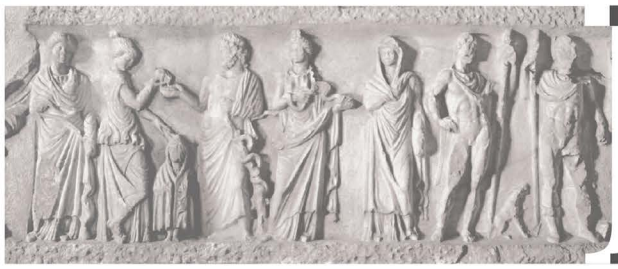

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XIII NATIONAL MEDICAL PHYSICS AND BIOMEDICAL ENGINEERING CONFERENCE: NMPEC-2020

with international participation

Organizer:
Bulgarian Society of Biomedical Physics and Engineering

Co-organizer:
Medical University of Plovdiv

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XIII NATIONAL MEDICAL PHYSICS AND BIOMEDICAL ENGINEERING CONFERENCE: NMPEC-2020

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dedicated to humanity

MEDICAL UNIVERSITY OF PLOVDIV

PHYSICS AND ENGINEERING - UNLOCKING DOORS IN MEDICINE TOGETHER

NOVEMBER 2020
MEDICAL UNIVERSITY OF PLOVDIV
BULGARIA

International Organization for Medical Physics

IOMP

EFOMP

The Organizing and Scientific Committees gratefully acknowledge the support of Medical University - Plovdiv

WELCOME ADDRESS

It is my enormous pleasure to welcome you to the 13th National Medical Physics and Biomedical Engineering Conference 2020 with international participation.

This is the first conference organized by the Bulgarian Society of Biomedical Physics and Engineering which is conducted completely on a digital platform due to the COVID-19 pandemic. The theme of this conference is "Physics and Engineering: Unlocking doors in Medicine Together". The conference is dedicated to the International Day of Medical Physics, which is held this year under the motto "Medical Physicist as a Health Professional".

We are proud to announce that this conference is being conducted along with the cooperation of the Medical University of Plovdiv, endorsed by the European Federation of Organizations for Medical Physics and sponsored by the International Organization for Medical Physics.

We are privileged to have eminent speakers from all over the world. During the conference educational webinars will be presented in all fields of medical physics and biomedical engineering, including non-ionizing radiation, diagnostic and interventional radiology, radiation therapy, nuclear medicine, biophysics, modelling and simulation, and special session, dedicated to the International Day of Medical Physics.

I would like to thank and acknowledge our eminent speakers, the Organizing, Local Organizing and Scientific Program Committees for their hard work and dedication. We are also thankful to all participants and we eagerly await their contributions.

Simona Avramova-Cholakova

President of the Bulgarian Society
of Biomedical Physics and Engineering

Contents

INVITED TALKS

Medical physicist as a health professional

M. Stoeva

Department of Diagnostic Imaging, Medical University of Plovdiv, Bulgaria
International Organization for Medical Physics (IOMP)

Introduction: The International Organization for Medical Physics (IOMP) represents about 29,000 medical physicists worldwide and 86 adhering national member organisations and 1 affiliate.[1] The mission of IOMP is to advance medical physics practice worldwide by disseminating scientific and technical information, fostering the educational and professional development of medical physicists, and promoting the highest quality medical services for patients. The International Day of Medical Physics (IDMP) is an annual event celebrated on November 7th, Marie Sklodowska-Curie's birthday.[2]

Aim: The IDMP is focused on medical physicists worldwide and supports their scientific and professional development, the dissemination of information related to medical physics and the networking between medical physicists at national, regional and global scale. IDMP 2020's theme is "Medical Physicist as a Health Professional".[3]

Results: Medical physicists play an important role in healthcare services, research, development of healthcare technologies and clinical techniques, education and training of healthcare professionals. For 8 consecutive years IDMP successfully promotes the visibility and professional status of the medical physicists and our role in the community. IDMP is officially celebrated in numerous of countries around the world and has received official support by world's leading institutions, among which IAEA and WHO.[4]

2020 is challenging to healthcare systems worldwide and medical physicists are among the front-liners dealing with the COVID-19 situation. We hope that this year's theme will bring awareness on the importance of our profession in the healthcare.

Conclusion: This year we celebrate IDMP to honor our profession. The unusual situation is a chance for us to further develop our knowledge and skills, to find new approaches to work together for the benefit of science and healthcare.

Keywords: IOMP, IDMP, Medical Physics

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125th anniversary of the discovery of X-rays and the 175th birthday of W. Röntgen

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The discovery of X-Rays by Wilhelm Konrad Röntgen back in 1895 turned into a leading factor for the development of human knowledge. The way we see the world and the way we look at and into our bodies changed dramatically. Science, technology, medicine, even arts – all of them were touched by the epochal discovery. New scientific disciplines developed rapidly at the turn of the 20th century, turning it into the century of the X-rays.

It all began on March 27, 1845 with the birth of Wilhelm Conrad Röntgen in Lennep, Germany. Despite the difficulties he faced during his academic career, he finally managed to reveal his unique scientific abilities and in 1870 was appointment assistant at the Julius Maximilians University of Würzburg. In Würzburg, Roentgen began researching the cathode rays. On November 8, 1895 however, during one of his regular experiments something drew his attention. Roentgen attributed this to something unknown to scientists and called it the X-rays. He immediately started to work towards dissemination this important discover y to the scientific community.

125 years after this sensational discovery and 175 years after Roentgen's birth, we rely on these X-Rays more than ever. They have found numerous applications in modern live. Diagnostic Imaging and Medical Physics are among the leading disciplines, existing and dynamically developing thanks to Roentgen's discovery of the X-Rays.

Keywords: X-rays, Roentgen, diagnostic imaging, medical physics

Virtual clinical trials in breast imaging

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National and international regulatory boards required appropriate optimization in terms of high clinical image quality and acceptable radiation dose to the patient before any new technology for breast tumor diagnosis is entered into clinical practice. In addition, they must show the introduced benefits in terms of clinical outcome in comparison to gold standard (Digital Mammography, DM). Currently, these studies are realized by means of clinical trials, which in addition arise ethical considerations related to the delivery of additional patient dose, require an extensive amount of financial and institutional support.[1-3] Virtual clinical trials (VCT) are an alternative approach to real clinical trials, capable of producing clinical outcome data as it relates to new imaging technology without the added cost and complexity of real clinical trials. VCT are in-silico reproductions of real examinations, which adopt digital models of patients and simulated apparatuses. They can produce clinical outcomes data and avoid ethical issues and costs related to real clinical trials with a patient population. Generally, analytical approaches are usually adopted for breast projection computation[4-7] in order to keep the computational time and power consumption low, but in this approach photon scatter estimation is not usually taken into account. In order to overcome such limitation, recent research projects[8,9] have explored the possibility of simulating DM and Digital Breast Tomosynthesis (DBT) by means of Monte Carlo simulations. In comparison to purely analytical approaches, MC methods permit the tracking of individual

photons (or electrons if needed) interacting with the voxelized patient model and absorbing in the simulated detector for the purpose of radiation dosimetry and projection image simulations.

This work presents the more recent activities in this research field and the AGATA project, funded by the INFN (Italy), with the aim to realize the first platform, entirely based on MC Carlo code and with digital organ models produced from high-resolution clinical breast images.

Keywords: virtual clinical trials, digital mammography, digital tomosynthesis, breast CT

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e-Learning in medical physics – current perspectives based on 20+ years experience

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Introduction: Medical physics is one of the pioneers of e-learning. The presentation includes lessons learned over 20+ years of developing and implementing e-learning in education.

Methods: The paper presents briefly the e-learning methods developed by the original projects coordinated by the author and team of over 350 specialists. The development methods, testing and implementation of e-learning in the profession are described, together with the feedback from the users/students and lecturers. These include also views for the future implementation of e-learning in medical physics.

Results: Over 20 years the author has spread the use of medical physics e-learning in 82 countries and has

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supported the development of 17 MSc courses worldwide. The paper highlights the challenges of the development and introduction of e-learning in medical physics. The application of computer simulations is discussed and examples are presented.

The outcomes of 7 international projects are summarised, including 5 e-books; 5 educational Image Databases; 3 Educational web sites; A Multilingual Dictionary (31 languages) and on-line Encyclopaedia of Medical Physics (www.emitel2.eu). Currently these e-materials are used by 4000+ colleagues per month worldwide and have received many awards.

The use of the Moodle VLE is briefly described with examples. The specificities of online assessment are presented with examples. The presentation includes suggestions for building/delivery of e-learning, plus examples of e-learning introduction at: http://www.emerald2.eu/mep_index.html

Conclusion: e-Learning is imperative for a dynamic profession as medical physics, where updates of materials are essential. The experience of the author, and the conferences on e-learning, show that e-learning is effective only when it is blended with classical learning. The short longevity of the e-learning materials and simulations require quick exchange of information and the author presents information from the created by him specific Journal – Medical Physics International (www.mpijournal.org) – aiming to support medical physics educational and professional topics.

