Sam Session - Joint Symposium
Room: Ballroom 1
Imaging and Radiotherapy for SBRT Liver & Lung

SA-A-Ballroom 1-01
SBRT for Non-Small Cell Lung Cancer
K Kowalchik, Mayo Clinic, Jacksonville, Fl.

The field of radiation oncology is constantly evolving with continuous technological advances.

One of these advances is stereotactic body radiation therapy (SBRT). This is the delivery of high dose radiation, outside of the cranium, delivered in a single or multiple fractions. This is performed using appropriate equipment with multiple narrow beams delivered through noncoplanar isocentric arcs. SBRT has been applied to multiple sites including tumors of the spine, lung, liver, pancreas and prostate.

This lecture will focus on SBRT treatment of the lung. We will review the clinical background and imaging of lung cancer patients and review the rationale for treating lung cancer with SBRT. We will review the techniques and finally, the ongoing research on SBRT to the lung.

Educational objectives include a review of the following:

1. Epidemiology of lung cancer
2. Workup of lung cancer
3. Staging of lung cancer
4. Screening for lung cancer
5. Imaging review
6. Treatment options for early stage lung cancers
7. SBRT lung publications
8. SBRT technique
9. SBRT toxicity
10. SBRT ongoing trials

SA-A-Ballroom 1-02
Imaging and Radiotherapy for SBRT Liver
Stereotactic Body Radiotherapy (SBRT) for Liver Metastases

Stereotactic body radiation therapy (SBRT) is a highly sophisticated delivery of radiation therapy to an extracranial lesion in 5 or fewer high dose treatments. Modeled after intracranial stereotactic radiosurgery (SRS), treatment of brain metastases with a single high dose fraction, SBRT allows for potent ablative doses to be delivered to extracranial lesions with acceptable toxicity in appropriately selected patients. The application of SBRT is currently under study in multiple sites including tumors of the spine, lung, pancreas, prostate, and liver.

The liver is a common site for metastatic disease from a wide variety of malignancies. Management is dependent on the location and extent of both intrahepatic and extrahepatic disease. In select patients with limited liver involvement SBRT is an efficacious and well tolerated treatment.

This lecture will focus on SBRT treatment of cancers in the liver. We will review the clinical background of cancers involving the liver that are amenable to SBRT treatment. We will review the technologic advancements, the treatment techniques, and the ongoing investigations of SBRT to the liver.

Educational objectives:
1. To understand the definition and technical aspects of SBRT
2. To understand the rationale, indications, and logistics of SBRT for the liver
3. To review the clinical outcomes of SBRT of the liver, including efficacy and toxicity
4. To discuss the Mayo Clinic Jacksonville experience with utilizing SBRT for the liver

Mammography Symposium
Room: Ampitheater
ACR Accreditation and QC of Digital Mammography Equipment

SA-C-Ampitheater-01
MQSA Regulations and ACR Mammography Accreditation Update
P Butler*, American College of Radiology, Reston, VA

The ACR Mammography Accreditation Program has been in existence since 1987. The Mammography Quality Standards Act was signed by the President in 1993 and required that any facility performing x-ray imaging of the breast (for screening and/or diagnostic purposes) be accredited and certified by 1994. The FDA published interim regulations in 1994 and final regulations in 1997. As of January 1, 2011, 19,000 mammography units at 8000 facilities are accredited and certified. Although the vast majority of facilities are conscientiously meeting the MQSA requirements, some poor quality facilities have required investigation by both the ACR and the FDA and some, fines and criminal penalties. In spite of these anomalies, mammography has significantly improved in the United States, mainly due to these accreditation standards and regulations. Full-field digital mammography (FFDM) is introducing new challenges to maintaining this hard-won quality improvement. In 2010, the FDA revised its clearance criteria for new FFDM units to allow for applications under the 510k process (rather than the more strict PMA process). This is resulting in a larger volume and variety of new FFDM units reaching the market in a shorter timeframe. The ACR is developing a universal FFDM quality control manual for FFDM to make the QC process across the different vendors more uniform. The purpose of this presentation is to provide updates on the ACR Mammography Accreditation Program and the FDA regulations.

Goals:
1. Learn about MQSA history.
2. Understand the impact of FFDM on mammography in the US.

SA-C-Ampitheater-02
ACR Mammography QC in the Digital Era
D Pfeiffer[1] *, (1) Blackthorn Medical Physics, Westminster, CO

Due to advances in technology, the regulation and testing of digital mammography systems has become complicated. Not only does each mammographic x-ray unit model have its own test protocol, peripheral equipment must also be tested according to manufacturer specifications. This plethora of testing methodologies and requirements can cause much confusion for facilities and physicists. To ameliorate the situation, the American College of Radiology has established a committee to specify a set of tests applicable to all digital mammography systems that can be used uniformly to satisfy quality control and regulatory requirements. A new mammography phantom is also being designed. This talk will present the current thinking of the committee regarding tests to be included in and excluded from the specification. Design elements of a prototype phantom will be presented.

Therapy Symposium
Room: Ballroom 1
The Use of In-room kV Imaging for IGRT

SA-C-Ballroom 1-01
The Use of In-Room KV Imaging for IGRT
J Wong[1], D Jaffray[2], F Yin[3], (1) Department of Radiation Oncology and Molecular Radiation Sciences, Johns Hopkins University, School of Medicine, Baltimore, MD, (2) Departments of Radiation Oncology and Medical Biophysics, Princess Margaret Hospital, Toronto, ON, (3) Department of Radiation Oncology, Duke University Medical Center, Durham, NC

Over a short period of less than a decade, the use of in-room kilovoltage (kV) x-ray imaging for target localization and treatment intervention is becoming common practice in the community. Several distinct systems are commercially available which include rail-track-mounted systems,

ceiling/floor-mounted systems and gantry-mounted systems. These systems are developed with different focuses of applications, ranging from the provision of tomographic images for soft tissue guidance to radiographic projection images for intra-fraction verification. These systems have different limitations pertaining to image quality, imaging dose and the validity of the information. The systems also have different levels of operational complexity. The presentation will provide an overview of the challenges of treatment verification, the application principles and performance of the various in-room systems. Requirements for effective utilization of these systems in terms of implementation, quality assurance and clinical applications will be presented.

