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International Atomic Energy Agency

INDC(NDS)-365
Distr.: G + MR

INDC

INTERNATIONAL NUCLEAR DATA COMMITTEE

Status of Nuclear Data Needed for Radiation Therapy and Existing Data Development Activities in Member States

Summary Report of a Consultants' Meeting
held at IAEA Headquarters Vienna, Austria
9 - 11 December 1996

Prepared by N.P. Kocherov
IAEA Nuclear Data Section

January 1997

Reproduced by the IAEA in Austria
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Abstract

The present report contains the summary of the IAEA Consultants' Meeting on the "Status of nuclear data needed for radiation therapy and existing data development activities in Member States" held at the IAEA Headquarters, Vienna, 9-11 December 1996. The present activities on nuclear data for radiotherapy are summarized in Member States, the present status of nuclear data for photon, neutron and proton therapy is reviewed and topics which are not presently covered by other institutions are identified.

Prepared by N.P. Kocherov
IAEA Nuclear Data Section

January 1997

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Introduction

Today, radiotherapy is applied in many clinical centers worldwide. More than 10% of all cancer patients are treated with radiotherapy and this number has a tendency to grow in the future. Modern radiotherapy uses different radiations, e.g., photons, electrons, thermal and fast neutrons, protons and heavy ions for treatment of patients. The main goal of radiotherapy is to deliver a well defined dose of radiation to the specified location of the body of a patient. At the same time it is necessary to minimize the dose received by other regions of the body. The dose should be accurate to 3.5 - 5% in different cases. Determination of absorbed dose in tissue depends upon the knowledge of energy spectra of radiation, effects of scattering in the collimators and diaphragms, kerma of the constituent elements of tissue etc. Determination of these factors in turn requires good quality nuclear data (microscopic cross-sections, energy spectra, angular distributions) for calculation of collimation, shielding, kerma and finally the distribution of radiation dose in the body.

The Nuclear Data Section of the IAEA started its program on nuclear and atomic data for radiotherapy in 1985 and organized two Coordinated Research Programs on "Nuclear Data for Neutron Therapy" and "Atomic and Molecular Data for Radiotherapy". These programs terminated in 1993 and 1994, respectively.

This meeting was held with the goal to collect information on current activities in the field of Nuclear Data for Radiotherapy in the Member States, to review the status of such data and to determine the future role of the IAEA in this field.

The present document contains the conclusions and recommendations of the participants of the meeting. The List of Participants and Agenda are given in Appendix 1 and Appendix 2, respectively.

SUMMARY AND RECOMMENDATIONS

All participants were present when the meeting opened and they were welcomed by Drs. Oblozinsky and Kocherov on behalf of the IAEA. Presentations by each of the Consultants then followed. Summaries of these presentations are attached. Dr. Oblozinsky also outlined the recent activities of the IAEA CRP on "Compilation and Evaluation of Photonuclear Data". D.T.L. Jones was elected Chairman of the group.

The Consultants discussed the initiatives which should be taken by the present panel and took cognisance of other groups which are presently active in related fields. These are:

- IAEA CRP on Nuclear Data Needed for Neutron Therapy (completed, report pending)
- IAEA CRP on Applications of Heavy Charged Particles in Cancer Radiotherapy
- IAEA CRP on Compilation and Evaluation of Photonuclear Data
- ICRU Report Committee on Nuclear Data for Fast Neutron and Proton Radiation Therapy
- IAEA CRP on Charged Particle Cross Section Database for Medical Radioisotope Production

The Consultants resolved that as far as possible there should be no overlap with the activities of the above groups. It is therefore recommended that relevant information and nuclear data for the following topics, which are not presently being considered by these groups, be followed:

- Accelerator-based neutron capture therapy (physical aspects)
- Heavy-ion radiation therapy (^{12}C and heavier)
- Therapeutic radionuclides
- Activation cross sections of tissue and shielding elements by particle therapy beams

It is recommended that:

(1) The IAEA should use its international standing to disseminate the information on nuclear data as widely as possible, especially to those developing countries which have financial difficulties. This recommendation applies in particular to the information contained in the ICRU report on Nuclear Data for Fast Neutron and Proton Radiation Therapy, which is currently in preparation and is expected to be published in 1997/98.

(2) More generally, an agreement should be sought with the ICRU for achieving a broad distribution of such scientific information on a continuing basis.

(3) The IAEA Nuclear Data Section should closely follow the nuclear data needs related to the IAEA CRP on Applications of Heavy Charged Particles in Cancer Radiotherapy (IAEA Division of Human Health).

(4) Consideration should be given to joint activities between the IAEA Nuclear Data Section and the IAEA Industrial Chemistry and Applications Section in the field of therapeutic radionuclides.