Magnetic resonance safety

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Magnetic resonance imaging (MRI) is considered as a safe imaging modality because it does not alter the structure, composition and properties of atoms. But the MRI environment presents some potential risks due to three magnetic fields – the strong static magnetic fields, the gradient magnetic fields and the pulsed radiofrequency (RF) fields.

The purpose is to give an overview of current magnetic resonance safety guidelines and discuss the safety risks of magnetic fields in an MRI suite. These risks associated with MRI, if not controlled, have the potential to cause serious harm to anyone in an MRI procedure room. Therefore a comprehensive MRI safety training to protect patients and other healthcare workers from potential bioeffects and risks of the magnetic fields in an MRI suite is essential.

Keywords: magnetic resonance imaging, safety, magnetic fields

BIOMEDICAL ENGINEERING

Prototype of low-cost portable ventilator system for COVID-19

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In this work, a novel model of low-cost non-invasive ventilation device has been proposed and realized for the pandemic of Covid-19. One of the main problems on the pandemic of Covid-19 is lack of mechanical ventilation for patients. There are several solutions of resolving this shortcoming in the period of Covid-19. Majid et al. (2020) proposed a conceptual design of a portable ventilator for Covid-19 patients. In their design proposal, they used a dc motor and a set of bendable wires to pump the air tank mechanically. They proposed only the conceptual design of the pumping mechanism and explained what could be added to improve performance and build the whole ventilation system. Hirani (2020) developed a prototype of a mechanical ventilator for Covid-19 patients using a motorized bellow system. He used a rack and pinion gear system triggered by a stepper motor to actuate the bellow compression mechanism. An air inlet for oxygen supply, pressure and flow sensors in the ventilation pipe were also integrated to increase the performance of the whole system.

Most of the ventilation system is used bag-valve masks or Ambu-bags. Although this Ambu-bags based design is successful in some ways, it is bulky and takes up a lot of space in the ventilator mechanism. Our proposed non-invasive ventilator (NIV) system works with using two blowers system and sensors. The airflow system which is designed for this low-cost portable ventilation is produced by a 3D printer. The main aim of the proposed ventilation system is designed as a portable and suitable for rapid manufacturing against Covid-19 and our system providing a basic specification of ventilation systems. The price aim of proposed low-cost NIV system is below 250$. The prototype produced is aimed to meet ISO 80601, ISO 5367 and IEC 62304 standards in mass production.

Keywords: ventilator, non-invasive ventilator, Covid-19, 3D printer, rapid prototyping, low-cost

BIOPHYSICS IN BIOLOGY AND MEDICINE

Binding studies of cisplatin accord chemotherapy drug with blood plasma proteins, a microcalorimetry and spectroscopy study

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Cancer is the second leading cause of death worldwide. Chemotherapy is one of the main approaches for treatment of cancer patients. Cisplatin accord (CA) is an antitumor drug which has been widely used in cancer treatment for the past three decades. Characterization of drug binding to human blood plasma proteins is of essential importance for a better understanding of drug absorption, distribution and turnover in the circulation.

Albumin, the most prominent protein in the plasma, plays a fundamental role in the transport of drugs. The binding of a drug with albumin is a key factor in controlling the kinetics and efficacy of drug transport in the blood.

High levels of plasma fibrinogen have been observed in people with cancer, and fibrinogen has been shown to play an important role in tumorigenesis and tumor progression.

Using Differential Scanning Calorimetry, Fluorescence and UV-Vis spectroscopy, here we set out to characterize the CA interactions with blood plasma proteins, specifically with albumin and fibrinogen, in simulated physiological conditions.

The quenching mechanism of Human Serum Albumin and Fibrinogen fluorescence was analysed based on interaction studies carried out at different temperatures (298, 303 and 309 K). Stern-Volmer constant (KSV), quenching rate constant (kq), and activation energy of bimolecular quenching (Ea) were evaluated. UV/VIS absorption spectra were used to confirm the quenching mechanism. Also, thermodynamic parameters (heat capacity Cp, Gibbs free energy change (ΔG°), and enthalpy change (ΔH°) were calculated.

Our findings provide new insights regarding the mechanism of Cisplatin accord drug transport and disposition in the circulation.

Keywords: cisplatin accord, human serum albumin, fibrinogen, spectroscopy, fluorescence, differential scanning calorimetry, drug binding

Acknowledgements: This work was supported by Grant D-241/19.12.2019 by SMN at Medical University of Sofia.

Interaction of a monoclonal antibody drug, Pertuzumab, with human serum albumin (HSA): application of spectroscopic and thermoanalytical techniques

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Human epidermal growth factor receptor (HER) 2 (HER2) is overexpressed in 20%–30% of breast cancers. HER2 is a preferred target for treating HER2-positive breast cancer. Pertuzumab is an intravenous drug, used as adjuvant therapy to treat metastatic HER2-positive breast cancer. It belongs to a class of drugs called monoclonal antibodies. The understanding of the molecular mechanisms underlying the action of pertuzumab is essential for moving forward to achieve high efficacy in treating HER2-positive breast cancer. Binding of therapeutic agents to plasma proteins, particularly to serum albumin, provides valuable information in the drug effectiveness. This study was designed to evaluate the binding interaction of pertuzumab with human serum albumin (HSA). Spectrofluorometric, UV-Vis spectrophotometric, and differential scanning calorimetry experiments were performed to study this interaction. The fluorescence of HSA is attributed to the presence of tryptophan (Trp) residues. The fluorescence of HSA in presence of pertuzumab was studied using the excitation wavelength of 280 nm and the emission was measured at 300-500 nm at three different temperatures. Pertuzumab quenched the HSA intrinsic fluorescence by static mechanism. A complex formation occurred due to the interaction leading to HSA absorption shift. The fluorescence, UV-V is absorption, three dimensional fluorescence, and DSC data showed conformational changes occurred in HSA after interaction with pertuzumab. The binding constant value was measured. The specific heat capacity Cp and enthalpy change ΔH of the HAS – pertuzumab were calculated.

Keywords: breast cancer, pertuzumab, human serum albumin, fluorescence spectroscopy, differential scanning calorimetry, drug binding

Acknowledgements: This work was supported by Grant D-241/19.12.2019 by SMN at Medical University – Sofia

Initial evaluation of the parameters of chemiluminescent method to characterise polymorphonuclear leukocytes in patients with inflammation

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Introduction: There is tight multidirectional interaction between polymorphonuclear leukocytes (PMNL) and inflammation. Diverse interactions of PMNL with blood circulatory network, substances from pathologic sites, blood cells (leukocytes, erythrocytes, platelets etc.), complement system, coagulation system and recovery system create PMNL with different characteristics, i.e. different functional state, determined with chemiluminescent method.

Aim: Initial evaluation of the parameters of chemiluminescent method to characterise PMNL in some patients with inflammation.

Methods: Luminol-enhanced chemiluminescence (LCL) was used. Chemiluminescence derived from whole-blood PMNL was measured using pre-opsonized zymozan as a stimulant.

Results: The chemiluminescent responses of zymozan-stimulated PMNL were studied at blood dilutions from 1:15 up to 1: 150. The used zymozan concentrations were in the range of 0.1 mg/ml to 4 mg/ml and serum or plasma were tested for opsonization. For each kinetic response several standard LCL parameters were calculated (I_{max}, T_{Imax}, $T_{½Imax}$ and T_{width}) and analysis based on the mathematical model, which defines different functional state of PMNL.

Conclusions: Optimal for the experimental conditions of chemiluminescent intensity, standard and model parameters of chemiluminescent kinetics are: blood dilution 1:50, zymosan concentration 1 or 2 mg/ml and opsonization of zymosan with blood plasma.

Keywords: chemiluminescence, polymorphonuclear leukocytes, inflammation

Some novel neutrophil roles in human biology

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Introduction: Involvement of neutrophils in human biology is much bigger than originally known. This is mirrored in many new roles, by taking part not only in immunity. Cardiovascular function is preservation of blood flow necessary to serve for the transport, defence, acid-basic equilibrium and haemostasis of the body. Lastly emerge evidences about interaction of neutrophils and neuronal network in the brain.

Aim: Participation of neutrophils in the inflammatory modulated pathology of hypertension and in interaction of the immune system with neuronal system of the brain.

Discussion: According to the Poiseulle-Hagen law the pressure gradient and the total peripheral resistance R, including vascular and whole blood resistance (Rv and Rη), determine the needed blood flow.

