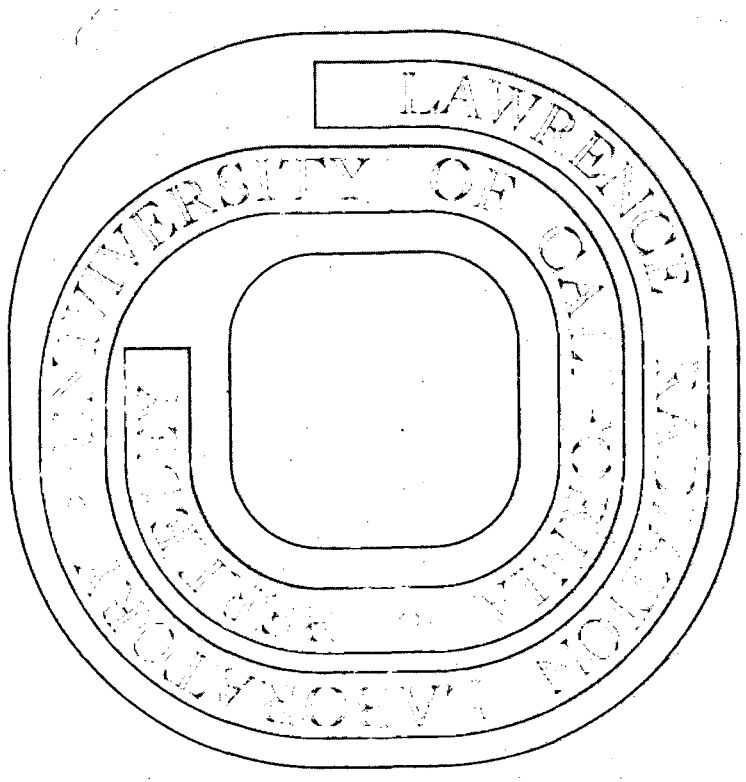
Summary of Guest Lecture
given at Dosimetry Workshop
Conference, Santa Barbara, CA.,
Feb. 16, 1971



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UCRL-20626
Preprint

HEAVY CHARGED PARTICLES IN RADIATION THERAPY: PHYSICAL AND RADIOBIOLOGICAL ASPECTS

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AEC Contract No. W-7405-eng-48

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HEAVY CHARGED PARTICLES IN RADIATION THERAPY: PHYSICAL AND RADIOBIOLOGICAL ASPECTS*

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February 1971

Modern methods of dosimetry provide the means of delivering precisely measured doses of radiation. This precision, together with improvements in radiobiology, is providing a scientific basis to radiation therapy. Precise dosimetric techniques are also helpful in conducting therapeutic trials to find the optimum fractionation schedules.

Ideally one would like to deliver a tumoricidal dose to the tumor, but in practice this is rarely done because the dose that can be given to the tumor is limited by injury to normal tissue. By confining the high-dose region as close to the tumor volume as possible, thereby minimizing the dose to the adjacent normal tissue, it is possible to deliver tumoricidal doses without undue normal tissue reactions. How well this can be done depends on the location of the tumor, the physical properties of the radiation, and the techniques used.

Significant progress has been made by using high-energy γ rays and electrons because of their favourable depth-dose distributions. In spite of these developments, failure to cure is still common (Kaplan, 1969).

Tumors usually, outgrow blood supply, hence most tumors contain a small proportion of hypoxic cells because of inadequate

circulation of blood within the tumor. The dose of γ rays or electrons required to sterilize these hypoxic cells is about three times that needed for the oxygenated cells. Thus, the presence of hypoxic cells increases the tumoricidal dose needed. The failure to cure in certain cases is probably due to the presence of hypoxic cells in the tumor, making it impossible to give tumoricidal doses of γ rays or electrons without undue reactions to normal tissue.

Heavy charged particles all have the unique property of delivering more dose at depth than at the surface, and practically zero dose a short distance beyond the range (Lawrence and Tobias, 1965). Uniform dose can be delivered over a tumor of any size located at any desired depth by introducing a variable absorber in to a beam of proper energy.

Biological effects of protons are not significantly different from those of γ rays and electrons. However, dose-localization characteristics of protons are far superior to those of even the 22-MeV γ rays currently used in some radiotherapy centers. Thus, one can expect significant improvements in radiotherapy if protons are used. Protons have been successfully used in pituitary treatment in cases such as acromegaly of diabetic retinopathy. A biomedical program using protons has been instituted at Harvard University Cyclotron. More and more cyclotron centers, both in this country and in Soviet Union, are currently planning to have biomedical facilities for radiotherapy at these cyclotrons.

The depth-dose distribution of helium ions is very similar to that of protons. In addition the He ions can to a certain extent overcome the hypoxic cell problem (Raju et al., 1970). Helium ions have

been extensively used for pituitary treatments at the biomedical facility of the 184-inch sychrocyclotron at Berkeley, and there are plans to use this facility for other radiotherapeutic applications.

No facilities exist at present to accelerate ions heavier than helium with ranges suitable for radiotherapy (although there are plans to build such a facility at Berkeley). Heavy ions, which have favourable depth-dose distribution, more nearly overcome the hypoxic cell problem than do helium ions (Tobias et al., 1971).

Negative π mesons share the properties of heavy charged particles. In addition, when they come to rest, they are captured by the nuclei in the medium and produce stars consisting of many short-range, heavily ionizing fragments. These fragments enhance the dose as well as the biological effect in the region of interest (tumor), and overcome the oxygen effect significantly (Fowler and Perkins, 1961). Intense sources of π^- mesons are being built at Los Alamos (U.S.A.), Stanford (U.S.A.), Vancouver (Canada), and Zürich (Switzerland). These accelerators are expected to be completed by 1972 or 1973, and radiotherapy facilities are being planned at each (Raju and Richman, 1969, 1971).

Heavy-charged-particle facilities (protons, helium, heavy ions, π^- mesons) are rather expensive, and cannot easily be provided at many radiotherapy centers. However, use of the above-mentioned particles at various accelerators could improve radiotherapy results, could lead to greater understanding of the problems involved, and could open up new developments in dosimetry. The technology does exist to use such a facility at a large radiotherapy center if current efforts at the accelerator warrant its installation.

Footnote and References

* Work done under auspices of the U. S. Atomic Energy Commission.

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