Educational objectives:
1. Understand the challenges for treatment verification
2. Understand the configurations and operation principles of different in room kV x-ray imaging systems
3. Understand the requirements for effective implementation and quality assurance for IGRT
4. Understand the clinical applications and the associated limitations

Therapy Symposium
Room: Ballroom 1
IGRT X-ray Imaging Dose to Therapy Patients

SA-D-Ballroom 1-01
A Perspective View of X-Ray Imaging Doses to Radiotherapy Patients for IGRT
G Ding*, Vanderbilt University, Nashville, TN

X-ray imaging devices, especially kilovoltage x-ray imaging devices integrated to a radiation treatment unit, are increasingly available for image guided radiation therapy (IGRT). The conventional portal imaging setup fields using megavoltage are still available and being used as well.

This lecture will provide an overview and examples of the additional radiation exposure to radiosensitive organs of patient resulting from image-guided procedures, especially for widely used kV cone beam CT (kV-CBCT) acquisitions.

The lecture presents a perspective view of kV x-ray imaging dose to radiotherapy patients in comparison to conventional techniques using MV portal imaging devices (EPID) for patient positioning.

The talk also discusses pro and cons of image modalities and techniques used in the image guidance concerning the imaging dose to patients.

Learning Objectives:
1. Gaining knowledge on the amount of radiation exposure to radiosensitive organs of a patient resulting from different image guidance procedures
2. Obtaining a perspective view on the magnitude of the imaging dose from different image guidance procedures related to the therapeutic dose.
3. Learning the techniques to reduce the imaging dose in clinical applications including kV x-ray and MV x-ray imaging.

Sam Session - Mammography Symposium
Room: Ampitheater
Stereotactic Breast Biopsy and Breast Specimen Radiography

SA-D-Ampitheater-01
Mammography Track - Stereotactic Breast Biopsy - Physics Evaluations
M Martin*, Therapy Physics, Inc., Gardena, CA

The performance of the eleven required physics tests on a Stereotactic Breast Biopsy (SBB) System as required for accreditation by the American College of Radiology (ACR) will be covered in this presentation covering systems both with and without Automatic Exposure Control Systems. Expected values for Half-Value-Layer (HVL) and patient doses for each matrix size available on SBB systems will be discussed. Clnical advantages/disadvantages of both major systems will be covered relative to approach methods and areas available for sampling. The importance of testing the location of the biopsy needle or tissue sampling device for reproducibility and accuracy will be discussed relative to various phantoms that may be used to verify this location accuracy. Quality Control (QC) tests to be performed by the mammography technologist will be covered in addition to the physics required tests. Requirements for training and education of the staff (physician, physicist, and technologist) required to achieve accreditation by the ACR will be reviewed now that there is a requirement for SBB units to be accredited for breast imaging centers to obtain the ACR designation of a Breast Imaging Center of Excellence.

Educational Objectives:
1. Attendees will be aware of the required physics tests to be performed annually and for acceptance of Stereotactic Breast Biopsy (SBB) System.
2. Attendees will be aware of the expected values of Half-Value Layer and patient doses for SBB systems for common matrix sizes available on these units.
3. Attendees will be aware of the requirements for personnel performing SBB exams or physics evaluations in both Continuing Education and Continuing Experience for accreditation by the American College of Radiology.
4. Attendees will be aware of the required Quality Control Tests to be performed by both the technologist and physicist on SBB units.

SA-D-Ampitheater-02
Specification and Quality Control Testing of Specimen X-Ray Systems for Breast Specimens
W Geiser*, UT MD Anderson Cancer Center, Houston, TX

At M D Anderson cancer center specimen radiography for breast specimens is considered to be one of the best ways to ensure good outcomes for patients undergoing segmental mastectomy, total mastectomy and stereotactic breast biopsy. Without proper imaging and review of breast specimens we believe that our re-excision rate would be about double what it is today.

At MD Anderson Cancer Center breast specimen radiography is performed while the patient is in the operating room under anesthesia. The specimen is imaged, a radiologist reads the images and reports directly back to the pathologist while the patient is on the table. If necessary the pathologist will recommend that the surgeon take more tissue if it is deemed necessary. Specification and testing of specimen radiographic equipment is deemed necessary to ensure that the images taken are of high quality and meet the needs of the pathology lab and the radiologists viewing the images.

This lecture is designed to give the medical physicist the information necessary to choose proper equipment for breast specimen radiography, and to perform acceptance testing as well as annual evaluations of specimen radiographic systems.

Educational Objectives:
1. Understand the need for good specimen radiographic systems.
2. Understand set up of the specimen radiography system for use in the OR.
3. Be able to set up a comprehensive QC program for testing of specimen radiography systems for breast specimen radiography.

Therapy Symposium
Room: Ballroom 1
SBRT: The University of Kentucky Experience

SA-F-Ballroom 1-01
SBRT at the University of Kentucky
U Langner*, J Gorman , R McGarry, University of Kentucky, Lexington, KY

The goal of stereotactic body radiotherapy (SBRT) is to deliver highly conformal larger biologically equivalent doses to tumors, while minimizing toxicity to normal structures. This goal is more easily achievable in parallel structures, e.g. lung and liver, by going to extreme measures to limit the volume of normal tissue exposed to a threshold dose. This high degree of conformality and sharp dose gradient necessary for SBRT are achieved through hypofractionated treatments, small margins, and a large number of non-coplanar beams.

