ABSTRACTS OF RECENT Ph.D. THESES PERTINENT TO MEDICAL PHYSICS

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A computer-aided diagnostic scheme for classification of clustered microcalcifications in mammograms

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The hypothesis of this dissertation is that computer-aided diagnosis (CAD) can improve radiologists' diagnostic performance in breast cancer diagnosis. An automated computerized classification scheme was developed to differentiate malignant from benign clustered microcalcifications. This computer scheme used an artificial neural network (ANN) to analyze eight computer-extracted image features based on number, size, uniformity, and shape of individual microcalcifications, and on size and shape of a cluster. The features correlated qualitatively with radiologists' perceptual experience. The performance of this computer scheme was evaluated on two independent databases of standard-view mammograms digitized at 0.1-mm pixel size: database A contained mammograms from 53 patients with biopsies and database B contained mammograms from 104 patients in a consecutive biopsy series. The computer scheme performed better than radiologists on both databases ($p=0.03$ and $p<0.0001$, respectively). An observer performance study was conducted using database B. Ten radiologists read the original standard- and magnification-view mammograms with and without the aid of our computer scheme. The performance of the radiologists improved significantly ($p<0.0001$) when the computer aid was used: on average, each radiologist recommended 6.4 more biopsies for malignant tumors ($p=0.0006$) and 6.0 fewer biopsies for benign lesions ($p=0.003$). We concluded that our computer scheme classifies malignant and benign clustered microcalcifications more accurately than radiologists, and that it can be used to reduce the number of biopsies for benign lesions while maintaining or improving sensitivity for breast cancer diagnosis.

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The design and evaluation of interstitial ultrasound applicators for controlled thermal treatment of localized tumors

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This dissertation investigates the design and development of interstitial ultrasound applicators to provide localized and controlled heating of tissue for potential clinical implementation as an alternative thermal treatment of cancerous and benign diseases. Implantable ultrasound applicators were designed and fabricated using cylindrical piezoceramic transducers (1.5–2.5 mm o.d., frequency =6.5–7.5 MHz) in a direct-coupled configuration. Transducers were longitudinally sectioned to produce specific angular sectors of acoustic output (90°–360°). Applicators were also constructed using multiple transducer elements (3) with individual power control. An internal cooling mechanism (air or water) was implemented to remove excessive thermal energy from the inner transducer surface (h=700–4200 W/m^{2}K). Measurements of the relative acoustic intensity were used to characterize the efficiency, quality, and directivity of the ultrasound beam output. Thermal performance was experimentally evaluated through multiple heating trials *in vivo* (canine prostate, porcine liver, and thigh muscle), *in vitro* (porcine liver, muscle, and kidney), and in tissue-mimicking phantom for both hyperthermia and coagulative thermal therapy. Theoretical capabilities of these applicators were evaluated using biothermal computer simulations to model the acoustic output and resultant heating in tissue. In general, results demonstrated excellent thermal performance and control of heating in tissue. Directed and collimated thermal coagulation was produced in both the angular and axial expanse, and found to correspond to the active acoustic sector of the transducer. The use of multiple transducer elements provided active control of axial heating in the tissue. Increased levels of applied power (12–48 W) with transducer cooling substantially improved radial depths of coagulation (8–22 mm) and decreased sonication times (0.5–5 min). This ability to control and direct heating shows great potential for the treatment of localized tumors in sites such as the prostate, brain, liver, and breast, without damaging the surrounding healthy tissue.

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Image quality degradation by light scattering processes in high performance display devices for medical imaging

