO (*ISBN 92 890 2034 2, 1985*), repeatedly mentioned in the context of the principles and methods of preservation and protection of human health in projections to 2020. For the EU countries health protection is the fundamental right contemplated by the *Bill of Rights*, particularly regarding the access to preventive health care and the benefit of adequate medical care. According to the WHO definition radiation oncology is a form of distributive composition of the system of care. Within the WHO guidelines (*EURO 327/1966*), the assistance pyramid provides an interdisciplinary network with modulated complexity in which the patients are grouped according to the intensity of their need for care, determined by the degree of disease.

Recalling that, following the Conference of Alma Ata guidelines (1978), at the base of national health systems lies the area of primary care, hospital services take on the crucial role of supporting primary care and specialist level with criteria of effective and efficient organization and management (*WHO 1985*), still highlighted creed by the WHO European Regional Committee of the 48th session (1998). The radiation oncology services form part of the treatment technologies with medical instrument whose constituents are represented by the triad of *factors-personal-technology* and the elements of organization identifies functional areas, technical and technological support in patterns of correlation related to the moments of organization, functioning and structure as provided by WHO (1974) in relation to the definition of the hospital for our times: "The hospital is the set of activities aimed to define and establish the broad guidelines in terms of time and provide the structures and resources" (*Aktouf O., 1989*). The cancer is an important component of care for its dissemination and resources absorption for the monitoring and enforcement for its restraint.

The production lines of radiation oncology is a fundamental means of intervention and the dynamics of evolution and the expected results for therapeutic allow us to envisage the possibility of further progress in basic research and applied to these forms of energy for health purposes.

For the Nations of the Europe Council (but the contents have meant extensive guidance) remember historically the resolution of the Committee of Ministers (*The lower cost of medical care - 1970*) who had already placed out that the best quality of health determine the need for government investment flows and expenditure of the assistance programs, as the humanities and social expectations of the

people and the evolution of medical and biological sciences led to the demand of exponential resources required for high levels of systems of care (*Teseleanu G. Renzulli L. - ISBN 973-8260 - 37 - X, 2000*). The fund of radiation oncology for its structure absorbs important resources and the health policies of national health care trends have sector strategies and methods according to WHO guidelines regarding health planning (*4104/1972 EURO, EURO 4107/1974*) and Programming (*J. Stringer - 1974*) in terms of human health. The research development trend in the domain of nuclear physics applied to health is open to results horizons in progress, with expectations of improving the prognosis of healing for the treated diseases. How do people live the globalization of markets, also knowledge in medical and biological sciences shows its future in a constant tendency to articulate and extensive continents networking, and for the health system of every nation, this means that the scientific world tends, through the multimedia voice and road, to the cooperative research of the highest possible quality of life (*Renzulli L. - 1999*) on the earth today, tomorrow in the cosmos.