SBRT has become a prominent treatment option for patients with inoperable Stage I non-small cell lung cancer and has shown high rates of local control. SBRT can also be used as a boost for post chemoradiation regiments if residual disease is present for stage II/III lung tumors. Because of the high conformality and sharp dose gradients achieved with SBRT, it is also used for spine lesions or for local control in asymptomatic spine lesions in our clinic. SBRT is only an option for patients with tumors smaller than 5cm in our clinic.

The biggest problem with lung and liver tumors is the effective and reproducible reduction of tumor motion during treatment. Tumor motion reduction in our clinic is mainly achieved by using abdominal compression to induce forced shallow breathing, when possible. For patient's where abdominal compression is not an option, maximum intensity pixel images for lung tumors (or minimum intensity pixel images for liver tumors) acquired through four dimensional computed tomography (4D CT) are used. To achieve the degree of safety and accuracy necessary to effectively deliver the large doses per fraction associated with SBRT, requires submillimeter accuracy in setup, treatment planning, and treatment delivery, which can only be accomplished through a dedicated team approach. In this presentation the University of Kentucky's approach will be discussed. The importance of reproducible and reliable setup during CT simulation and treatment will be discussed, as well as the importance of motion management for lung and liver tumors and daily image guidance. Implementation of guidelines of AAPM TaskGroup 101 and 142 reports, on stereotactic radiation therapy and machine QA respectively, in our clinic will also be discussed.

Educational objectives:
1. Understand the underlying principles of SBRT
2. Understand the essential requirements for successful SBRT treatments
3. Understand the planning process for SBRT treatments

SA-F-Ballroom 1-02

SBRT: The University of Kentucky Experience - Dosimetric Verification of Stereotactic Body Radiotherapy Using Cone-Beam Computed Tomography Images

G Narayanasamy *, J Feddock, J Gleason, R McGarry, J Molloy, Department of Radiation Medicine, University of Kentucky Medical Center, Lexington, KY

Purpose: To assess the accuracy with which stereotactic body radiotherapy (SBRT) is delivered via conebeam CT (CBCT)-based image-guided delivery methods. Methods and Materials: SBRT treatment plans from ten patients with primary lung tumor were retrospectively reviewed. In this retrospective study on ten lung cancer SBRT patients, ten free-breathing planning CT (pCT) scans were acquired along with 38 CBCT scans. Virtual simulation was performed using pCT scans and a CBCT image was acquired on each fraction of treatment to ensure set up accuracy. The CBCT information acquired just prior to the treatment provides the latest patient anatomical information and provides a way to independently verify the dose delivered to any organ of interest. Contours of the gross tumor volume (GTV), planning tumor volume (PTV) and relevant organs at risk (OAR) were drawn by the physician on the pCT and on each of the CBCT images. These contours were transferred from each of the CBCT images to the pCT image, after performing rigid-registration between the image pair. Treatment plan dose, delivered dose and dose volume histograms (DVH) were calculated in the pCT image from both the original contours and the additional set of contours derived from CBCT images which were then compared. The ratio of mean PTV delivered dose to the mean PTV planned dose was compared with the ratio of intersection of volume of PTV pair to union of the planned and delivered PTV volumes. A motion phantom study was performed to deduce the error in estimation of tumor volume in pCT and CBCT imaging systems. Results: Reduction of tumor volume with treatment was insignificant within 2 weeks of SBRT. When averaged across patients over all fractions, the mean delivered dose to GTV and PTV had deviated from the planned dose by -1.1% and -2.4%, respectively. In only 1 of 38 fractions delivered to 10 patients, there was a substantial reduction in the mean dose delivered to GTV and PTV by 9.3% and 16.8%, respectively. While the maximum delivered-doses did not change significantly (<0.1%), the minimum delivered-doses to GTV and PTV deviated by -4.3±4.6% and -19.4±15.2%, respectively, when averaged across patients over all fractions. The substantial reduction in the minimum delivered dose to GTV and PTV compared to the minimum doses in the treatment plan is possibly attributable to breathing motion and tumor deformation. The mean and maximum doses to spinal cord and esophagus showed a negligible increase and were within the tolerance limits mentioned in RTOG protocol. A strong correlation coefficient of 0.75 exists between the ratio of delivered dose to the planned dose to PTV with ratio of volume of intersection of planned and delivered PTV volumes. Motion phantom study revealed errors of 6.9% and 5.1% in the estimated lesion volumes in pCT and the CBCT images, respectively.

Educational Objectives:
1. Understand the methodology of dose verification via online imaging methods.
2. Understand the differences between pCT and CBCT and their inherent deficiencies in estimation of tumor volume.

SA-F-Ballroom 1-03

Comparison of SBRT Treatment Plans Using Conventional Linear Accelerator Based Non-Coplanar Beam Arrangements Versus Tomotherapy