Neutrophil influences Rv in inflammatory modulated hypertension. Rv depends on: geometrical parameters of the vessels changed by lesion and plaque formation; viscoelastic properties of the wall altered after remodelling of vascular wall; decreased microcirculatory cross-section by the vascular rarefaction.

The whole blood viscosity Rη depends on the haematocrit, plasma viscosity and aggregates of erythrocytes (dominant part), platelet, neutrophils and mixed three sort cells aggregates. Aggregates are formed by reactive oxygen species, proteolytic enzymes, interleukins, cytokines, chemokines, thromboxane and prostaglandins secreted from activated neutrophils. Interaction of aggregates, neutrophils and coagulation system originate clots in sites with turbulence within bends, bifurcations and after formed plaques in all parts of the vascular tree.

Innate immune cells first meet pathogens and they secrete proinflammatory cytokines that affect the brain and cause fever, fatigue, and sleepiness. The cytokines are responsible for relation between chronic inflammation and depression. Relation is bidirectional. Neutrophils produce a wide spectrum of cytokines and they are non-nervous cells that can release neurotransmitters and modulate neuronal sensory signals. Sensory neurons can inhibit phagocytosis, releasing neuropeptides.

Neutrophils can cross the blood brain barrier (BBB) and can induce neuronal damage by releasing cytotoxic and inflammatory mediators. These processes elucidate possibility for treatment of neurological diseases.

Conclusions: New roles of neutrophils impart authenticity to chronic systemic inflammation in hypertension and neuro-immune modulation.

Key words: neutrophils, inflammation, hypertension, neuro-immune modulation

Surface electrostatic potential of mutants of S-protein of SARS-CoV-2 virus

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The infectious disease COVID-19 is caused by the coronavirus SARS-CoV-2, which enters the respiratory tract epithelial cells by using receptor-mediated endocytosis, after binding with the cell ACE-2 receptor (angiotensin-converting enzyme-2) with its S-protein (a protein, integrated in the lipid membrane surrounding the viral RNA). During the ongoing epidemic, a few mutant virus strains have emerged – they were caused by errors in the replication of viral RNA, and it was determined that some of them could possibly change the association constant of the S-protein and ACE-2 receptor (and by doing that – have effect of the infectivity of the virus), and especially important are these mutations, which lead to a change in the electrostatic interactions between the two macromolecules in the binding site, by causing replacement of uncharged with charged amino acid residues (or the opposite).

The **aim** of our study was to calculate the surface electrostatic potential of the viral S-protein with programs for protein electrostatics, using data from published amino acid sequences of the polypeptide chain of the S-protein with point mutations, and determining the position of mutated amino acid residues in the 3D-structure, reconstructed by methods of macromolecule modeling on the basis of homologous protein structures. The 3D-atomic coordinates of the macromolecule are used to calculate the parameters of S-protein in native state: pKa-values of ionizable groups, pH-dependence of overall charge, isoelectric point, and to visualize reconstructed macromolecule models, mutated amino acid residues and the distribution of electrostatic potential on the surface of the molecule. On the basis of changes in surface electrostatic potential, we have selected the mutants, which change the association constant and could have effect on the infectivity of the virus.

Keywords: SARS-CoV-2, S-protein, mutation, electrostatic potential, macromolecule models

EDUCATION TRAINING AND PROFESSIONAL DEVELOPMENT

Aspects of successful project management model – the MaXIMA H2020 project case

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Since Bulgaria became a part of the EU, project activities have consistently become a major tool for public and private organizations to achieve a concrete outcome for a defined short-term period. The relatively small experience in project management of the research groups in Bulgaria places the country in an unfavourable position in a highly competitive environment. This has led to the necessity of acquiring and applying new knowledge, skills and techniques in order to achieve successful project management. Moreover, the difference in competences of the research teams in terms of overall project management, was considered as a weakness affecting the economic development of Europe.

The EU responded to this challenge with HORIZON 2020 program, which is the largest Framework Program for Research and Innovation till present. The program invests in enhancing the competences of research teams through calls such as TWINNING, TEAMING, ERA CHAIRS. The MaXIMA project has been approved and received funding under this call, with a main objective of increasing the scientific and innovative capacity of the home university. The team has managed to accumulate new management skills in terms of smooth monitoring of project progress, effective use of financial resources, quality and risk management, partnership and collaboration with other scientific teams, etc.

This work aims to present the MaXIMA project management model, which took the team across the path of growth – from greener to an example of good practice in project management. The team started with the clear idea that would face a double challenge – to be a successful project leader, while developing its managerial skills. This necessitated a proactive approach from the first project stage – the initiation. A number of inquiries were carried out: team selection, appropriate funding program, potential partners, time coverage, provision of the necessary infrastructure, etc. This detailed preliminary analysis contributed to the successful implementation of the overall idea and objectives.

Approaching the final stage – MaXIMA project closure, the team reports on the achievement of the initially set goals and has managed to exceed the expected impact of the project results.

Keywords: project monitoring and management, research and scientific projects

INFORMATION SYSTEMS AND DATABASES IN HEALTHCARE AND MEDICINE

Web-based platforms presenting regional health data for Bulgaria: an overview

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Overcoming regional health inequalities is at the centre of the policies of many international health organizations. In order to resolve them an analysis of the population's health status based on various indicators must be made. The current work aims to examine the specific characteristics of different web-based platforms with free access to regional health data for Bulgaria.

The National Statistical Institute (NSI) has by far the most extensive platform in terms of health information related to the Bulgarian population. However, the number of health indicators is limited and missing entries for indicators can be found through the available years. The NSI presents the information mainly with tables. Although, convenient it usually requires further data processing. Cartographic presentation is available for some of the indicators and mostly on the level of provinces and regions and rarely for municipalities. Another provider of regional health data for Bulgaria is the Institute for Market Economics. They focus more on the user experience with user-friendly interactive maps and options for graphics. The available health indicators are considerably limited compared to NSI. Furthermore, the information is only available at the level of provinces. The monitoring, evaluation and control system for implementation of the NSRBIR, on the other hand, provides only information for a specific ethnicity – the Roma people. Various indicators are presented by choropleth maps and graphics. However, no data for municipalities is available and the health indicators are limited to just a few with missing entries for some of the available years. Eurostat collects and presents data for the countries in the European Union as well as for Bulgaria. The data is presented in terms of tables, graphics and choropleth maps, but it is only available on the level of countries and planning regions with mostly general health indicators.

Web-based interactive platforms are an excellent tool for visualizing and presenting vast statistical information, such as the regional health profiles. However, the available platforms for Bulgaria lack the extensive data needed for drawing in-depth adequate conclusions and/or are hard to operate with not so user-friendly interface and with menus buried deep into the website.

Keywords: web-based platform, health profiles, regional profiles, Bulgaria

Acknowledgement: Authors thanks the National Scientific Program "Young Scientists and Postdoctoral Students".

MEDICAL PHYSICS

Prospects for study flash effect whit protons and heavy ions respectively on CERN LINAC-4 accelerator and Nuclotron at Dubna

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Treatment of tumors with proton and ion beams is a modern and avant-garde approach in modern therapy. The advantage of this therapy over photon irradiation is that it allows the dose to be delivered to the tumor, while maximally sparing the tissues located in front of and behind it. This is due to the specifics of the interaction of charged particles with the substance, which have the property to deposit the greatest energy in a limited area (Bragg peak) at the end of its trajectory.

Recently, there has been progress and development, the so-called FLASH therapy. It uses several orders of magnitude higher dose rate than conventional therapy. A number of preclinical studies have repeatedly shown that FLASH therapy is sparing for normal tissue while retaining its antitumor properties. This allows to further increase the difference in the response of healthy and cancerous tissue to the effects of ionizing radiation. Although the effect is known for many years the first patient treatment has been done in 2019 with an electron beam. There are no published studies of the FLASH effect with ion beams. The study of the FLASH effect with protons and heavy ions is further limited by the lack of suitable accelerators capable of delivering the required high dose rate. Only a few modern accelerators are capable to overcome the limitations.

The **purpose** of this study was to check if the beams provided by CERN LINAC-4 accelerator and Nuclotron at Dubna are suitable for biophysical experiments on FLASH effect. In this work we check for the suitability of the beams of LINAC-4 and Nuclotron accelerators for the FLASH effect study by means of dedicated computer simulations. GEANT4 and FLUKA are used to simulate the accelerator beam with a designed phantom for irradiation of in-vitro cell cultures. The main **results** are dose maps obtained after simulation the proton and ion beams with the proposed experimental setup. As a conclusion our results show that LINAC-4 and Nuclotron are suitable for study of the FLASH effect.

