

**Materials and Methods:** Two Lanthanum halide scintillation detectors – LaBr<sub>3</sub>:Ce and CeBr<sub>3</sub> were built and tested. The LaBr<sub>3</sub>:Ce detector has a cylindrical shape. The geometry is optimized for spectroscopy. This detector will be used as an etalon. The CeBr<sub>3</sub> detector consists of scintillator with rectangular parallelepiped shape. Many sources were used in this study, covering a range of 20 keV to 1.3 MeV. They were placed in front of the scintillator and the detector was left to count. Energy and efficiency calibrations were performed. Energy resolution as a function of full peak energy was studied.

**Results:** A very good energy resolution, 4.2% (FWHM) at 121.8 keV is achieved for the LaBr<sub>3</sub>:Ce scintillation detector. The energy resolution for the CeBr<sub>3</sub> detector is obtained to be smaller – 10.8% at the same energy. The thicker LaBr<sub>3</sub>:Ce detector has a larger efficiency than the CeBr<sub>3</sub> detector. Also, due to the geometry, the LaBr<sub>3</sub>:Ce detector has a better peak/background ratio  $R = 0.21$  when compared to the performance of the CeBr<sub>3</sub> detector  $R = 0.12$ .

**Conclusions:** Two scintillation detectors, capable of detecting X- and  $\gamma$ -ray energies, are now being tested in Sofia University within NDeGRA project, funded by the Bulgarian Science fund, contract number DN18/17. Exceptional energy resolution leads to various applications of these detectors mainly in  $\gamma$ -ray spectroscopy. Our very promising results also show that these LaBr<sub>3</sub>:Ce and CeBr<sub>3</sub> detectors can be used in the nuclear medicine, for imaging diagnostics such as PET.

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### Additional step into team approach and optimisation of paediatric patient care and treatment – From CT scan images to 3D models

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**Introduction:** Segmentation software allow to extract the structures of interest from 3D medical CT imaging data and generate anatomically accurate 3D models. We present how they could be used for optimisation of the routine practice for better representation of paediatric patient's congenital heart malformations (CHM) for pre-operative surgical planning. A team approach is applied between paediatric cardiologist, radiologist, medical physicist, paediatric cardiac surgeons and radiographer, for the development of optimized paediatric clinical protocol.

**Methods and materials:** An optimised CT angiography (CTA) protocol (80 kV, TCM, 0.828 pitch, 12.5 SD, 0.35 s, 3.3 mGy maxCTDI<sub>vol</sub>) was developed on 64-slice CT scanner (Toshiba, Aquilion). Anatomically accurate patient-specific 3D models of CHM were segmented from CTA image data for 10 paediatric patients. 4 patients with Double aortic arch; 1 – Tetralogy of Fallot; 2 – muscular VSDs (ventricular septal defects); 1 – aorto-pulmonary fenestration; 1 – Pulmonary atresia, ventricular septal defect and major aorto-pulmonary collateral arteries (PA, VSD, MAPCAs), 1 – double outlet right ventricle, multiple VSDs, D-malposition of the great arteries (DORV, multiple VSDs, D-MGA).

**Results:** The 3D models were compared with imaging studies, intraoperative findings and in two cases – PA, VSD, MAPCAs and DORV, multiple VSDs, D-MGA – with the post-mortem specimen. There is a clear overlap between primary imaging, segmented image, printed model and the intra-operative/post-mortem findings and dimensions. This indicates that 3D modelling is an accurate method for representing cardiac anatomy.

**Conclusions:** 3D segmentation imaging and 3D printing is a useful method which provides in-depth imaging of complex anatomical relations. 3D models are useful in the preoperative preparation and planning of operative strategy. The method is beneficial in cases

of complex or rare CHM where conventional imaging is difficult. The method is yet unreliable for assessment of valvular lesions. The implementation of this methodology in the clinical practice benefits form a multidisciplinary approach.

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### Evaluation of SSDE value of a single CBCT OBI patient verification system

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**Introduction:** The accurate positioning of patient is an essential part of modern radiotherapy. The aim of the study was to investigate and to evaluate the dose from different cone-beam computed tomography (CBCT) scan protocols using size-specific dose estimate (SSDE).

**Materials and methods:** The study was performed on an OBI 13.5, Varian Medical Systems. Four groups of 20 patients with different anatomy localization were selected. Each group was scanned by one or more of the routine protocols as follows; Pelvic - Pelvis Spot Light (PI) and Pelvis (PII), Lung - Low dose thorax (L-LDTh), Head & Neck - Standard Dose Head (H&N-SD) and Low Dose Thorax (H&N-LDTh), Brain - Low Dose Head (B-LDH), Standard Dose Head (B-SDH) and High Quality Head (B-HQH). Conversion factors were applied in order to calculate the patient's SSDE as a function of the sum of the lateral and AP dimensions, as well as the CTDI<sub>vol</sub> for the relevant scan protocol. The average SSDE values for each protocol and patient group were calculated.

**Results:** The analysis of the results showed deviations between 1.3% and 90% depending on the type of localization and protocols. Summary of the observed results for the SSDE values is as follows: PI – 91.1 mGy, PII – 97.2 mGy, L-LDTh – 20.7 mGy, H&N-SD – 33.3 mGy, H&N-LDTh – 33.7 mGy, B-LDH – 7.7 mGy, B-SDH – 15.4 mGy and B-HQH – 77.8 mGy.

**Conclusions:** Patient positioning verification is an important issue. However, the application of the CBCT systems lead to additional patient exposure. This puts the question for the balance of the frequency of their application and the optimization of radiation therapy process. Proper and optimized application is needed in order to reduce patient exposure.

