Radiological Risk and Safety Assessment

A. D. Oliveira

Radiological risk is concerned with biological effects of radiation. The importance of the biological effects of ionizing radiation has gathered recently a lot of attention from researchers due to possible new implications in radiation protection. One of the main aspects to consider is related with the recognition of the existence of non targeted effects such as, for example, the bystander effect. This means that well established paradigms of radiobiology are nowadays challenged, leading to a growing development of biophysical and biochemical research activities related with such radiobiological studies. Recognizing this new trend in research a new member integrates the group with expertise in molecular biology. In that field the conference Lowrad 2008, 7th International Meeting on the Effects of Low Doses on Radiation in Biological Systems is in preparation. Also a worl-wide radiobiological consortium is under development aiming to study the "mechanisms developed by mammals exposed to low doses of ionizing radiation".

Traditional radiobiology applications such as dosimetry by cytogenetics methods, specifically related with uranium mining are an activity that ends in this year. However, new plans are in development for an increase of this methodology with new applications.

Design and production of radiopharmaceuticals involves a reasonable time of activity of this group with collaboration with Poland researchers, concerning mainly with application of bisphosphonates and Auger electron studies in a potential therapeutic application and special concerns with radiation protection aspects.

In safety assessment of radiological facilities, it was decided that routine safety assessment are not an objective of ITN. Radiation safety assessments of radiological facilities it was restricted to services provided to owners of complex facilities such as radiotherapy and nuclear medicine which had been carried out together with the group RPRWM (Radiological Protection and Radioactive Waste Management). Concerning radiation protection regulations some activity was accomplished from the point of view of qualified expert advisory.

It was increased the activity in risk assessment and radiation protection from the scientific point of view concerned with interventional radiology. A master thesis is under development and a new one is programmed to start in 2008. More developments are expected in near future.

Research Team

Researchers

A. D. OLIVEIRA, Aux., Group Leader
P. VAZ, Princ.
M. A. NEVES, Princ.
O. GIL, Aux.
M. GOULART, Aux., since Dec 1

Students

P. CARDOSO, FCT grant, until Aug 31
L. FERNANDES, PEPAP grant until May 31

Technical Personnel

T. ANTUNES, superior technician

Collaborators

D. ALVES, since May
M. SARAIVA, until May

Radiological Safety Assessment in interventional cardiology

P. Vaz, I.F. Gonçalves[1], C. Carrapiço[2] , A.D. Oliveira and L Terramoto[3]

Objectives

Concerning Interventional Radiology, two separate lines of activities were developed during 2008. One of the lines of activity was mainly in computational simulation while the other was mainly in experimental measures in real hospital cardiologic intervention. Future works will cross the results of these different approaches.

Results

Simulations were accomplished within a Coordinated Network for Radiation Dosimetry – Computational Dosimetry, within the CONRAD – COordinated Network for RAdiation Dosimetry (CONRAD) the Project CONRAD was a collaborative effort led by the Technical University of Delft and involving several European institutions under the umbrella of EURADOS (the European Radiation Dosimetry group). Its activities are funded by the European Union in the 6th Framework Programme for Research and Development. In this context, it participates in the computation of two exercises entitled "Medical Staff Dosimetry in Interventional Cardiology" and in the measurement of staff doses, aiming at estimating the effective dose to the cardiologist due to the X-ray machine and to compare it with the personal dosemeter readings. The ITN team together with experts of SCK/CEN (Belgium), CEA and IRSN (France) and TU-Delft has performed Monte Carlo simulations in the framework of an intercomparison exercise.

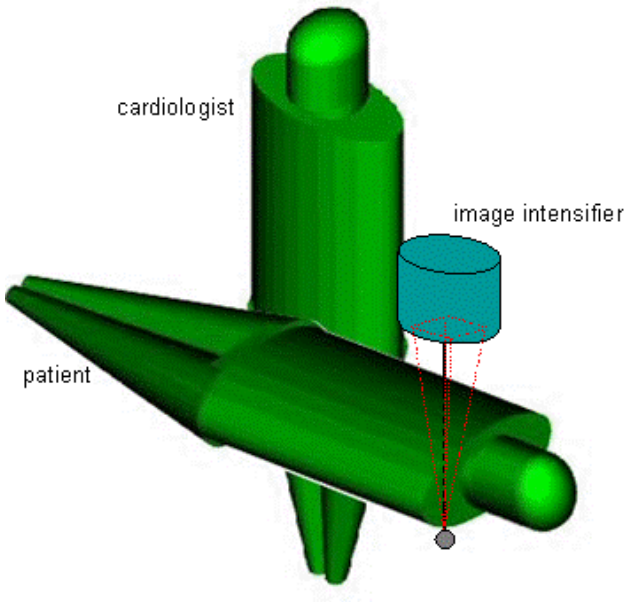
Experimental measures were made considering that, the procedures involved in IC are complex, and not easy to describe. There are many variables to consider for a complete description of the procedures. Some of them are: the procedures are geometrically dynamic; the radiation field is uneven; the filtration is not the same during the intervention (depends of the operational mode); patients have different sizes from each other (influences the scattered radiation field). Studying and collecting data for all the different procedures would be time consuming, so we used well defined rotation and angulation's geometries of the fluoroscopic device to make doses assessment. The ITN team participates in the determination of patient and staff doses in interventional radiology in collaboration with a national Hospital. The scope was to assess incident dose rates in several conditions, in order to create a procedure that can be used in medical facilities.