Keywords: hadron therapy, FLASH therapy, computer simulations, GEANT4, FLUKA, interaction of ionizing radiation with the matter

Optimisation of chest radiography exposure parameters and image quality evaluation using 2.5D pseudoanthropomorphic premature chest phantom

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Chest X-ray examinations are of critical importance for neonates pathology diagnostics, especially in cases of prematurely born neonates with serious or life-threatening diseases. Treatment and diagnosis of such dis-

eases often requires frequent chest x-ray examinations. The higher radiosensitivity of infants than adults and their longer life expectancy increase the risk of radiation-induced effects. Therefore following the ALARA principle, the optimisation of the radiography technique and the exposure parameters for paediatric patients is of critical importance.

All images were acquired on two X-ray units by using 3D printed pseudoanthropomorphic premature chest phantom shared under creative common license. Different exposure parameters and radiography techniques were used. Image quality was evaluated quantitatively in terms of noise, contrast and CNR for different regions of interest and subjectively by experienced radiologists.

The survey suggested optimised exposure parameters for chest X-rays of prematurely born neonates with acceptable image quality. The phantom was also used for educational and training purposes of the radiographers in two different departments.

Keywords: 3D printed, chest phantom, optimisation, neonates

Time-resolved imaging of contrast kinetics. Principles and application

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Learning objectives:

1. The aim of this work was to describe the physical principles for obtaining MR angiographic images by applying contrast agent by two different techniques:
   - 3D CE-MRA (Contrast-Enhanced MR Angiography)
   - 3D TRICKS (Time-Resolved Imaging of Contrast KineticS)

2. To make a parallel comparison of the advantages and disadvantages from physical and technical point of view.

3. To show and analyze different clinical cases using the two MR angiographic techniques.

Conclusion: Significantly higher temporal resolution, due to special k-space sampling ("keyhole imaging"), "video" format, which allows passage of contrast material to be viewed directly without any predetermined timing, makes TRICKS technique the first choice for diagnostics of various vascular pathologies and anomalies.

Keywords: contrast kinetics, magnetic resonance angiography

Study of the DNA damage in flash therapy mode, using GEANT4-DNA simulations

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Radiotherapy, together with surgery and chemotherapy, is one of the methods of tumor treatments. Their purpose is to kill cancer cells while sparing as much as possible the nearby healthy tissues. The most widely

used threatened devices use gamma or electron beams to irradiate the tumors, but nowadays proton beams and ion beams are also employed in dedicated medical centers. The advantage of proton and ion beams is that due to Bragg peak the energy deposit is very high in a small area. This feature is used to target precisely the malignant tissue, while protecting the nearby normal tissue.

In the last years the so called FLASH therapy is a hot-topic. In FLASH therapy the dose is delivered in a very short burst leading to extremely high dose rates. The FLASH effect further increase the differential response between the healthy and malignant tissue in respect to the conventional therapy. The exact mechanism of this effect is still not well understood. Possible explanation is that the ultra-high dose rate depletes the cell oxygen levels and in this way affects the physicochemical and chemical reactions in the cells and decrease the secondary damage to the cell DNA.

The aim of the study was to evaluate the secondary damage to the cell DNA by means of computer simulation. The simulation is a first step towards an experimental study of the FLASH effect using proton and carbon ion beams. We use GEANT4 package to perform Monte Carlo simulations of proton and ion beams passing through matter, while the physicochemical and chemical steps are simulated trough a dedicated GEANT4-DNA package. As a result of the study we obtained the time evolution of the yield of different chemical species in a water phantom due to irradiation with proton and ion beams with different energies.

Keywords: DNA, hadron therapy, FLASH therapy, computer simulations, GEANT4, GEANT4-DNA, interaction of ionizing radiation with the matter

MODELLING AND SIMULATION

Creation and evaluation of physical and computational breast anthropomorphic phantoms

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Anthropomorphic phantoms are a major instrument in many tasks in Diagnostic Radiology. They permit unlimited exposure during important tasks such as training activities, image quality assessment, patient dose optimisation, clinical commissioning, which is in fact their strong advantage. In breast imaging, they are used to validate, evaluate and optimise novel imaging techniques for screening and diagnosing the breast, as well as for systems' quality control, optimisation of protocols and image reconstruction algorithms, dose estimation and are a major tool in virtual clinical trials. This work addresses the most recent advances in creation of x-ray breast anthropomorphic models using both computational and manufacturing techniques and their applications in 2D and 3D imaging.

Approaches for creation of computational breast anthropomorphic phantoms consist of wide range of techniques such as constructive solid geometry, voxel, polygon-mesh, and hybrid techniques, applied to model the breast as accurate as possible with all anatomical variations. In practice, the most popular approaches are based on mathematical formulations and patient medical images. Mathematical breast models consists of mathematical description of the breast structures. Their realism is assessed mainly through evaluation of generated synthetic mammograms. One limitation of these models is the impossibility of encompassing all clinical cases and all possible breast densities. On the other hand, patient-based anthropomorphic breast phantoms with realistic tissue distributions may be created from segmented clinical datasets acquired by breast CT. Such approach guarantees a very high degree of realism.

Cast-based, 3D printing and paper-based approaches are the main methods for creation of physical breast anthropomorphic models. Among them, 3D printing technologies provide an excellent opportunity to create realistic models of the breast by using a number of printing materials with physical and x-ray characteristics similar to these of human tissues. On the other hand, paper-based breast phantoms have been recently reported as a low cost approach to produce physical breast phantoms due to widely availability of inkjet printers, low-cost ink enhancers and cheap add-on materials.

Anthropomorphic phantoms are excellent tool for research and everyday clinical tasks. Novel methodologies for the creation of breast anthropomorphic models are continuously emerging, resulting in improved anatomical and radiological realism.

Keywords: anthropomorphic breast models, computational breast models, physical breast models, modelling approaches

Acknowledgement: This research is supported by the Bulgarian National Science Fund under grant agreement DN17/2.

A method for construction of anthropomorphic models based on inkjet printer: calibration phantom development

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Introduction: 3D anthropomorphic models of human tissues have become a requirement for conducting realistic virtual clinical studies. Current research is in the field of physical models created with 3D printing technologies using various materials – resins, polymers, etc. and combining different materials with specific features. In the radiology field, this research requires the creation of new materials, which physical and radiological characteristics are similar to these of the human tissues.

Aim: The goal of the current study is the development of a calibration radiology phantom when inkjet printing technology is considered. This phantom will serve as the basis for the creation of realistic physical anthropomorphic phantoms dedicated to radiological studies.

Materials and methods: A software calibration model was created using specialized software application called *XRAYImagingSimulator*. The simulation model consists of 11 objects with parallelepiped shape with base size of 20 mm x 20 mm and heights ranging from 0.01 mm to 0.11 mm. Simulated x-ray images were generated at 45 kVp. An inkjet printer was used to create the physical model. The printer cartridge was injected with 0.6 g/ml solution of potassium iodide (KI) and an image was printed on a plain office paper (80 g/m^2). X-ray images were obtained with Sedecal X Plus LP+ with anode voltage and current of 45 kVp and 125 mA, respectively.

Results and discussion: Two calibration phantoms were created: a computer-based and its physical version by using inkjet printer. The physical object comprised of ten plane sheets with printed squares of the computer models. These sheets were stacked together resulting in a phantom with a total thickness of 1.1 mm. The visual comparison of experimental and simulated x-ray images demonstrated an apparent similarity. The objective evaluation included contrast and profile assessment by using a dedicated software application.

Conclusions: The proposed method will be exploited for the extraction of complete determination of the x-ray attenuation coefficient of the synthesized printing material. Based on this the complete anthropomorphic model will be modelled and manufactured.

Keywords: 3D models, 3D simulations, radiology image, inkjet printing

Acknowledgement: This research is supported by the Bulgarian National Science Fund under grant agreement DN17/2.

Investigation of models for breast contrast-enhanced mammography: simulation results

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Awareness of the early detection of breast cancer is rising more within the years. New technologies are presented to the hospitals with one main aim – as early as possible detection of this women killer. One of this new technology is Contrast Enhanced Spectral Mammography (CESM). Nevertheless, some of the doctors are not yet convinced that injecting patients with iodine will improve the quality of the image in such a way so the suspected lesion to be detected easily compared to the techniques used now. Phantoms-software or anthropomorphic are ideal to prove this. The purpose of this study is the creation and validation of three software phantoms for contrast enhanced spectral mammography.