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This thesis addresses the characterization of light scattering processes that degrade image quality in high performance electronic display devices for radiography. Using novel experimental and computational tools, we study the lateral diffusion of light in emissive displays that causes extensive veiling glare and significant reduction of the contrast. In addition, we examine the deleterious effects of ambient light reflections that affect the contrast of low luminance regions, and superimpose unwanted structured signal. To model veiling glare and display reflections, we use a Monte Carlo light transport simulation code, DETECT-II, that tracks individual photons through multiple scattering events. The simulation accounts for the photon polarization state, and provides descriptions for rough surfaces and thin film coatings. A new experimental method to measure veiling glare is described based on a conic collimated probe that minimizes unwanted contributions from bright areas. We show that veiling glare ratios in the order of a few hundreds can be measured with an uncertainty of a few percent. For a high performance medical imaging monitor with anti-reflective coating, the veiling glare ratio for a 1 cm diameter dark spot was measured to be 240. Finally, we introduce experimental techniques for measurements of display reflectance, and we compare measured reflection coefficients with Monte Carlo estimates. In spite of having comparable reflection coefficients, the low maximum luminance of current cathode-ray tube devices worsens the effect of ambient light reflections when compared to radiographic film. Flat panel technologies can perform even better than film due to a thin faceplate, increased light absorption, and high brightness.

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Predicted radiation dose and risk associated with pediatric diagnostic x-ray procedures

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Risks from exposure to radiation are assessed by calculating individual tissue absorbed doses and subsequently determining the effective dose. The absorbed dose to specific tissues has traditionally been difficult and time consuming to measure. This research describes a new methodology that permits rapid measurement of the effective dose and associated risks to pediatric patients for a variety of plain film diagnostic examinations. The methodology utilizes an anthropomorphic phantom of a one-year-old, incorporating direct reading MOSFET dosimetry that allows the rapid determination of absorbed dose to individual organs. The research integrated clinical examinations, dosimetry measurements, and BEIR V risk assessments for pediatric patients undergoing clinical radiology exams. Site surveys were performed at ten facilities using standardized exams to characterize variations in effective dose related to clinical practice and detailed quantitative studies for a variety of examinations were performed at Shands at UF. The effective dose for these procedures ranged from 0.1 mrem for an AP skull exam that utilized thyroid shielding, to 9.2 mrem for an AP upright abdomen exam. The relative leukemia carcinogenic risk ranged from 1.000 041 for the skull exam, to 1.002 732 for the abdomen exam, with corresponding excess risks from 10^6 exams of 0.005 and 0.3 leukemias per year, respectively. These individual examinations provided a significant benefit to the patient with minimal risk. This dissertation provided the basis for continuing research to quantify long-term risks, as well as providing a clinical tool to evaluate the effective dose delivered to pediatric patients from current and emerging radiology imaging modalities.

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Dose perturbations produced by thermoluminescent dosimeters and ionization chambers in high energy photon beams (in French)

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The thesis studied perturbation by thermoluminescent dosimeters (TLDs) and ionization chambers of the absorbed dose measured in a medium irradiated with photon beams from ^{60}Co γ-rays to 25-MV x-rays. The perturbations were evaluated using experimental and theoretical techniques involving analytical calculations and the Monte Carlo (MC) method (EGS4-PRESTA I). The MC results agree with experimental data better than within 0.4%, with specific uncertainties (1 s.d.) less than 0.1% for MC and 0.3% for experimental values. We used Burlin's general cavity theory and MC to determine the influence of TLD detector material, its form, size, density, and dopant concentration in the energy correction factors. The size and density influence the energy correction factors about 2%. The dopant concentration does not have a significant effect. For the specific use of TLDs in radiotherapy postal quality checks by the Gustave–Roussy Institute, we investigated the influence on absorbed dose of the TLD holder (0.5% to 2%), the thermal conditioning of the TLD (1%), and heterogeneities around the dosimeters (2%). Uncertainties in the absorbed dose determination in water with TLD were evaluated to be about 1.7% for the ^{60}Co and 2% for the x-rays. In ionization chambers, correction factors were determined for the walls, waterproofing caps, and the central electrode from Exradin, Nuclear Enterprise, and Wellhöfer chambers. Global perturbation correction factors were evaluated for primary (BIPM) and secondary (IRD) standard ionization chambers. This determination validated the MC method for the calculation of global perturbation correction factors for the determination of the absorbed dose to water.

[A copy of this thesis in French is available from Institut Gustave–Roussy, Service de Physique, 39 rue Camille Desmoulins, 94805 Villejuif, France, FAX: 33 1 42 11 52 99 or e-mail: equal@igr.fr]