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VOL. XVII, N. 4, 2001, October-December

Commentary/Review Paper

The future of photon external-beam radiotherapy: the dream and the reality

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Manuscript received: April 20, 2001; revised July 17, 2001

Accepted for publication: October 4, 2001

Abstract

This paper is a Commentary on the future of the science of radiotherapy with specific respect to its technical basis. The Commentary is rooted as far as possible from an appreciation of the current frontiers of the subject, and the work at both this Centre and worldwide together with due note of some lessons from history.

KEYWORDS: Physics of radiotherapy, radiotherapy, future predictions.

In vivo dosimetry in pelvis treatments: an *a priori* evaluation compared to clinical data

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Manuscript received: February 12, 2001; revised April 27, June 29 and August 29, 2001

Accepted for publication: September 4, 2001

Abstract

The aim of this study is to develop a method based on in vivo measurements to assure set up and dosimetry accuracy in external beam radiotherapy. This method introduces specific action levels and transfers them to clinical treatments, considering all patient variables. Moreover, *in vivo* dosimetric data (entrance and exit doses) were compared to dose values reconstructed by a radiotherapy treatment planning system (RTPS) for about 180 patients. Entrance and exit measurements were performed with Scanditronix EDP20 semiconductor detectors during pelvis treatments, adopting a box technique for supine patient and a posterior-anterior (PA) conformal field combined with two opposite lateral wedged conformal fields for prone patient. Complex correction factors (derived from measurements in homogeneous phantom) are needed to account for specific treatment conditions, such as short SSD's (less than 85 cm) or beam angles differing from 90°, when a wedge and/or a tray is interposed to the beam. Entrance dose clinical data shows a mean deviation of 0.04% and a relative standard deviation of 2.9%, while exit dose mean deviation is -1.6%, with a 3.8% standard deviation, showing a good agreement between RTPS previsions and *in vivo* dosimetry. On the basis of these results, the method provides a reliable tool to asses the actual accuracy of treatment delivery.

KEYWORDS: Radiotherapy, *in vivo* dosimetry, diodes, pelvis treatments.

Technical Note

Pulsed Laser Deposition of Hydroxyapatite Films by KrF Excimer

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Manuscript received: January 8, 2001; revised: April 30, 2001

Accepted for publication: July 24, 2001

Abstract

Hydroxyapatite (HA) is an excellent biocompatible ceramic useful to improve the bone adhesion and the osteo-conductivity of medical devices, such as hip and knee prostheses, dental implants, artificial eardrum hammer and bone screws.

The bioceramics can be deposited as a thin films using the Pulsed Laser Deposition (PLD) technique.
A KrF laser, 248 nm wavelength, 20 ns pulse width, 15 hertz pulse rate, 100-500 mJ pulse energy, 1-20 mm^2 diameter spot, was employed to irradiate in vacuum HA targets.

Ablated material was deposited on the surface of a near substrate (silicon or titanium) at temperature of 500 °C. Deposited films were characterized by Raman and FTIR spectroscopy, SEM, XRF and XRD analysis. Results indicate high erosion yields in the target with clusters emission. Deposited films are granular with 1.5 mm average grain size.

A comparison of results obtained with PLD deposition using different laser wavelengths is presented and discussed.

KEYWORDS: Hydroxyapatite, pulsed laser deposition, biomaterials.

Technical Note

Computer Simulation of the Optic Properties of the Human Eye

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Manuscript received: February 18, 2001; revised June 9 and September 21, 2001

Accepted for publication: September 25, 2001

Abstract

It is proposed a computational model that simulates with good approximation the optic properties of the human eye and accounts for the reduction of the aberrations effects. This model is based on the physiological parameters characterising the eye and approximates the variation of the crystalline index of refraction with a function compatible with experimental evidence.

The model traces the various refractions of the rays constituting a light beam emitted by a point source. A detailed analysis of the path of the last refracted ray, incident on retina, is carried out. Deviations from perfect focusing are discussed in terms of: source position, angle of incidence, accommodation of the crystalline, variation of the lens refractive index. The results are compatible with the experimental values measured by various authors under different conditions.

KEYWORDS: Eye, crystalline refractive index, aberrations, focusing.