For the creation of the phantoms, an in-house software tool, the *XRAYImagingSimulator* is used. The first phantom is a container with a semi cylindrical shape, made of PMMA. Six iodinated inserts with the same radius of 10 mm and height – 2, 3, 4, 5, 6, 8 mm were inserted. The second phantom is a PMMA parallelepiped with a base dimensions of 203 mm x 152 mm and thickness of 25 mm. Six iodinated inserts with a radius of 9.5 mm and varying heights: from 0.5 mm to 20 mm were inserted in the container. The third phantom is heterogenous breast phantom which is replica of the first one with included heterogeneous background in the form of spheres of different diameters. The iodinated inserts were modelled from Omnipauque. For each phantom, two simulated radiographs were taken: one with an energy below the K-edge of the iodine concentration – 20 keV and one with a higher energy above the K-edge – 34 keV. The images were processed to a recombined iodine image which shows the iodine contrast agent and suppresses the surrounding background tissue. Simulated spectral images demonstrated improvement of the image quality compared to low-energy images of the phantoms. The simulations with the inhomogeneous model revealed that the heterogeneous background has been successively depressed while improving the visibility of the iodine inserts. Further work is related to simulation of x-ray spectra used with contrast enhanced mammography, adding a photon noise and experimental validation.

Keywords: breast software phantom, contrast-enhanced spectral mammography, iodine concentration, modelling, simulation

Acknowledgement: This research is supported by the Bulgarian National Science Fund under grant agreement DN17/2.

NEW TECHNOLOGIES IN MEDICINE AND SAFETY

Analysis of fold distribution in a hybrid detector array

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Gamma and X-rays emission multiplicity strongly depends on the undergoing nuclear process. Fusion/Fission reactions generate events of high multiplicity, while Coulomb excitation, neutron capture and beta decay processes are usually associated with low multiplicities. When those high-energy photons are registered by a multidetector array, several detectors may be hit in coincidence depending on the de-excitation mechanism, the detectors used and the combinatorics. The number of detectors fired in one event is called fold. For example, in PET (Positron Emission Tomography) scanners, the ideal fold is two. However, often the number of registered photons is different from two. The aim of this study was to analyze the effect that fold logic has on the quality of the experimental data.

The current study was conducted at the Tandem accelerator in *"IFIN-HH"*, Magurele, Romania. The emitted Gamma and X-rays were detected by a hybrid detector array, called *RoSphere*. *RoSphere* consisted of three types of detectors: ten scintillator detectors with $LaBr_3$:Ce crystals, twelve coaxial and three planar semiconductor detectors. The experimental set-up aimed to populate ^{105}Ru nucleus. However, several reaction mechanisms were competing, leading to enormous data contamination. In order to select the reaction of interest, conditions on the fold were applied.

First results of this experiment show that for the logic trigger on coaxial-coaxial semiconductor detectors the most probable fold is three, while for the planar-planar trigger the fold is two. For coaxial-planar detectors the most probable fold is six. The analyses are ongoing but the preliminary results show that the fold can be used as a selective tool.

Unwanted events registered by a multidetector array can be suppressed electronically online or offline by the logic of the experiment. High-fold events can be partially suppressed by pulse discrimination. These procedures are widely used in the nuclear research physics laboratories. Choosing correctly the background suppression will have a great impact on the collected statistics and potentially to the patient dose, for example in the PET. Analyzing the fold distribution will provide unique insights in different areas of the physics, such as high spins, transfer reactions, isomer spectroscopy, astrophysics and medical physics.

Keywords: fold distribution, hybrid detector array, gamma and X-rays emission.

Application of simulators with virtual reality in training for laparoscopic surgery

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In the last decade, minimally invasive laparoscopic manipulations have gained popularity in many of the large healthcare centers in Bulgaria. In most of the operative interventions, these manipulations have become a gold standard and the first method of choice among specialists. This in turn has imposed the need for highly qualified specialists with needed theoretical knowledge and specific psychomotor skills for this technology. Until recently, training of physicians in this field was carried out according to the classical method, in real clinical conditions, where a doctor-specialist performs part or all of the surgery operation under the direct supervision of his mentor specialist. This method is safe, but at the same time requires a long period of training for a limited number of specialists. The use of new technologies, such as medical simulators in teaching and training activities may result in qualified specialists in surgery, as well as maintaining the qualifications of experienced surgeons. In this preliminary study we report on the initial results of using a medical simulator for laparoscopic surgery for training of doctor-specialists.

Our aim is to assess the application of simulators with virtual reality in training for laparoscopic surgery. For the period from 2018 to 2020, 20 residents have undergone training in the basic skills for laparoscopic surgery at the Department of General and Operative Surgery, Medical University – Varna. The training included virtual reality simulation and practice on patients. The criteria of the training were camera manipulation, hand-eye coordination, clipping, and cutting activity. The simulator system used was Simbionix Lap mentor III with 3D glasses for virtual reality. The trainees were divided in two groups depending on previous virtual reality training before starting real laparoscopic surgery. The results showed improvement of the basic laparoscopic skills after virtual reality training.

Keywords: simulators, laparoscopic simulators, surgery, training, virtual reality, laparoscopic surgery, minimally invasive surgery

PHYSICAL FACTORS

Human health protection on using optical radiation sources for therapeutic and cosmetic purposes

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Numerous sources of optical radiation emitting high levels of optical radiation are used by humans for therapeutic, cosmetic, and entertainment purposes. The legislation for human health protection is missing or is not adequately applied. Considering that a large part of the consumers are young people the control of optical radiation sources is issue of great public health and social importance.

The aim of the study is to propose an approach for health protection on using optical radiation sources for therapeutic and cosmetic applications on the basis of scientific literature and our own experience.

There are many proven harmful health effects of optical radiation. For many optical sources, only technological standards exist that regulate only the product's performance. For others, the requirements are set in voluntary standards. Generally, the legislation does not cover applications of optical radiation not defined as medical treatment. Serious problem with the cosmetic applications is the fact that they are used at a personal choice of the consumer – exposure is voluntary.

The problems of protection are addressed for the common sources for cosmetic (solaria, IPL systems), therapeutic purposes (lasers, therapeutic lamps, etc.). The specific risks connected to the sources application and problems of protection are discussed. Following the problem analysis we propose an approach for development of specific legislation for these sources corresponding to the health risks.

There is a need to develop specific policy for human health protection on using optical radiation sources. It should contain as a minimum: technical requirements, use, protection, control, communicating risks, etc.

Keywords: optical radiation, solaria, cosmetic and therapeutic applications, public health protection

5G technology. Public concern and probable health consequences

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Over the past two years, civic organizations against the development of wireless technologies have become more active, especially at the time of the COVID-19 pandemic, which was linked extremely illogical with the introduction of 5G technology.

Establishment of an effective communication program that counteracts to the fake news and provides adequate scientific information on the health impact of radio frequency fields.

Proven methods of communication are applied, such as: measurement data, information materials, web page, interviews, publications, banner, based on the WHO, EC and other international organizations' statements.

The results of the campaign significantly reduced the fears among the population regarding the impact of radio frequency fields on humans. The scientific thesis about the thermal effect of radio frequencies and the fact that millimeter waves do not penetrate into the body was confirmed in the information space.

It becomes clear that population would accept the new wireless technology with less fear if it will be included in the process of its introduction and if there is appropriate information and interpretation of scientific data.

The fears of the population regarding the new wireless technology will be reduced by improving the quality of scientific research. A positive result would be the creation of a common concept for informing the population on the basis of the EU Action Plan from 2016, which would present scientific data from the member states, compared to the results of measurements. This will actually counteract the huge number of publications with fake news in the world press and in social networks, most often distributed by non-professionals in this field.

Keywords: public concern, 5G, RF fields, fake news

QUALITY ASSURANCE AND QUALITY CONTROL

Verification of dose calibrator accuracy for ^{99m}Tc

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The **purpose** of this study is to examine the accuracy of the dose calibrators when measuring the most commonly used nuclide in nuclear medicine (NM) – ^{99m}Tc.

Manufacturers recommend checking and calibrating the accuracy of the dose calibrators with a long-lived reference source of ^{137}Cs. In the course of verifying the accuracy of the dose calibrators in the country with 2 long-lived reference sources, we noticed that calibration with ^{137}Cs does not guarantee accuracy for other reference source. This fact also raised reasonable doubts about the accuracy of the measurement of ^{99m}Tc, a nuclide which is mainly used in NM. The problem is the lack of a reference long-lived source to test such hypothesis).

A **method** was developed to study the precision of ^{99m}Tc measurement by a comparative study. A sample of ^{99m}Tc was measured at 12 dose calibrators in eight NM departments in Sofia in a 4-hour time interval. The average of 10 measurements per dose calibrator was recalculated back to the starting point of the measurements.

Results From the resulting series of 12 values 3 dose calibrators with almost identical results were selected as reference ones. The main argument for this selection was their recent installation. In terms of the reference dose calibrators, the deviations of the remaining dose calibrators were in the range +1,2% -12,9%.

The deviations identified in the course of the paper can be corrected by the "isotope factor" for ^{99m}Tc of the dose calibrator. The correction can be made with or without a reference dose calibrator. It should be stressed that the proposed solution is temporary until the possibility of servicing the dose calibrator has been arranged.