U Langner*, P Kallenberg, J Molloy , University of Kentucky, Lexington, KY

Introduction The growth of stereotactic body radiation therapy (SBRT) as a treatment modality for patients with lung cancer is evidenced by the proliferation of related clinical protocols. The key principles for an effective SBRT plans is high dose conformality to the planning target volume (PTV) and large dose gradients outside of the PTV. This is traditionally achieved through a large number of non-coplanar beams. In this study SBRT treatment plans generated using the helical treatment delivery capabilities of Tomotherapy are compared to that of a conventional linear accelerator (linac) based non-coplanar approach. Although Tomotherapy is not capable of producing non-coplanar beams, it has the potential advantage of optimizing and delivering hundreds of individual beamlets, i.e. an intensity modulated radiation therapy (IMRT) approach to SBRT. In this work, we compared treatment plans for each of these two treatment modalities, in order to assess their relative ability to deliver conformal SBRT. **Method and Materials** Treatment plans generated with the CMS XIO planning system for six patients treated with 7- 10 conventional non-coplanar beams were recalculated for delivery on a Tomotherapy linac. The prescription was set to 95% of the PTV shall receive 48Gy in 4 fractions. The GTV minimum was set to 52Gy and maximum 60Gy. The plans were then compared using the conformality and dosimetric structure limits as specified in the RTOG0915 protocol for the 48Gy arm as a metric. **Results** For each of the twelve plans, the maximum dose fell within the gross tumor volume (GTV) and was within the allowable range specified by the RTOG0915 protocol. The Tomotherapy SBRT plans had a systematically lower maximum dose (53.3Gy to 56.6 Gy) than the Linac SBRT plans (57.3Gy to 62.3Gy). Most organs maintained equivalent doses for the two different planning systems. The dose delivered to the lung was found to be higher for Tomotherapy SBRT. Although this increase is small for the V20 (increasing by about 1% for all patients), the V5 increased by ~50% (from 20% - 30%). All 6 linac SBRT plans had deviations from the protocol for the maximum dose 2cm away from the PTV (5 minor 1 major), while none of the Tomotherapy plans had deviations. The Tomotherapy SBRT plans consistently delivered more integral dose by as much as 30% than the conventional linac SBRT plans. **Conclusion:** By driving our study with conformality as the goal we were able to see that Tomotherapy SBRT has the capability of conforming the high isodose lines tightly around the PTV. It is therefore feasible to treat SBRT patients using Tomotherapy. More conformal plans and sharper dose gradients can be achieved with Tomotherapy when the prescription isodose line is closer to 80% instead of 90%, i.e. the hotspot in the GTVis allowed to increase.

Educational objectives:
1. Understand the differences between helical tomotherapy and conventional non-coplanar SBRT delivery.
2. Understand the advantages and disadvantages of using tomotherapy for SBRT

Mammography Symposium
Room: Ampitheater
Advances in Breast Imaging

SA-F-Ampitheater-01
Breast Tomosynthesis
L Niklason*, Hologic Inc, Bedford, MA

Breast tomosynthesis was recently approved by the FDA for use in screening and diagnosis of breast cancer. The use of breast tomosynthesis in combination with conventional mammography has been shown to significantly improve the clinical performance of radiologists as measured by the ROC curves. The major impact of tomosynthesis will be improved detection and characterization of masses and architectural distortion. Reader studies have demonstrated improved performance in both fatty and dense breasts. The methods used for obtaining and reviewing tomosynthesis images will be demonstrated. Physics testing of these systems will also be described and compared to the testing used for FFDM. This presentation will discuss the use of breast tomosynthesis as a screening modality and will review the performance for calcification and non-calcification lesions and the clinical utility in both fatty and dense breasts.

Educational Objectives:
1. Describe the methods for acquiring breast tomosynthesis images
2. Appreciate the physics testing methods
3. Describe the clinical utility and research supporting the use of breast tomosynthesis for breast cancer screening.

SA-F-Ampitheater-02
Molecular Breast Imaging: Development of a Low-Dose Screening Test for Dense Breasts
C Hruska*, Mayo Clinic, Rochester, MN

Molecular Breast Imaging (MBI) describes nuclear medicine technologies which employ dedicated gamma cameras for imaging the functional uptake of a radiotracer in the breast. Through research at Mayo Clinic over the last 9 years, we have developed a dual-head semiconductor cadmium zinc telluride gamma camera system for MBI and evaluated its promising clinical role in settings such as the preoperative workup of patients with breast cancer, monitoring response to neoadjuvant therapy, and screening in women with mammographically dense breasts. We recently demonstrated that the addition of MBI to screening mammography significantly increases detection of mammographically occult cancers in dense breasts.

Despite these findings, the systemic radiation dose received from MBI with standard intravenous administration of Tc-99m sestamibi (typically 20-30 mCi) is associated with more than 10 times the effective radiation dose of a screening mammogram. To allow safe implementation of MBI in the screening setting, recent work has focused on dose-reduction schemes for MBI, including changes to collimation, energy acceptance window settings, and post-processing denoising algorithms.

This lecture will provide an overview of the advantages and disadvantages of various breast imaging technologies with respect to imaging dense breasts and illustrate the potential clinical role of MBI. The radiation risks associated with MBI will be discussed and compared to radiation risks from mammography and background radiation. Ongoing technical work to reduce radiation dose necessary for MBI screening will be presented.

Educational Objectives:
1. Appreciate the impact of breast density on the efficacy of screening mammography.
2. Discuss the potential clinical role of Molecular Breast Imaging technologies for imaging dense breasts.
3. Understand the radiation risks associated with MBI and current dose-reduction strategies for MBI.

Therapy Symposium
Room: Ballroom 1
Image Registration, Deformation, and Enhanced Contouring for Radiotherapy

SU-A-Ballroom 1-01
Image Registration, Deformation, and Enhanced Contouring for Radiotherapy with MIM MaestroTM

D Brinkmann[1] *, J Piper[2] *, (1) Mayo Clinic, Rochester, MN, (2) MIM Software Inc., Cleveland, OH

Utilization of rigid and deformable image registration as well as enhanced contouring tools for radiotherapy is increasing rapidly, with a variety of commercially available systems providing this functionality. Such tools can facilitate image registration between images acquired in the treatment position with those that were not, adaptive re-contouring to deform contours from the original treatment planning images onto new images acquired during the treatment course, deformable dose accumulation for adaptive therapy or re-treatments, and advanced segmentation tools with the potential to improve efficiency and consistency. Understanding the strengths and limitations of a given system can help the medical physicist use the system effectively and avoid or anticipate unexpected results caused by exceeding the system's capabilities.

This presentation will step through the functionality and algorithms available for image registration and advanced contouring tools in MIM Maestro™ version 5.1 (MIM Software Inc., Cleveland, OH), as well as touch on functionality under development. Clinical examples using these tools will be presented, highlighting cases that have worked well and cases that have been challenging, including rigid and deformable registration, propagating deformed contours onto a new scan, workflows to provide consistent procedures with instructions, advanced segmentation tools, and initial experience with atlas-based contouring.