Conference Paper

Correlation of Structure and Function with Dual Modality Imaging*

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Manuscript received: April 30, 2001; revised: September 21, 2001

Accepted for publication: September 25, 2001

Abstract

Radionuclide imaging is used clinically to assess the metabolic and physiologic status of patients with disease. However, radionuclide images lack anatomical information and suffer from qualitative and quantitative errors due to photon attenuation, scattered radiation, and limited spatial resolution. Dual-modality imaging systems acquire both anatomical data (e.g., with CT) and functional data (e.g., with SPECT) in a consistent geometry and during a single imaging session. This allows the functional and anatomical images to be coregistered, to improve localization of the physiological data and to differentiate normal from abnormal radiopharmaceutical uptake. In addition, *a priori* anatomical information from CT can be used to compensate the radionuclide image for errors due to photon attenuation, scattered radiation, and spatial resolution limitations. These techniques are applicable to both oncological imaging and myocardial perfusion assessments. Overall, dual-modality imaging has the potential to improve both the quality and the quantitative accuracy of radionuclide imaging.

KEYWORDS: Dual-modality imaging, attenuation correction, image fusion.

Conference Paper

Combined CT-SPECT tomography system for breast cancer study*

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Manuscript received: May 14, 2001; revised: July 5, 2001

Accepted for publication: July 9, 2001

Abstract

We have developed a dedicated breast imager, which makes use of a pendulum geometry of the breast and of a combined imaging modality, namely CT and SPECT co-registration. The CT scanner is composed by a quasi-monochromatic source which produces a 28 keV-fan beam and a linear digital detection system. X-ray source and digital detector are assembled on a toroidal tomograph gantry with about 13 cm of circular field of view. The gantry also contains the SPECT acquisition system, composed by a detector made of CsI scintillating crystal matrices coupled to Hamamatsu position sensitive photomultipliers and lead collimators. The toroid rotates under computer control so as to acquire separated slices over an angle of 180 deg. Each X-ray and SPECT image is acquired and reconstructed by using a specifically developed software, that also allows the fusion of the morphological with the functional information. In this paper a description of the prototype and the preliminary results are presented. Images of various test phantoms have been acquired with both modalities and first images with the fusion technique are presented.

KEYWORDS: CT, quesi-monochromatic beams, Bragg diffraction, SPECT, image fusion.

Conference Paper

Integrating PET and CT: an Obvious Choice for Integrating Two Imaging Modalities*

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Manuscript received: May 11, 2001; revised: June 21, 2001
Accepted for publication: June 28, 2001

Abstract

FDG-PET is an excellent tool for the staging of tumors and the monitoring of therapy response. Integration of PET with a CT scanner into one system has the advantage to provide inherently matched images of both modalities in one study. The anatomical information in the CT images are likely to improve both lesion localization and characterization. The CT images can additionally be employed to correct for attenuation in the PET images. The attenuation correction data obtained is virtually noise-free, and the total acquisition time is reduced by 30%. As a consequence patient throughput is increased and may make the system cost-effective despite the expensive hardware.

KEYWORDS: Combined PET-CT, PET tumor staging, cost-effectiveness, image fusion.

Conference Paper

Integrated visualization of functional and anatomical brain images*

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Manuscript received: April 30, 2001; revised September 24, 2001
Accepted for publication: October 2, 2001

Abstract

The mental translation and integration of multimodal medical image data into a 3-D representation of the patient is a very difficult task. Integrated visualization of medical images aims to assist the clinician in this task by efficiently presenting information from different sources, usually combining functional with anatomical data. The present paper describes the research we performed over the past decade in the area of integrated visualization of functional and anatomical brain images.

A brief survey of integrated 2-D and 3-D medical image display techniques is presented. Special attention is paid to Normal Fusion, a surface mapping 3-D visualization technique combined with hue-saturation-value color encoding that has typically been applied for functio-anatomical brain visualization.

The key issue for clinical acceptance of novel visualization techniques is whether they can improve diagnosis and/ or facilitate the information transfer to the referring specialist. To investigate these issues, several evaluation studies have been performed over recent years. Extensive evaluation of SPECT/MRI brain images showed that integrated visualization provides an increased performance of localizing physiological abnormalities, while enhancing the confidence of the observers in their localizations. Studies in a clinical setting showed that integrated visualization improves the pre-surgical evaluation of patients with epilepsy and may be of considerable assistance in the understanding and interpretation of complicated processes as, e.g., seizure related cortical blood flow changes, which require a highly efficient presentation of enormous amounts of multimodal image data. We conclude that methods for integrated visualization of functional and anatomical brain images can be powerful tools to assist the clinician in the retrieval of relevant information from multimodal medical image data.