Conclusion It is indicated that the calibration of the dose calibrator with ^{137}Cs does not guarantee its accuracy for other nuclides.
A comparative method is proposed to check the accuracy of the dose calibrators for ^{99m}Tc.
A dose calibrator setting method for ^{99m}Tc – with or without an auxiliary reference dose calibrator is proposed. It is recommended that the accuracy check of dose calibrators be carried out with 2 reference sources. The comparative method presented can be used for targeted verification of all dose calibrators in the country.

Keywords: dose calibrator, accuracy, calibration, reference sources

Quality assurance of the CyberKnife M6 Accuray robotic stereotactic radiosurgery system

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CyberKnife is the only system for Stereotactic Radiosurgery and Stereotactic Body Radiation Therapy where a linear accelerator, that provides multiple narrow high energy photon beams, is directly mounted on a KUKA Robot System. It delivers radiation to the tumor from numerous different directions with high precision and ensures maximum radiation dose to the target while sparing surrounding healthy tissue. The system receives real-time stereoscopic kV images, which serve to track the movement of the tumor during the treatment and to guide the robotic manipulator. An important CyberKnife M6 feature is the InCise™ Multileaf Collimator allowing to shape the radiation in accordance to the tumor and to shorten the treatment time.

Quality control is extremely important for achieving the desired therapeutic effect and for preserving the healthy tissues around the tumor from irradiation. Clinical Quality Assurance (QA) for the CyberKnife follows mainly the instructions of the manufacturer – Accuray, due to the lack of independent recommendations. The technology itself continues to evolve, and CyberKnife's quality assurance (QA) tools and techniques are constantly changing and will continue to improve with the users' clinical experience.

Here we present the calibration procedure for the CyberKnife MC Accuray machine installed at the Clinic of Radiotherapy, St George University Hospital, Plovdiv. Relative and absolute X-ray beam dosimetry were carried out by using a PTW MP3-M water phantom. The relative dosimetry includes evaluation of profiles, tissue-phantom ratio, and output factors. The measurements were performed by using a PTW microSilicon camera and a PTW Tandem electrometer. The signals were further processed by using the Mephysto mc^2 software.

The absolute dosimetry measurements were carried out by using a PTW Semiflex 0.125cc camera directly connected to a PTW Unidos E electrometer. The geometrical precision was tested by using a Ball-Cube-II Film Cassette and Head Phantom.

The obtained results have shown that all factors compared to those made during the installation of the CyberKnife are within acceptable values.

Keywords: CyberKnife, quality assurance, stereotactic radiosurgery, stereotactic body radiation therapy, X-rays, dosimetry

Comparison between automated dispensing system and radionuclide calibrator, clinically used in a PET/CT department: first results

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Introduction: The accuracy of the administered activity during PET/CT imaging directly affects the variance in the SUVs, used for quantitative assessment in diagnosis and follow-up of cancer patients. The quantitative performance and longitudinal accuracy of the activimeters should be done on a regular basis. IAEA recommends an accuracy of ±5% between prescribed and infused activity. In its latest Guideline for ^{18}F-FDG imaging the EANM recommends even higher accuracy range of ±3%.

Aim: The aim of this study is to confirm the declared reliability of automated dispensing and injection system for ^{18}F(FDG) (IRIS system (COMECHER) by comparison with a radionuclide calibrator (CRC-55tR (CAPINTEC)), used in this study as a reference activimeter.

Materials and methods: The investigation was divided in two parts: measurement and comparison of 1) mother vials and 2) 100 MBq preset activity of ^{18}F(FDG). Measurement time and activity were recorded and activities were corrected for the decay. Results were compared and analyzed. The agreement between both methods was accessed by Bland Altman plot analysis.

Results: Multidose vial measurements: 189 multidose vials were measured, with activity range of 3500 to 9500 MBq. The median value of discrepancy between IRIS and CRC-55tR was 0.1% with a range between -13.2% and 10.2%, SD 2.6%. In 96% (181) of cases the accuracy was below 5%, in 3% (5) of cases, between 5% and 10% and in 2% (3) of cases, between 10% and 15%. **Preset activity measurements**: fifteen samples of 100 MBq preset activity were dispensed and injected to a 10 ml glass vial. Results for discrepancies between IRIS and CRC-55tR were as follows: -4.9% (median), -5.4% (minimum), -3.6% (maximum), -4.8% (Mean), 0.6% (SD).

Conclusions: Comparison between IRIS system and radionuclide calibrator CRC-55tR showed that IRIS system complies with the IAEA requirements when dealing with patient doses, but not with the EANM recommendations. The overall accuracy of the IRIS system, declared by the manufacturer, is ±5% and further actions by the user will not increase its accuracy. Analyzing multidose vial measurements the observed discrepancy between activimeters, higher than 5%, can be attached to a random or technical error during the measurement.

Keywords: PET/CT, automated dispensing and injection system, activimeter, accuracy

RADIATION PROTECTION AND SAFETY

Survey of the practice and evaluation of the typical and effective doses of patients during arteriography of the lower limbs and phlebography

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The aim of the present study is to assess the typical doses and the effective doses of patients during arteriography of the lower limbs and phlebography, and to prove whether an optimization of the radiation protection is possible and to evaluate if there is a chance of having a skin injury.

The study was performed in Military Medical Academy, Sofia with angiography X-ray system. For each procedure and every patient, the following data were collected: age, sex, height and weight of the patient, kerma – area product – P_{ka}, fluoroscopy time – FT, cumulative dose – CD, number of series acquired, as well as some other clinical patient data. The effective dose was calculated by using conversion factors proposed in the literature – 0.26 mSv/Gy.cm^2 for arteriography of the lower limbs and 0.1 mSv/Gy.cm^2 for phlebography.

The study was conducted with a total of 40 patients, of which 20 undergoing arteriography of the lower limbs and 20 – phlebography. The mean values for P_{ka} and FT were respectively: 62.6 Gy.cm^2 and 2.1 min for arteriography of the lower limbs and 5.6 Gy.cm^2 and 0.2 min for the phlebography. The calculated mean values for the effective dose were: 16.3 mSv for lower limbs angiography and 0.6 mSv for phlebography.

In the current study the patient doses during arteriography of the lower limbs were with approximately 10% higher than some of the doses reported in the literature, but with a big standard deviation – 66.5 Gy.cm^2, so that must be investigated in addition. The obtained values of P_{ka} during phlebography are not compared with DRL, due to the fact that both in Bulgaria and in other countries around the world, such have not been established yet, but the data can be used, as typical values of the patient's dose for this type of procedures. The estimated effective doses of the patients in both the procedures showed that there is a minimal risk of occurrence of stochastic effects. These studies should become routine in the practice, to allow comparing of the doses between different compartments in order to standardize of the practices and reduce radiation doses.

Keywords: typical doses, effective doses, radiation protection, arteriography of the lower limbs, phlebography.

Initial study of the radiation exposure to patients in CT Brain Perfusion

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CT Brain Perfusion is a relatively new technique that is used to evaluate blood flow to the parenchyma of the brain in the setting of suspected ischemia and stroke. The aim of the current investigation is to perform a pilot study on the practice and typical doses of patients for CT Brain Perfusion examinations.

The study is made on a 64-slice CT scanner. In order to evaluate the median CT radiation dose of the patients, two parameters are used: volume computed tomography dose index ($CTDI_{vol}$) and dose length product (DLP). Additional exposure parameters as: anode voltage and current used, slice thickness, the width of the radiation beam, the rotation time and some patient data – sex, age, weight and height are also recorded.

The CT Brain Perfusion examination is performed in average of 4 series: one native and three with a contrast. First results for the median values of $CTDI_{vol}$ and DLP, and standard deviation in parentheses, during the native phase are respectively: 51.7 (0.0) mGy and 1149.0 (45.6) mGy.cm. The $CTDI_{vol}$ and DLP for the first contrast phase are respectively: 117.0 (0.0) mGy and 468.0 (0.0) mGy.cm. The median values for the second and third contrast phase, per phase, are: $CTDI_{vol}$ = 38.5 (15.3) mGy and DLP = 1114.5 (42.3) mGy.cm. The total result for the whole examination is calculated to be: $CTDI_{vol}$ = 245.7 mGy and DLP = 3846.0 mGy.cm.

As a result of the current study, it is concluded that CT Brain Perfusion can result in relatively high radiation exposure to the patients from the repeatedly scanning of only one location of the head. With CT Brain Perfusion, there is no clinical advantage with relatively higher dose settings because the purpose of the CT examination is to provide information of time-dependent perfusion and not to visualize any specific anatomic detail. Given this, any increase in radiation dose compared with the standard CT head or brain protocol could be considered as unnecessary radiation exposure.

Keywords: radiation protection, patient doses, CT Brain Perfusion.