Published work

"Intercomparison of Active Personal Dosemeters in Interventional Radiology", I. Clairand et. al., Proceedings of Workshop on "Safety and Efficacy for New Techniques and Imaging using New equipment to support European Legislation" (SENTINEL), Delft (Holanda) de 18 a 20 de Abril de 2007, accepted for publication in Radiation Protection Dosimetry (2008)

"Staff Doses in Interventional Cardiology: Use of C-Arm standard positions to assess incident dose rate", L. Terramoto, A.D. Oliveira, E. Leite, T. Matoso, 13ª Jornadas da Sociedade Portuguesa de Protecção Contra Radiações, Nov. 2007.

"Radiologia de Intervenção", AD Oliveira, Workshop: Aplicações médicas das radiações ionizantes em Portugal – investigação científica e prestação de serviços, ITN, Nov. 2007.



Safety Assessment
A.D. Oliveira, P. Vaz, T. Antunes, D. Alves, M. Saraiva

It was increased the activity in risk assessment and radiation protection from the scientific point of view concerning interventional radiology. Some new insights in interventional cardiology were achieved, working in collaboration with a reference hospital. The dynamics in space, time and technical parameters is shortly the scope of the work. A master thesis is under development and a new one is programmed to start in 2008. Radiation safety assessments of complex radiological facilities such as radiotherapy and nuclear medicine had been carried out together with the group RPRWM (Radiological Protection and Radioactive Waste Management). These services are provided according to international recommendations NCRP, IAEA, DIN, etc.
Concerning radiation protection regulations some activity was accomplished from the point of view of qualified expert advisory in order to help the national authorities to fulfil the recommendations of IAEA and the European Community. Participation in IAEA committee RASSC it was a major goal of the activity mainly concerned with the implementation of the IAEA safety standards.

Radiobiology and dosimetry by cytogenetic methods applied to populations living near old uranium mining areas and compared with population living in areas without uranium mines
O. Monteiro Gil, P.A. Cardoso Painço

We finished the work regarding the evaluation of the biological effects of low-level ionizing radiation and genotoxic damage as a result of chronic exposure to ionizing radiation in populations living near old uranium mines and tailings (Canas de Senhorim) started in partnership with INSA. The report has been already published.
Evaluation of the reference populational group belonging to a region from Alentejo (without uranium mines) is also finished. Equally in this study, chromosomes 1, 2, 4 were analysed for chromosomal translocations, by the FISH technique (Fluorescent *In Situ* Hybridization) for irradiated (blood irradiated *in vitro* with 2 Gy gamma radiation for the challenge assay, 700 methapases studied for each donor) and unirradiated samples (2000 methapases studied for each donor). A total of 62645 methapases were studied for unirradiated samples and 24181 methapases were studied for the irradiated ones.
We also initiated the elaboration of an *in vitro* dose response curve using the FISH technique (at this moment this work is stopped because I have to finish writing my PhD thesis).

Auger and low energy electrons therapy
M. Neves

Participation in projects related to the development of new targeted radiotherapy agents with Auger and low electrons emitters, in collaboration with INETI and the Institute of Nuclear Chemistry and Technology (IcHTJ) of Warsaw, Poland under a EU Marie Curie Transfer of Knowledge project and Portugal/Poland scientific agreement. Indazolebisphosphonates and carboxylbiguanides derivatives were synthetized and complexed with the radiometals (Sc-46, Rh-105 and Lu-177). Radiochemical and biologic activities were tested.