KEYWORDS: Integrated visualization, image fusion, multimodality display, brain imaging.

Conference Paper

2-dimensional fusion of cerebral cross-modality images employing a mutual information algorithm*

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Manuscript received: April 27, 2001; revised July 17, 2001

Accepted for publication: July 24, 2001

Abstract

Diagnosis and treatment monitoring of neurological diseases require a variety of different functional and anatomical neuroimaging procedures. However, each of these favour or lack specific bio-physical information e.g., on the cerebral parenchyma, and neurologic disease requiring complex interpretation by the physician. Image fusion may be a suitable solution to gather different information of the brain in one image and, thus, enable a more accurate diagnosis.

In this pilot study, 2-dimensional (2D) cranial computed tomography (CCT), magnetic resonance tomography (MRT) and three-dimensional (3D) transcranial color-coded sonography (TCCS) data sets were registered and fused with the ANALYZE-AVW software (Biomedical Imaging Resource, Mayo Foundation, Rochester, USA). A procedure was developed allowing rapid overlay of the images. First, identical anatomic structures in each data set were identified and segmented before a mutual information algorithm was used to create a transformation matrix. With the knowledge of this matrix one of the different modalities could be registered to the other modality. In a final step, fusion of the two image modalities was performed. 2D image registration and fusing of CCT / MRT with TCCS was achieved in a short time resulting in images presenting multiple pathological features of various neurologic diseases. Additional information on brain structures as well as flow data in cerebral vessels as detected by ultrasound were overlaid to CCT and MRT images with high accuracy. Image fusion may be a potential solution to enhance modern neuroimaging tools. Further studies have to be pursued focusing on the following questions: the stability and accuracy of the mutual information algorithm for fusion of 3D data sets, and the optimal intensity and color map for each image data set.

KEYWORDS: Multimodality, mutual information, neuroimaging, ultrasound.

Conference Paper

Clinical Implementation of the World's First Primatom, a Combination of CT Scanner and Linear Accelerator, for Precise Tumor Targeting and Treatment*

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Manuscript received: June 16, 2001; revised October 8, 2001

Accepted for publication: October 10, 2001

Abstract

A novel image guided radiation treatment technique by a CT-on-rail coupled with a linear accelerator (Primatom, Figure 1) was developed. The system is designed so that daily tumor target localization can be performed prior to each radiation treatment, and thus, reducing the extrinsic and intrinsic uncertainties that are associated with patient set up and organ motion respectively.
The Primatom consists of a linear accelerator (PRImus) and a CT scanner (SOMATOM) that is movable on a pair of horizontal rails. Because the linear accelerator and the CT were installed in different times, the accuracy and effectiveness of each components (linear accelerator and CT) have to be checked and measured when they function together as a unit. To achieve this task, a Rando phantom study was performed prior to clinical implentation. Thirteen patients with biopsy proven prostate cancers were treated with the Primatom using 3D conformal radiation treatment. The clinical stages of these patients range from T1c to T3, with a Gleason range of 6-8, and a PSA range of 4.1-239. These patients are scanned by the CT which is movable on a pair of horizontal rails. During the scanning, there is no movement of the couch. The exact location of the prostate, seminal vesicles, and rectum can be identified and localized. These positions are then compared to the planned position. The daily movement of the prostate and rectum are corrected for, and a new isocenter derived. The patient is then treated immediately with the new isocenter.

Rando phantom study showed that the Primatom is accurate and effective, with a positional acccuracy reproduced to within 2 mm. Of the 13 patients treated, a total of 63 consecutive daily CT scans were performed on the last part of the treatment. 32% of the treatment sessions required no new isocenter adjustment. 68% (43/63) required a shift of isocenter $\geqslant$3 mm in the APPA(anteroposterior and posteroanterior) direction. Among those adjustments, 17% (11/63) required a shift of >10 mm. The additional time for acquiring the CT scan, calculating and adjusting the shift of isocenter is about 20 minutes daily.

By performing daily verification using CT scanning with the Primatom, target movement due to external set up variabilities/ error, or due to intrinic internal organ movements can be minimized. This technique has significant implications for the radiation treatment of cancers, especially in terms of dose escalations, minimizing toxicities, and most importantly, maximizing the dose delivered to the tumor.

KEYWORDS: Image-Guided Radiation Therapy, Prostate Cancer, Radiation therapy, organ motion.