Educational Objectives:
1. To review the functionality and algorithms available in MIM Maestro™ for image registration and enhanced contouring.
2. To understand strengths and limitations of the MIM Maestro™ image registration and enhanced contouring tools
3. To provide some clinical examples using MIM Maestro™ for image registration and enhanced contouring

SU-A-Ballroom 1-02
Image Registration, Deformation, and Enhanced Contouring for Radiotherapy with VelocityAI

A Smith[1] *, D Caruthers[2] *, (1) Mayo Clinic, Jacksonville, FL, (2) Velocity Medical Solutions, Atlanta, GA

VelocityAI (Velocity Medical Solutions, Atlanta, GA), is one of the commercially available imaging software tools that includes automated deformable image registration, contouring capabilities, and atlas-based segmentation. Automated deformable image registration can improve the efficiency and quality of radiation therapy planning by making it possible to fuse treatment planning images to a set of images that were not acquired in the treatment position. Additionally, contours can be transferred to a new set of images and deformed. This is very useful when a patient is replanned during the course of their treatment. The atlas-based segmentation allows adaptive contouring to adjust contours, which has the potential to reduce contouring time. Additional enhanced contouring tools have also been designed to increase efficiency.

This lecture will provide an overview of the technical aspects of Velocity, clinical implementation, and the future direction of the Velocity software. Clinical issues to be discussed include capabilities of Velocity registration and contouring tools, usefulness of atlas-based segmentation, and clinical examples of the strengths and limitations of the Velocity software.

Educational Objectives:
1. Understand the technical implementation and future direction of the Velocity software
2. Understand the issues related to automated deformable image registration
3. Understand the issues related to clinical application of atlas-based anatomical segmentation

One of the presenters is an employee of Velocity Medical Solutions, Atlanta, GA.

Diagnostic Symposium
Room: Ampitheater
MRI

SU-A-Ampitheater-01
MRI Accreditation: The Basics and Beyond

R Pooley*, Mayo Clinic, Jacksonville, FL

The ACR MR accreditation program is well-described in documents on the ACR website, and the clinical medical physicist involved in accreditation should be fully aware of the contents of these documents. A brief review of program requirements will be presented highlighting key elements for successful accreditation. While most questions are adequately addressed in the program documents, the physicist may be presented with additional questions and issues not directly addressed in these documents. Some common issues to look for will be discussed.

While many of the tests used to judge phantom image quality are objective with published criteria, some issues of quality (for example those related to artifacts or low contrast detectability) may fall in “grey” areas in which the medical physicist will need to decide if service should be called to resolve an issue or if the images are adequate and the site may submit the images hoping they will pass. Images of less than ideal quality will be presented for discussion.

After accreditation is granted, a program of on-going quality control and annual physics surveys must be established and maintained. The medical physicist should be involved to help set up and monitor this program. Several concepts in on-going quality control will be presented. And after everything is set up and running smoothly are you confident that your site would perform well during an inspection? Information will be discussed regarding what the ACR may look for during an inspection.

This presentation will briefly review key elements important for successful MR accreditation, and will go beyond the basics to provide additional information that may be helpful to the clinical medical physicist.

Educational Objectives:
1. Understand key elements required for successful ACR MR accreditation.
2. Review issues related to phantom image quality.
3. Discuss on-going requirements to maintain accreditation.
4. Understand what may be reviewed during an inspection.

Therapy Symposium
Room: Ballroom 1
Characteristics and Clinical Use of a New Digital Accelerator

SU-D-Ballroom 1-01
Digital Versus Analogue Control Systems

I Brezovich*, University of Alabama at Birmingham, Birmingham, AL

Modern radiotherapy procedures like IGRT, SRS, SBRT, gating and dose-escalated prostate therapy require increasingly accurate delivery. The mechanical movements of traditional analogue accelerators typically use potentiometers as transducers for readout and positioning of x-ray jaws, couch, collimator and gantry angles. However, even precision potentiometers have 0.1% tolerances on linearity, i.e., three-digit accuracy that can translate into 0.4 mm inaccuracy in the positioning of jaws for a 40 cm wide field.

Voltage signals have to be digitized, and are affected by ageing of electronic components that further degrade the already marginal accuracy. The digital signals from rotary and linear encoders, on the other hand, are immediately amenable to computer processing and are less susceptible to aging until outright failure.

Absolute encoders produce unambiguous digital signals for angles and linear positions, whereas incremental encoders measure distances in relation to a reference point by counting the number of light beam interruptions or pulses from a Hall generator. Stepper motors rotate a fraction of a revolution for each input pulse, directly translating digital signals into angular position. Using high gear ratios, positioning signals can be obtained with any desired number of significant digits, and precisely ground spindles and gears translate these into positions with accuracy typically in the 10 micron range. Because of such high precision, even the positions of flattening filters, light field projectors and other critical collimator components can be digitally adjusted from the keyboard of the accelerator.

Gantry flex can be accounted for by gantry-angle dependent position corrections of kV images. Output calibrations are done by typing the measured dose produced per MU into the computer. Because signals are digital, accelerator performance can be readily monitored remotely. Using the processing power of computers, correction signals in the feedback loops for beam symmetry, beam position, rf driver frequency, etc., can be monitored automatically and applied during energy selection, thereby reducing the initially inaccurate irradiation after each beam interruption.

Medical physicists appreciate the fewer calibrations of jaw, couch, gantry and other motions, and the ease of radiation output calibrations. However, they must be aware of "bugs" and accept the occasional rebooting inherent to computerized systems. Somewhat lengthy initializations of mechanical motions become necessary when incremental transducers lose count due to noise spikes or power interruptions. Shielding sensitive computer components with boron impregnated polyethylene to prevent single-event upsets and other improvements are being implemented. Nevertheless, frequent spot checks as protection against typical computer glitches are recommended.