CANDIDE – Coordination Action on Nuclear Data for Industrial Developments in Europe
P. Vaz, I.F. Gonçalves[1]

CANDIDE is a European Union co-financed Coordination Action (ref. FP6-036397) in the 6th Framework Program EURATOM. It addresses the following two objectives:
1. Establishment of better links between academia, research centres and industry end users of nuclear data.
2. Assessment of nuclear data needs for advanced nuclear reactors. The emphasis is on the radioactive waste issue, i.e., either waste transmutation in critical or sub-critical devices or minimizing the production of nuclear waste in future nuclear reactors, as envisaged in, e.g., the GEN-IV systems.
The ITN team has participated during 2007 in the Work Package 3 entitled "Nuclear Data Assessment", erforming activites related to the assessment of the state-of-the-art nuclear data libraries.

[1] ITN / Physics Sector

EUROpean Research Programme for the TRANSmutation of High Level Nuclear Waste in an Accelerator Driven System (IP-EUROTRANS)

P. Vaz[1], I.F. Gonçalves[2], I. Paiva[1], R. Pires[3], Y. Romanets[4], P. Teles[4], R. Trindade[1]

IP EUROTRANS is a European Union co-financed project (ref. FI6W-CT-2004-516520) in the 6th Framework Program EURATOM. The objective of IP EUROTRANS is the design and the feasibility assessment of an industrial ADS (Accelerator Driven System) prototype dedicated to the transmutation of high-radiotoxicity and long-lived radioactive waste. The Portuguese team, led by ITN, actively participated in:

- Dosimetry (dose and neutron flux distributions) and radiation shielding calculations,
- Assessment of the radiation damage of the structural components,
- Reliability of the accelerator system,

in the following Domains:

- DM1-DESIGN – "***Development of a detailed design of XT-ADS and a conceptual design of the European Facility for Industrial Transmutation EFIT with heavy liquid metal cooling****"* – participating in WP 1.2 ("Development and Assessment of XT-ADS and EFIT Designs") and WP 1.3 ("High Power Proton Accelerator Development").
- DM2 – ECATS – *"**Experiment on the Coupling of an Accelerator, a spallation Target and a Sub-critical blanket**"*, participating in WP 2.1 (Experiments at YALINA – current to flux reactivity on-line monitoring techniques, interim calibration techniques used at beam trips and full calibration techniques for kinetic parameters) and WP2.3 (The GUINEVERE project – Study of the reactivity monitoring methodology for an ADS in a modified lead VENUS reactor coupled to a modified continuous-beam GENEPI accelerator).

1 – ITN / DPRSN; 2 - ITN / Physics Sector; 3 – Fac. de Engenharia / Univ. Católica Portuguesa; 4- ITN fellow

Participation of ITN in the n-TOF-Ph2 experiment (PS213) at CERN

P. Vaz[1], I.F. Gonçalves[2], C. Cruz[2], J. Neves[2], C. Carrapiço[3], C. Santos[3], L. Ferreira[4], L. Távora[5]

An experimental programme is being carried out since 2001 by the n-TOF Collaboration (a consortium of 40 laboratories in Europe, U.S.A. and Japan) at the neutron time of flight (TOF) facility at CERN, using the CERN/PS accelerator complex. A single proton pulse of $7 \cdot 10^{12}$ protons of 20 GeV impinges on a lead target every 2.4 seconds. After collimation, a neutron flux of the order of 10^5 neutrons/cm^2/pulse is available for cross section measurements in the detectors station located 185 m downstream the target area.

These cross-sections measurements are required in many applications such as the design of innovative Accelerator Driven Systems (ADS) for incineration of nuclear waste and energy production, radioisotope production for medical and industrial applications and many other subjects in Astrophysics, Nuclear Physics and Nuclear Technology. New or improved measurements of neutron cross-sections will also be very valuable for Radiation Shielding, Dosimetry and Monte Carlo Radiation Transport calculations. During 2007, ITN researchers in cooperation with researchers from CIEMAT/Madrid and CEA/Saclay:

- Participated in the design studies of the new shielding system for the TAC calorimeter, performing simulations using the state-of-the-art Monte Carlo program GEANT4
- Performed Monte Carlo simulation studies of the neutron and gamma fluxes for alternative targets at n-TOF, for different materials (e.g. Tungsten) and geometries, using the Monte Carlo program MCNPX
- Participated in the analysis of the ^{233}U data

The ITN participation was undertaken in the framework of two projects funded by the Portuguese Foundation for the Science and Technology (FCT).

1- ITN / DPRSN; 2 – IST / Physics Department; 3 – project fellow; 4- DF/ IST; 5 –C. de Instrumentação / U. Coimbra

PATEROS - Partitioning and Transmutation European Roadmap for Sustainable Nuclear Energy

P. Vaz[1]

PATEROS is a European Union co-financed Coordinated Action (ref. FP6-036418) in the 6th Framework Program EURATOM, under the specific programme for Research and Training in Nuclear Energy.