Initial results from a survey of the radiation dose to patients undergoing percutaneous transluminal angioplasty

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The percutaneous transluminal angioplasty (*PTA*) is type of interventional procedure, which results in substantial patient radiation doses. The aim of this survey is to perform a pilot study of the typical patient doses for *PTA* procedures and to explore the potential for optimization of the radiation protection practice.

The current investigation is performed on a C-arm flat panel system. In order to estimate the patient radiation doses, the air kerma-area product (P_{KA}) is used. Additional data for the following exposure parameters is also collected: fluoroscopy time (*FT*), tube voltage and tube current, number of series and images obtained. Patient sex and age are also recorded. All the *PTAs* are performed using femoral approach and are mostly with low and medium complexity.

30% of all the patients undergoing the investigated *PTA* procedures, are women and 70 % – men. The results for the median values of the P_{KA} and *FT* (with the standard deviation) are 15.7 (9.2) $Gy.cm^2$ and 31.5 (39.2) min, respectively. The number of the acquired series and the total number of images are 14 (20) and 338 (169), respectively. The rate at which the images are displayed is 9 (2) frames/second. All *PTA* procedures are performed under automatic brightness control, in which the tube potential and tube current are automatically adjusted.

The analysis of the results of the current study show that the difference in the P_{KA} median values depends on the complexity of the *PTA* procedure, the patient anthropometric data, the exposure data, the operator's technique and the radiology practice. The *PTA* involves single or double stent and/or balloon deployment, which results in relatively high radiation doses due to the increased complexity of the procedure and the increased fluoroscopy time.

Keywords: radiation protection, patient doses, vascular procedures

Comparison of different methods for calculation of patient effective dose from multiple CT examinations

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Purpose: The purpose of the present study is to compare different methods for effective dose (E) estimation of patients that have undergone several CT examinations with cumulative effective dose (CED) of 100 mSv and above.

Material and Methods: Patient data were retrospectively extracted using a dose management software (DMS). Firstly, patients exposed to CED of 100 mSv and above (from multiple CT examinations) were identified. Then, ten patients with effective diameter close to the median value of the whole sample, as provided by the DMS, were selected. Twelve different methods were applied to determine E from each separate phase and exam, and then the cumulative value from all exams of a particular patient. The methods considered included: the use of typical published values of E to determine the contribution of each exam; multiplication of published conversion coefficients by the dose-length product (DLP) from either each phase of the exam or the total DLP from the whole exam (including contribution from projection radiograph and monitoring of contrast injection); use of the same conversion coefficients applied to typical department DLP values; calculation with the ImPACT Patient Dosimetry Calculator, CT Expo and the National Cancer Institute (NCI) dosimetry system, either for each separate phase taking into account patient exposure data, or based on the typical department values of volume computed tomography dose index (CTDIvol) and DLP. The software estimations were performed with two different approaches: by adjusting either the CTDIvol or the DLP to match as close as possible the patient data as provided by the DMS.

Results: The effective dose from a particular phase of the examination on a particular patient varied with a ratio from 1.3 up to 4.6, depending on the calculation method used, while the CED variation was between 1.8 and 4.3 times. In the most extreme case, the difference in the estimated CED for one of the patients varied from 125 mSv (using published values of effective dose) up to 541 mSv (multiplying the phase DLP by conversion coefficient).

Conclusions: Although effective dose estimation is not recommended for individual patients, this is sometimes needed in clinical practice. It is highly dependent on the method used. CED estimations can differ up to 4-5 times or even more. The large uncertainties related to this should always be taken into account.

Keywords: computed tomography, effective dose

Patient exposure monitoring in medical imaging

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Patient radiation dose is a key element for balancing the benefits of the use of ionizing radiation in medical imaging and the associated radiation risks. Most imaging modalities display modality-specific dose indexes that are registered and used to optimize imaging protocols. The international radiation protection standards require diagnostic reference levels (DRLs) to be established and used as a benchmarking tool for optimization.

The modern radiology systems allow for storing and transmitting images in a standardized digital format along with the information about the exposure, including dose indexes. The easier access to this big amount of data converted the need of "dose surveys" once in a few years to a permanent process of patient radiation exposure monitoring using specialized software products.

The monitoring process includes recording of relevant patient exposure and dose related data at the facility, their collection and analysis. The amount of information and the method of recording and collecting depend on the purpose, modality and model. Collected data from different patients, modalities, and units are combined and processed to perform relevant dose analysis, which might include statistics, trending, tracking, or comparisons. This can be done at local, regional, national or international level. Data quality evaluations should be conducted at all steps. Analysis of collected data may be at the level of group of patients, or at the level of individual patients. Analysis at the level of group include setting typical doses and DRLs, procedural optimization, monitoring operations and trends in the clinical practice, tracking over time. Samples based on specific examination, patient group or acquisition conditions should be well defined. Availability of a good coding system of examination and protocol nomenclature is crucial. Tracking of exposure history of individuals requires patient identification. It is useful to avoid performing redundant radiological examination and optimize the overall patient care. A dose data management infrastructure may deploy an integrated electronic system, which interface and functionalities depend on the intentional user groups. Ideally, it should be integrated with the general patient information systems. If properly implemented, the patient exposure data management contributes to the improvement of radiation protection and patient care.

Keywords: medical imaging, patient dose, exposure monitoring, diagnostic radiology

Multicentric survey of radiology practice and patient doses in fluoroscopy guided diagnostic and interventional cardiac procedures

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Introduction: In the past decade an increase has been observed in the number and complexity of all performed cardiac procedures in Bulgaria. These procedures are often associated with higher patient exposure and require additional attention for the potential of radiation-induced effects.

Aim: 1) to present and analyze the typical kerma-area product values for percutaneous coronary intervention and coronary arteriography procedures in cardiology departments with high workload and to compare them with the National Diagnostic Reference Levels (NDRLs); 2) to compare the patient doses with the follow-up levels published in Ordinance 2, to identify patients at risk for radiation induced effects.

Materials and Methods: The study covered nine big hospitals, with a total number of fourteen angiography systems. The typical values of kerma-area product (KAP), cumulative dose (CD) and fluoroscopy time (FT) for percutaneous coronary intervention (PCI) and coronary arteriography (CA), were calculated. Data analysis, regarding the risk of radiation-induced skin effects due to interventional cardiac procedures, was performed.

Results: The results show that the typical KAP values are exceeding the NDRLs in three of the departments for PCI. Three-fold difference was observed between the maximal and minimal KAP value between the departments. For CA procedures five departments are exceeding the NDRLs and the difference between the minimal and maximal KAP value was almost five times. Patients exceeding at least one of the follow-up levels for PCI were observed in all departments. A system for patient follow-up was implemented in only one hospital.

Conclusions: The results show a potential for optimization in all departments. No radiation-induced effects were reported for the followed-up group of patients. A regular implementation into the routine clinical practice of „Patient instruction after interventional cardiac procedure(s) with greater complexity and prolonged fluoroscopy time" will help for timely diagnosis and treatment of radiation-induced skin effects after fluoroscopy guided cardiac procedures.

Keywords: National Diagnostic Reference Levels, radiation-induced effects, interventional cardiology

Optimisation of scan duration in a PET/CT ^{18}F(FDG) scanning protocol

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Introduction: Positron emission tomography with computed tomography (PET/CT) imaging with ^{18}F(FDG) has become a routine image procedure for the management of oncological patients. Occasionally a compromise may be required between imaging time and the possibility for the patient to keep still during the examination.

Aim: To present practical aspects used for implementation of a PET/CT scan protocol with optimized patient scan duration.

Materials and Methods: Patients were scanned in list mode at 2 minutes per bed position on a Discovery IQ 3R PET/CT scanner (GE Healthcare). Data were rebinned to simulate 1.75 min, 1.5 min and 1 min per bed position acquisitions, without changing other parameters. SUV_{max} and SUV_{mean} measurements over three reference tissues and lesions and visual inspection by two experienced nuclear medicine physicians were carried out. VPHD (iterative reconstruction algorithm) and Q.Clear (Bayesian penalized likelihood reconstruction algorithm) were utilized.

Results: Visual image quality assessment for retrospective reconstruction with 1 min per bed position showed poor image quality. Retrospective reconstruction with scan time of 1.5 and 1.75 min per bed position is of the same image quality as original. The maximum percentage change of median SUV_{max} value for 1.5 min per bed position is between 4 % and 6 %, no matter of the reference tissue. For the SUV_{mean} these discrepancies are even lower. The calculated percentage change of the median value for SUV_{max} in the lesion is up to 2 %, regardless of the scan time used or the reconstruction method.

Conclusions: Investigations on time minimization showed, that the time for patient examination can be reduced up to 25 % (up to 1.5 min per bed position). Depending on clinical indications scan duration could be reduced without compromising image quality.