Educational Objectives:
1. Understand the basic difference between the functioning of analogue and digital accelerators
2. Understand the clinical implications of digital control
3. Enable physicists to tailor quality assurance tests to the new technologies

SU-D-Ballroom 1-02

Characteristics and Clinical Implementation of the Varian TrueBeam Accelerator

R Popple, The University of Alabama at Birmingham, Birmingham, AL

The Varian Medical Systems TrueBeam incorporates several new technologies distinguishing it from previous models. First, it uses a completely digital control system. Each subsystem, such as the on-board imaging system, has a control computer that issues commands and monitors the subsystem. The subsystem computers are overseen by a master computer, the supervisor. Second, the waveguide and filter design allows 5 flattened photon energies up to 20 MV. Third, the electron scattering foils are of a new design. Finally, it implements 6 MV and 10 MV flattening filter free (FFF) beams that provide dose rates up to 2400 monitor units per minute.

Acceptance and commissioning are similar to previous models. Beam data collection does not require procedures different from standard photon beams except for the FFF beams. Due to the higher dose per pulse, depth dose and profile measurements may require small corrections to account for changes in the recombination correction factor (Pion). Commissioning of the FFF beams in the Eclipse treatment planning system for calculation with the analytic anisotropic algorithm (AAA) is straightforward. The AAA for FFF beams achieves accuracy comparable to standard flattened beams.

Presently, routine quality assurance procedures are similar to those of previous models. In particular, commercial 5-chamber devices for daily monitoring of output, symmetry, and flatness are sufficient for monitoring the FFF beams as well. Presently, the tighter mechanical specifications of the TrueBeam relative to previous models do not require different QA procedures; however, as treatment techniques emerge that rely on the improved accuracy, new QA techniques will have to be developed.

The digital control system has implications in clinical practice. One example is improved dosimetry of dynamic MLC delivery. It is well known that trajectories requiring leaf velocities faster than the maximum velocity achievable by the MLC result in beam hold-offs and potentially significant dosimetric errors. Such leaf trajectories are delivered accurately on the TrueBeam because the supervisor computer prospectively reduces the dose rate rather than issuing a beam hold only after the MLC has fallen behind the planned position. This characteristic allows previously non-deliverable leaf trajectories that reduce the dose to critical structures to be used on the TrueBeam. The digital control system also has the potential to deliver exotic trajectories, in which all mechanical motions are possible as the beam is delivered with variable dose rate.

The TrueBeam is a general purpose linear accelerator and can be used for all patient types. For conventional fractionation, treatment times are decreased due to reduction in the time required to prepare for delivery of each field. For hypofractionation, radiosurgery, and respiratory gating using the FFF beams, the treatment times are decreased significantly due to the higher dose rate. Reduced treatment time improves patient comfort, targeting accuracy, and patient throughput.

Educational objectives:
1. Describe the TrueBeam system and its differences from previous models.
2. Understand commissioning and quality assurance of the TrueBeam.
3. Understand the clinical implications of the digital control system.
4. Describe clinical use of the TrueBeam capabilities.

Diagnostic Symposium
Room: Ampitheater
Imaging for Isotopes/ Accreditation

SU-D-Ampitheater-01

Imaging for Isotopes/ Accreditation

MT Madsen*, University of Iowa, Iowa City, IA

The Medicare Improvements for Patients and Providers Act of 2008 mandates that outpatient clinics which provide advanced imaging services (MRI, CT, PET and nuclear medicine) and bill for the technical component under the physician fee schedule must be accredited by January 1, 2012. Although this does not include most hospitals, it does affect a large number of private imaging clinics. In this presentation the accreditation options that are available for nuclear medicine facilities will be discussed. There are 3 organizations which are recognized as accreditation providers: the American College of Radiology (ACR), the Intersocietal Commission on Accreditation of Nuclear Laboratories and the Joint Commission.

A key component of accreditation is the quality assurance and quality control of equipment. All of the accreditation agencies embrace acceptance testing and having a well defined quality assurance program that addresses annual evaluations as well as more routine tests. For nuclear medicine, these procedures include evaluations of both planar and SPECT imaging system along with non-imaging devices such as the dose calibrator. PET quality control includes normalization procedures as well as quantitative evaluations.

Specific phantom imaging procedures are required by at least one of the accreditation providers. For nuclear medicine imaging these include planar uniformity and spatial resolution evaluation as well as SPECT uniformity, resolution and contrast measurements. For PET, validation of the standardized uptake value is required along with uniformity, spatial resolution and contrast. Recommendations for effective and efficient performance of these tests will be given. In addition, common pitfalls in these procedures will be discussed along with guidance as to how they can be avoided.

Educational Objectives:
1. Understand the basic quality control requirements for accreditation.
2. Understand the performance requirements for SPECT imaging systems along with avoiding the common problems that result in unsatisfactory scores.
3. Discuss reasonable approaches to quality control.

Joint Symposium
Room: Ballroom 1
Legislative Updates and National QMP

SU-F-Ballroom 1-01

Are You Driving the Bus Or Along for the Ride? How the Media Is Influencing Your Profession!

L Fairobent*, AAPM, College Park, MD

In the past year there has been a lot media coverage impacting the practice of medical physics. In this session we will address how the media can influence the regulatory and legislative session.

Topics will include:

- CARE Legislation
- S.99 – Medical Isotope Production
- Recent NRC Activities – Safety Culture Policy, Part 35 Amendments, Potential Changes to Part 20

SU-F-Ballroom 1-02

How the Media Influences the Regulatory and Legislative Environments Regulatory Response to Media Influence, Chipping Away at the Issues, "CRCPD Initiatives to Make the World a Safer Place"

D Gilley*, CRCPD, Tallahassee, FL

CRCPD is committed to finding methodologies to that support the beneficial uses of radiation while protecting the public from unnecessary exposure. This committed has defined itself in many ways that may have impact on the activities of medical physicists. The presented will discuss the current status of several initiatives geared towards **prevention** of radiation errors, the **security** of radioactive materials from malicious intent and preparedness through the training and mobilization of medical physicists to support response from a radiation incident.