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### Database dedicated to X-ray breast imaging

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Breast cancer computational models are a key instrument used in the development and optimization of new breast imaging techniques, new realistic test models for X-ray breast dosimetry, as well as reconstruction and image improvement algorithms. This requires the availability in one place of a large number of different breast cancer models and X-ray images from test objects. This work summarizes the types of lesions and X-ray images stored in the MAXIMA database (<http://maxima.tu-varna.bg/>). The database consists of data and images related to the breast. More specifically, it contains X-ray images from various scientific studies carried with physical phantoms with varying properties and shapes (including anthropomorphic) obtained from different facilities. These include synchrotron

facilities, research facilities with breast computed tomography (CT) and hospitals with different brands of CT and mammography machines. Furthermore, the database contains a number of anonymized X-ray patient images from tomosynthesis and mammograms, as well as whole body CT sets. Some of the images contain both benign and malignant formations, while others are lacking any kind of pathology. Besides the X-ray images the database also contains two types of breast computational lesion models. The first type is computational breast models, segmented from patient tomosynthesis images realized by using an in-house developed algorithm, while the second type of 3D models is created by applying mathematical algorithm based on a random walk approach. Currently, the database contains more than 70 images from breast tomosynthesis and 4 sets from whole body CT; 2 sets from scanned mastectomy cadavers, 50 segmented tumor models and 100 models generated by a mathematical algorithm. In addition, the database contains more than 50 different entries, which correspond to physical breast phantoms and step manufactured wedges. The developed database provides opportunities to researchers to study and work on improving techniques for early cancer detection.

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**In-house optical system for X-ray imaging validation of processes**  
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Phase-contrast imaging is an imaging technique, which has been investigated a lot during the last 20 years. Its main advantage over the traditional X-ray imaging is the enhancement of the contours of the tissues, thus providing higher contrast between tissues. Three main geometrical acquisition setups are used to achieve this enhancement: (i) free propagation setup with no additional optics added to the system, (ii) grating based-imaging setup, which uses gratings, and (iii) diffraction-based setup, which implements crystals to detect the X-rays deflected at a specific angle. In most cases, these require the use of highly coherent light and thus availability at any time of synchrotron facilities. To advance in this field, the LCSM team has built up a custom optical setup to generate phase contrast data in the optical range.

The experimental setup is composed of red light laser (635 nm, 4.5 mW), spatial filtering system, Digital Light Processor (DLP) for object development and a high resolution CMOS camera. The DLP integrated circuit is the DLP3010 of Texas Instruments with more than one million  $2\ \mu\text{m}$  in size mirrors. The digital image sensor has a size of  $5.70\ \text{mm} \times 4.28\ \text{mm}$  and  $2592 \times 1944$  active pixels used to form the image in real time. The current image sending data protocol is based on serial communication. Two software applications were developed under C++ to support the prototype device for: (a) image acquisition, and (b) forming the phase object to be irradiated.

The setup was tested successfully to produce diffraction images of the following objects: a non-transparent five pointed star, a transparent Swiss cross, various gratings, as well as breast lesions. It was proven that the prototype system can produce the famous Arago-Poisson spot behind a non-transparent circle. Excellent results were obtained by reproducing the Young's experiment. The same objects were used with simulation of the chain and then compared to the

results produced in x-ray imaging by means of simulations. The developed prototype will be used for validation studies in x-ray phase contrast imaging.

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### Evaluation of effective and peak skin dose of patients undergoing interventional cardiology procedures

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**Introduction:** Interventional cardiology procedures result in substantial patient radiation dose due to prolonged fluoroscopy time and radiographic exposure. These procedures not only lead to significant effective doses for the patient but also can potentially cause deterministic effects on the patient's skin. The aim of this study is to investigate the effective dose and peak skin dose (PSD) of patients during frequently performed cardiology procedures as: coronary angiography (CA) and combined – coronary angiography and percutaneous intervention (CA + PCI) and to evaluate if there is a chance of getting a skin injuries.

**Materials and methods:** The study was conducted in Military Medical Academy, Sofia on an angiography X-ray system. For each procedure and patient the following data were collected: age, sex, height and weight of the patient, air kerma-area product- $P_{KA}$ , fluoroscopy time-FT, cumulative dose-CD, number of series acquired, as well as some more clinical patient data. The effective dose was calculated by using conversion factors proposed in the literature, using NRPB and Bozkurt coefficients.

**Results:** The study was conducted with a total of 40 patients – 18 for CA and 22 for CA + PCI procedures. The mean values for  $P_{KA}$  and FT were respectively:  $55.6\ \text{Gycm}^2$  and 2.9 min. during CA and  $136.2\ \text{Gycm}^2$  and 7.4 min. during CA + PCI procedures. The calculated mean values for the effective dose were: 10.0 mSv (NRPB) and 6.1 mSv (Bozkurt) for CA and respectively 27.2 mSv (NRPB) and 17.7 mSv (Bozkurt) for CA + PCI procedures. PSD of the patients varied between 0.3–0.8 (mean value-0.5) Gy for CA and 0.4–1.7 (mean value-1.0) Gy for CA + PCI procedures.

**Conclusions:** The estimated effective dose of patients in both the procedures showed that there is a minimal risk of occurrence of stochastic effects. After the current study it was concluded that there are no patients with PSD larger than the trigger level set (3 Gy). A more extensive estimation of the patients dose is going to be done in order to evaluate if there is an additional risk of getting a skin injury.

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### A software application for grating design dedicated to optical imaging: Preliminary results

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**Introduction:** Grating-based phase contrast mammography imaging reveals great potential in screening and diagnosing the breast cancer. To optimize an imaging setup, a detailed modelling of the