(5) Relevant data for the IAEA CRPs on Compilation and Evaluation of Photonuclear Data and on Charged Particle Cross Section Database for Medical Radioisotope Production should be followed.

(6) The next Consultants' meeting in 1998 would be useful in order to evaluate progress in the field at that time and to recommend new initiatives that may be necessary.

CONSULTANTS' PRESENTATIONS

1. INTRODUCTION TO PARTICLE TELETHERAPY AND NUCLEAR DATA NEEDS

A. Wambersie

The use of non-conventional radiation therapy techniques has always been considered a promising approach for improving clinical results. However, to be used in a safe way and to be exploited in an optimum way, different types of information are required and in particular basic physical data. Nuclear data are indeed needed on the one hand to be able to calculate the absorbed dose at a point of interest in the tissue, and on the other hand to optimize the design of the treatment delivery system.

As far as fast neutron therapy is concerned the technical conditions under which it can be applied today are becoming comparable to those available with modern linear accelerators: beam penetration, skin sparing, multileaf collimators, rotational gantry etc. It is only under these conditions that the real value and benefit of fast neutrons (high-LET radiation) could be evaluated and compared to the best photon therapy techniques (low-LET radiation).

In fast neutron therapy a common dosimetry protocol, published by the ICRU (Report 45, 1989) is applied world-wide. However, neutron beams produced by charged particles with energies of at least 50 MeV are preferable. For this energy range accurate nuclear data are needed both to calculate the absorbed dose in the tissues (i.e. H, C, N, O for energies above 20 MeV) and to design the treatment delivery systems and the shielding devices (i.e. Al, Cu, Fe, Pb, W).

In contrast to fast neutron therapy, where the aim is to improve the differential effect between "tumor" and normal tissues, proton beam therapy only aims at improving the physical selectivity of the treatment. No benefit is expected from an improved (radiobiological) differential effect. On the other hand, the risk of unexpected complications is small. The benefit of proton beam therapy will become apparent mainly for the treatment of rather resistant tumors located close, adjacent to, or invading radiosensitive critical normal tissues. Some eye tumors (uveal melanomas), turmors of the base of the skull, AVMs (arteriovenous malformations), and some sarcomas located close to the spinal core are considered today to be the indications of choice for proton beam therapy.

To be applied in safe conditions, the following information should be available with good accuracy:

- dose at different points in different organs and tissues
- penetration of the beam (exact position of the Bragg peak and of the dose fall-off especially in non-homogeneous tissues)

Nuclear data are needed for these purposes and they are also useful for the optimum design of the treatment nozzle.

Therapy with heavy ions (e.g. C, Ne) aims at combining the benefit of the physical selectivity of proton beams with the biological advantages of neutron beams for some tumor types. Here again basic nuclear data are needed for the optimal application of heavy ion beams in the clinical situation. At the present time heavy ions are used only in Chiba (Japan) but treatments are planned to begin shortly at GSI-Darmstadt. In addition, at least two projects are under discussion in Europe (TERA, Italy, AUSTRON, Austria) and another one in Japan.

2. NEUTRON CAPTURE THERAPY

A. Wambersie, J.B. Smathers

Neutron capture therapy (NCT) is a completely different approach. Its rationale is based on the selective incorporation of a compound labelled with an isotope with a high thermal neutron cross section (primarily ^{10}B) in the malignant cells. In the second stage, a nuclear reaction occurs through bombardment by thermal neutrons and short-range (of the order of the cell diameter) high-LET particles or low energy gamma rays are emitted. The clinical benefit of NCT will depend mainly on the selective incorporation of the appropriate compound in <u>all</u> the cancer cells and in principle <u>not</u> in the normal cells and as such it is largely a pharmacological problem.

The use of nuclear reactors as sources of low energy neutrons for boron capture therapy has been well studied and clinical programs are now in place at MIT and Brookhaven National Laboratory in the USA, in Japan and Europe. However, some benefit can be expected through technical improvements. Thermal neutron beams have poor penetration in tissue, and the use of an epithermal beam can overcome this problem. The slowing down of the epithermal neutrons in tissue then results in the production of the appropriate thermal neutron flux at the depth of the tumor.

The use of thermal/epithermal neutron beams produced at a nuclear reactor implies some technical and practical constraints: availability of the beam, transportation of the patient, fixed beam configuration, lack of clinical facilities, etc.

The possibility of replacing reactor neutrons by epithermal neutron beams produced by low energy, high current accelerators is receiving increased attention. The favoured reactions are about 2 MeV protons or deuterons on Li or Be targets with appropriate filteration and moderation. This approach has several possible advantages:

(1) A compact (and relatively cheap) accelerator could be located within (or close to) a hospital and there would be no problem with patient transportation.

(2) The machine would be continuously available for treatment.