Topics will include:

- **Prevent:** The National Registry of Qualified Medical Physicists and Medical Event Reporting, CT Training
- **Security:** SCATR, NRC Part 37 Increased Control of Radioactive Material**,** and
- **Preparedness:** Mobilizing Radiation Professionals

Joint Symposium
Room: Ballroom 1
US Supply of Medical Isotopes

MO-A-Ballroom 1-01
US Supply of Medical Isotopes

P Staples[1] *, J Harvey[2] *, D Glenn[3] *, G Piefer[4] *, (1) DOE/NNSA, Washington, DC, (2) NorthStar Medical Radioisotopes, LLC, Madison, WI, (3) Babcock and Wilcox, Technical Services Group, Lynchburg, VA, (4) Phoenix Nuclear Labs, Middleton, WI

The supply of medical isotopes has been severely impacted over the past couple of years. Although the United States consumes 50% of the Molybdenum-99/Technetium-99m produced in the world, none is produced in the United States. Through its Global Threat Reduction Initiative (GTRI), the National Nuclear Security Administration's (NNSA) is working to minimize and, to the extent possible, eliminate the use of highly enriched uranium (HEU) in civilian nuclear applications, including in the production of medical radioisotopes.

Dr. Parrish Staples, NNSA's Director of European and African Threat Reduction will present an overview of the GTRI's efforts on US medical isotope production including an overview of the international HEU minimization projects to provide assistance to convert existing Mo-99 production from HEU to LEU, focusing on the South African project.

NNSA is currently developing projects to accelerate the establishment of domestic commercial sources of Mo-99 without the use of HEU. NNSA is working on several Cooperative Agreements to potential commercial Mo-99 producers, whose projects are in the most advanced stages of development, accelerating their efforts to begin producing Mo-99 in quantities adequate to the U.S. medical community's demand by the end of 2013. These commercial producers each use a different non-HEU technology, in support of our strategy to diversify the supply chain and move away from reliance on a sole technology and a limited number of facilities, such as used by today's foreign producers. Four co-operative agreements have been issued reflecting different approaches for production – Neutron Capture (General Electric [GE]-Hitachi); LEU Solution Reactor Technology (Babcock and Wilcox [B&W]); and Accelerator Technology (NorthStar Medical Radioisotopes, LLC and Morgridge Institute for Research). A presentation by each of the four NNSA's co-operative agreement partners will follow with a question and answer session.

Professional Symposium
Room: Ballroom 1
ABR Exam Review

MO-C-Ballroom 1-01
Update On the Activities of the American Board of Radiology

G Frey*, MUSC, Charleston, SC

This presentation is an update on the activities of the American Board of Radiology

Objectives:
1. Participants will be aware of the current requirements for those diplomats participating in the Maintenance of Certification Process
2. Participants will be aware of the changes in the requirements to sit for the board examination in 2014

MO-C-Ballroom 1-02
Preparing for the ABR Therapy Physics Boards: Part III (Oral Exam)

S Becker*, New York University Langone Medical Center, NY, NY

Preparing for Part III (Oral Exam) of the ABR Therapy Physics boards is more than just studying as much material as possible. There will always be material that is missed and gaps in one's knowledge. Therefore it is crucial to understand how the parts of the material relate to each other and to the clinical experience in order to fill those gaps. Part III presents its own challenges compared to the other written exams. It not only requires experience with clinical procedures but also the ability to explain orally how they are performed and what they mean. One must be able to easily and confidently respond to oral questions about all aspects of working in the clinic and clearly explain why those clinical methods and procedures are performed that way. This talk is not a comprehensive review of all required study material. Instead it focuses on the required experiences, skill sets, and study methods that are needed to pass Part III of the board exam.

Educational Objectives:
1. Gain a list of clinical experiences needed for the exam
2. Understand how the study material and clinical experiences relate to each other
3. Learn how to prepare for an oral style exam

CT Workshop
Room: Ampitheater
CT Workshop

MO-C-Ampitheater-01
Updating Image Quality and Dosimetric Metrics for CT

J Boone*, UC Davis Medical Center, Sacramento, CA

Computed Tomography (CT) is entering its fifth decade as a clinical modality, however the methods by which medical physicists assess image quality on CT images remain identical to those established in the first decade of CT. Prior to the Digital Imaging Communication in Medicine (DICOM) standard and the widespread use of Picture Archiving and Communication Systems (PACS), subjective visual evaluation was necessary for image quality assessment because the only output of the CT system was a film image. Current access to digital CT images suggests that more quantitative metrics can be used. CT dosimetry methods have been static over several decades as well. The increased clinical utilization of CT, combined with improvements in modern dosimetry hardware and increased sophistication in scanner acquisition modes provides motivation for a renewed approach to CT dosimetry, as well. A number of AAPM Task Groups (TG) have focused on the development of new methods for CT dosimetry (e.g. TG111, TG200, TG204). In addition, the International Commission on Radiological Units and Measurement (ICRU) will be publishing new recommendations for both dosimetry and quantitative assessment of image quality in CT next year. In this presentation, a number of new techniques for both image quality assessment and estimation of radiation dose in CT will be discussed.

Image Quality: The Modulation Transfer Function (MTF) in both the x-y and z dimensions is recommended for the assessment of spatial resolution, consistent with modern image science practice. The three dimensional Noise Power Spectrum (NPS) is recommended for the assessment of image noise. For this assessment, a cylindrical polyethylene phantom is scanned and the dose to the center of the phantom is adjusted to a standard level (10 mGy), and the NPS is then computed from homogeneous regions of the phantom at this standard dose setting. These methods will allow medical physicists to make quantitative image quality comparisons between CT scanner types and models, and also optimize CT protocols for a number of imaging procedures. The use of mathematically-rigorous quantitative techniques will reduce the subjectivity associated with visual assessment methods and thus allow higher precision in image quality measurement.