A closed fuel cycle is a prerequisite for making nuclear energy a sustainable one. This can be reached by deploying advanced partitioning and efficient transmutation systems to reduce the burden on the geological storage. This objective is of relevance both for countries committed to nuclear energy in the future and for countries not committed to a further deployment of nuclear energy. The objectives of this Coordinated Action is to deliver a European vision for the deployment of the partitioning and transmutation technology up to the scale level of pilot plants for all its components. ITN contributes to the activities of:

- Work Package 1: Rational and added value of P&T for waste management policies
- Work Package 2: Review & selection of Relevant Fuel Cycle Strategies in Europe supplemented by Regional Context for Development and Deployment.
- Work Package 6: Integration and Evaluation of Resources and Time Planning.

During 2007, ITN has contributed to the preparation of reports in the framework of the WP1 and WP2

1 – ITN / DPRSN

CONRAD – COordinated Network for RAdiation Dosimetry (CONRAD)
P. Vaz[1], I.F. Gonçalves[2] , C. Carrapiço[3] – SG4/WP4/WP7

The Project CONRAD was a collaborative effort led by the Technical University of Delft and involving several European institutions under the umbrella of EURADOS (the European Radiation Dosimetry group). Its activities are funded by the European Union in the 6th Framework Programme for Research and Development.
The ITN team participates in the determination of patient and staff doses in interventional radiology in collaboration with the "Hospital de Santa Maria" concerned with the following Work Packages of CONRAD:

- WP4 - Assessment of Uncertainties in Computational Dosimetry
- WP7 – Dosimetry for Radiation Protection of Medical Staff

In this context, it participates in the computation of two exercises entitled "Medical Staff Dosimetry in Interventional Cardiology" and in the measurement of staff doses, aiming at estimating the effective dose to the cardiologist due to the X-ray machine and to compare it with the personal dosemeter readings. The importance of wearing protective clothes (lead equivalent apron, thyroid collar, etc.) are used, as well as the influence of parameters such as the beam geometry and quality, the position of the dosemeter (above or below the apron) and the relevance of the usage of double dosimetry (one dosemeter above and another below the apron) will be performed. The ultimate goal is the determination of the effective dose to the professionals exposed.
The ITN team together with experts of SCK/CEN (Belgium), CEA and IRSN (France) and TU-Delft has performed Monte Carlo simulations in the framework of an intercomparison exercise.

1 – ITN / DPRSN; 2 - ITN / Physics Sector; 3 – ITN Fellow

EURISOL DS - Design Study of an European Isotope Separation On-Line Radioactive Ion Beam Facility
P. Vaz[1], J.G.Correia[2], I.F. Gonçalves[2], Y. Romanets[3]

The Project EURISOL-DS is a Collaboration of twenty institutions and laboratories in European countries and CERN. Its activities are funded by the European Union in the 6th Framework Programme for Research and Development ("Research Infrastructures Action").
EURISOL DS aims at performing the detailed design studies for the deployment in Europe of a world class Radioactive Ion Beam Facility, able to produce radioactive beams with much higher intensities than the ones currently available in other facilities worldwide. Very selective extraction methods combined to the high intensity of the beams will allow the discovery and study of new isotopes as well as the production of isotopes for a wide range of applications ranging from Fundamental Nuclear Physics and Astrophysics studies to Life Sciences, in particular Medicine. The innovative characteristics of such a facility are also associated to its multi-MegaWatt target unit where a high-intensity beam of protons of energy in the 1-2 GeV range will impinge on a high-Z material, mercury, tungsten or tantalum being currently considered as potential candidates. ITN is participating in the computational activities of the following sub-groups:

- WP2 ("Target Design Studies")
- WP5 ("Radiation Protection Issues")

During 2007, the ITN team has performed, together with the CERN team, Monte Carlo simulation studies to assess the feasibility of an alternative, so-called MAFF-like, design of the target system.

1 – ITN / DPRSN; 2 - ITN / Physics Sector; 3 – ITN Fellow

CANDIDE – Coordination Action on Nuclear Data for Industrial Developments in Europe
P. Vaz[1], I.F. Gonçalves[2]

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1. Establishment of better links between academia, research centres and industry end users of nuclear data.
2. Assessment of nuclear data needs for advanced nuclear reactors. The emphasis is on the radioactive waste issue, i.e., either waste transmutation in critical or sub-critical devices or minimizing the production of nuclear waste in future nuclear reactors, as envisaged in, e.g., the GEN-IV systems.
The ITN team has participated during 2007 in the Work Package 3 entitled "Nuclear Data Assessment", erforming activites related to the assessment of the state-of-the-art nuclear data libraries.

1 – ITN / DPRSN; 2 - ITN / Physics Sector