Keywords: PET/CT, optimization, scan time

RADIATION THERAPY

Characterization of an a-Si EPID for dose-guided radiotherapy

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Electronic Portal Imaging Devices (EPIDs) are used to perform Quality Assurance (QA) measurements of new modalities in external radiotherapy. The purpose of this work was to evaluate the dosimetric response of an amorphous silicon (a-Si) EPID for which a detailed characterization is required in different treatment conditions.

Using MATLAB software, we developed a simple algorithm to calibrate an a-Si EPID response to dose for transit dosimetry by comparison to an ionization matrix array.

In a first step, a water slab phantom (RW3) with a reference field size (10×10 cm^2) was used to perform measurements for the EPID characterization. We converted the greyscale image of the EPID into portal dose image using a calibration curve. Then, the behaviour of the EPID detector (off-axis pixel response) was measured for different field sizes and different phantom thicknesses.

We compared these results to those obtained with a 2D array chamber. A linear dose response was observed for the considered EPID. Moreover, the EPID showed an energy dependence up to 5%. The angular dependence was about 2% for 90° and 270° and lower than 1% for other angulations. Correction factors calculated for field size and phantom thickness using MATLAB script showed differences up to 15% between the EPID and the 2D array chamber.

This study has shown that an a-Si EPID is suitable to perform transit in vivo dosimetry by using the proposed method.

Keywords: a-Si EPID, in vivo dosimetry, 2D array dosimeter, external radiotherapy

Cone beam computed tomography based dose calculation for radiation therapy

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Cone beam computed tomography (CBCT) is used in radiotherapy as an imaging technique. It is implemented on the linear accelerator and allows the verification of the daily positions of the patients and the volumes of the organs in the treatment room before their irradiation session.

In this work, the acquired CBCT images are used for dose calculation. In order to evaluate dose calculation from CBCT images, these results are compared to those obtained from CT acquisitions.

In a first step, calibration curves have been determined respectively for CT (Philips CT scanner) and CBCT (Elekta Synergy XVI system) imaging modalities. These curves (called HU-ED curves) allow the conversion of Hounsfield units (HU) into electronic densities (ED). Dose calculation is then possible using a Treatment Planning System (TPS) on two different phantoms: the Catphan and the anthropomorphic phantom Rando Anderson.

By using the HU-ED curves established on the Catphan phantom, smaller deviations are observed between the results of the two imaging modalities. The differences recorded for the phantom Rando Anderson were slightly larger but not exceeding 3%.

The obtained results showed that the dose calculation from CBCT images represents an interesting approach for adaptive radiotherapy to solve the problems related to anatomical variations occurring during the treatment.

Keywords: CT imaging, CBCT imaging, Hounsfield units, calibration curves, adaptive radiotherapy

Adaptive radiation therapy for head and neck cancer

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In this study, benefits and advantages of adaptive radiotherapy on patients with cancer in the head and neck location are presented. In this case, calculation dose is performed by using cone beam CT (CBCT) acquisitions of the imaging system. The goal of our contribution is a dosimetric monitoring for adaptation of treatment after an anatomical change in the patient which may occur during radiotherapy treatment.

HU (Hounsfield Units) -ED (electronic density) calibration curves for CT and CBCT imaging modalities have been determined. The dose distributions obtained respectively for CT and CBCT and for the target volume and organs at risk (OARs) coverage for 15 patients have been compared. The treatment plans and structures that were produced on CT were transferred to the four series of CBCT images of each patient using a rigid registration of the images.

Values of the average coverage of PTVs as well as the average doses received by the OARs (Brainstem, optic nerves and Chiasm ...) for the CT series and the CBCT imaging series were reported for the patients considered in this study. We noticed differences between the doses calculated from the CT and CBCT images. These differences in dose caused an overdose as well as an exceeding of the tolerance in some OARs if the treatment plan is not readjusted. This is partly due to the positioning of the patients on the treatment table, respiratory movements during the acquisition of CBCT images and mainly at the significant weight loss of the patients.

This study has shown that the dose calculation on CBCT acquisitions offers an interesting approach for adaptive radiotherapy and can be used in clinical routine to solve the problems of anatomical variations occurring during the treatment and this in the objective to optimize the treatment and protect organs at risk.

Keywords: adaptive radiotherapy, CBCT, Hounsfield unit, calibration curve

Dose distribution prediction of gamma using Random Forest Regression – retrospective study

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The aim of the study is to investigate and compare gamma index (γ) results predicted from the Random Forest Regression (RFR) over 2088 observations of actual plan calculation. In this paper, we have used the well-known library sickit-learn to developing application and evaluate the output data. For the Random Forest Regression, we have used four features and one label which are as follows: monitor units (MU), norm point (NP), planning target volume PTV cm^3, Dose per Fraction (DF) in Gy and Gamma. The observation results for the Gama were obtained using ArckCheck SunNuclear, with chosen criteria 3%, 1 mm for plans with SRS treatment schema and 2%, 2 mm for conventional plans. We have obtained 97% accuracy value of the RFR model. To verify the dependency of the prediction with the device, we have analyzed the predicted value between 2 centers.

The methodology described here would allow a prediction of Gamma result before verification was made. This could speed up planning process and will increase quality of the plans.

Keywords: machine learning, radiotherapy, treatment planning

Setting up a system for on-site dosimetry audits in radiotherapy departments in Bulgaria: structure and methodology

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External audits are the mechanism which provides confidence in the accurate delivery of radiotherapy. In Bulgaria 15 runs of TLD comparisons were done between 1999 and 1975, and most departments have also participated in audits organized by the IAEA, ESTRO or other international organizations. Within a Twining project in 2006/7 multiple audits were performed, however this initiative was discontinued and currently there is no definitive dosimetry audit organization in place.

This work is part of the IAEA technical cooperation project "Establishing a national dosimetry audit system and dosimetry quality audit programme in radiation therapy" and aims to outline the structure and methodology for dosimetry audit visits in radiotherapy departments in Bulgaria.

Dosimetry audits will be organized by the National Centre of Radiobiology and Radiation Protection, using their calibrated equipment (received as part of the project). An audit group of medical physicists from different radiotherapy departments will be created and each visit will be performed by at least two qualified members of the group, not employed by the audited institution.

The proposed audit covers basic aspects of the dosimetry and planning process for external beam radiotherapy with high energy photons. It consists of mechanical checks, absolute and relative dosimetry of megavoltage photon beams (part 1), and basic testing of the treatment planning system (TPS) (part 2). Mechanical

checks include collimator, couch and gantry rotation, lasers and optical distance indicator accuracy. The auditors perform beam calibration following the IAEA TRS 398 code of practice, and compare the results to the output measured by the local team. Beam quality factor $TPR_{20,10}$ will also be measured. Wedge factor will be measured if wedges are used clinically, otherwise if no issues are identified the audit continues with dosimetric verification of several fields created in the TPS: MLC-defined 3×3 cm^2, 4×4 cm^2, 6×6 cm^2 and 10×10 cm^2, and jaw-defined 6×15 cm^2 and 15×6 cm^2. All fields are prescribed and verified isocentrically (SSD=90 cm, depth=10 cm).

The tolerances for the tests (taken from national legislation) are as follows: mechanical parameters ±2 mm/±0.5°, beam calibration, wedge factor check and TPS dose verification ±2% (±3%).

The methodology is currently being finalized, and will soon proceed into testing stage.

Keywords: radiotherapy, radiation dosimetry, dosimetry audit, on-site dosimetry visits

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Folia Medica

Frieze of the healing family (Front Cover)

One of the most beautiful reliefs of the healing cults in the Greco-Roman pantheon is the unique "Frieze of the healing family" exhibited in the Archeology Museum in Plovdiv.
It was excavated in the foundations of an old ruined Turkish mosque in 1921. The correct identification of all figures was performed by Professor Zapryanov in 1964 - Department of Social Medicine. The frieze, according to him, used to adorn a Roman valetudinaria - a military hospital - off the walls of the east entrance of the ancient city which was called Trimontium by the Romans in the late III century. It weighs about 3000 kg and is 2.80 m long and 1.08 m high. The figures on it are framed in a wide rim; it bears the personified images of the Moon (on the left) and the Sun (on the right).*
Presented on the frieze are (from left to right): Jaso and Panacea - Asclepios' daughters, Telesphor - the fortunate genius of the healing process, Asclepios - the god of healing art, Hygeia - his daughter, Epione - Asclepios' wife, Machaon and Podaleirios - his sons worshipped as military physicians.
All figures, except Panacea, are entirely in full face which is very rare in a general composition picture. The frieze's sculptor depicted in great detail the figures' anatomic features, clothes and peculiar attributes. All deities in the composition are on a par with the only association seen between Panacea and Asclepios (Panacea touches a bundle of herbs next to Telesphor's cowl with her left hand, while pouring the cure all (panacea) in Asclepios' bowl).

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* Folia Medica 1964; 6(3): 152 - 156