CT dosimetry: TG111 updated the traditional $CTDI_{vol}$ approach to include the dose consequences of scans longer than 100 mm in length. Pending ICRU recommendations include the TG111 measurement geometry but include a real time probe which results in substantially fewer measurements and a more complete assessment. TG204 deals with conversion factors to adjust dose estimates for patients of different size.

Overall, the transition from historically qualitatively CT image assessment to quantitative metrics, grounded in state-of-the-art image science techniques, should enable more meaningful CT scanner comparisons at the local, regional, and international levels.

Educational Objectives:
1. Ongoing activities of the AAPM and ICRU related to CT
2. Anticipated new methods for assessing image quality in CT
3. Anticipated new techniques for estimating dose in CT

MO-C-Ampitheater-02

ACR CTAP - The New Phantom Paradigm

D Pfeiffer*, Blackthorn Medical Physics, Westminster, CO

The CT accreditation program (CTAP) of the American College of Radiology has matured. Over the years since its inception, the technology of CT scanners has changed dramatically. The program was initially designed around single slice scanners, not all of which had helical scan capability. These technological changes have forced consideration of how phantom images should be submitted to the ACR for accreditation. Further, while quality control has always been required in the CTAP, no specific guidance similar to that in other accredited modalities has been provided. Therefore, a CT quality control manual is being developed. In this talk, the phantom scanning and submission procedure will be discussed, with hints and guidance provided. The talk will also review the current status of the quality control manual. Issues around the development of the manual and the specific tests will be discussed.

MO-C-Ampitheater-03

Hot Topics in CT

D Cody*, U.T.M.D Anderson Cancer Center, Houston, TX

CT Neuro-perfusion overexposures continue to emerge, well over a year after the widely publicized events at Cedars-Sinai Hospital in LA. All CT facilities offering this exam should have critically reviewed their CT perfusion protocols by now. Also some form of protocol protection or regular review should be implemented to insure that the parameters for these exams in particular are not altered without careful assessment of their impact on radiation dose.

The AAPM Working Group on CT Nomenclature & Protocols has provided vetted CT Neuro-perfusion parameter settings on the AAPM website, available to all current AAPM members. This group is developing example protocol parameters for more commonly used CT exams such as routine head, chest, abdomen, pelvis and combination exams. These example parameter sets are not meant to reflect optimized or gold standard examples, but have been reviewed by a team of technical experts and deemed to be a reasonable combination of parameter settings for these exams.

AAPM Task Group 204 has nearly completed its report which provides a method to calculate CT dose (in the form of CTDIvol) that is size corrected for individual patients, based on consistent experimental and computer modeling results obtained from several independent research laboratories. Use of this report will allow sites to more accurately assess and report CT dose for the wide variety of patient sizes that are typically encountered, and is a step beyond the current CTDI phantom size limitations.

An IEC CT committee has been working diligently to develop a new CT phantom, which will be appropriate for assessing dose using the Task Group 111 methodology and will also provide simple image quality metric targets. This phantom will allow dose and image quality to be quantified as a result of a single pass through the scanner, but will require more sophisticated software analysis tools than have been typically used in the past. Contrast resolution, noise (in the form of noise power spectrum) and spatial resolution (MTF) can be assessed with use of this phantom; it is anticipated that freeware will be widely available to support the image quality evaluation component.

Professional Symposium
Room: Ballroom 1
Medical Physicist Workforce Issues

MO-D-Ballroom 1-01

Medical Physics Workforce Issues in the USA

M Mills*, University of Louisville, Louisville, KY

The safety of patients treated with radiation oncology associated with personnel credentialing and staffing has become the focus of national and international concern. ASTRO is revisiting the question of personnel staffing levels by organizing and re-convening the "Blue Book" project; this is the first such effort since 1991. In addition, the International Atomic Energy Agency has convened an effort to establish recommended international staffing recommendations. These panels will deliver recommendations based on "best information" from various published sources. One such source is the *Abt study of medical physicist work values for radiation oncology physics services, Round III*, published by the AAPM. The 2008 Abt study measured qualified medical physicist (QMP) work associated with routine radiation oncology procedures as well as some special procedures. A work model was created to allow the medical physicist to defend QMP work and staffing based on both routine and special procedures service mix. Finally, a previously published supply and demand model for radiation oncology physicist is updated and presented to predict medical physicist employment market parameters through the year 2020.

Objectives:
1. Understand the current need to establish recommended personnel staffing levels in radiation oncology.
2. Understand the information documented in the Abt studies.
3. Understand a current model that predicts the supply and demand for radiation oncology physicists through 2020.

MO-D-Ballroom 1-02

Professional Doctorate in Medical Physics (DMP): Two Year Experience

C Coffey*, Vanderbilt Medical Center, Nashville, TN

The Medical Physics Program at Vanderbilt University officially accepted the first Professional Doctorate in Medical Physics (DMP) students in August, 2009. At that time a total of 11 students were admitted and/or transferred into the Program: three- Year 3 students, four- Year 2 students, and four- Year 1 students. In July of 2010, the Vanderbilt DMP Program with Therapy and Diagnostic Physics Tracks was CAMPEP-accredited as a combined program with both a medical physics graduate education component and a two-year medical physics residency component. At the beginning of the 2010-2011 Academic Year, the DMP Program had a total of 16 students. In June of this year, the first DMP graduating class of three students will complete the requirements for the DMP Degree. This presentation will provide a program status update and relate the lessons learned after two years experience.

Sam Session - CT Workshop
Room: Ampitheater
CT Workshop

MO-D-Ampitheater-01

CT Workshop - CA CT Dose Reporting Requirements

M Martin*, Therapy Physics, Inc., Gardena, CA

The recent passage of Senate Bill 1237 by the California Legislature requires all facilities to report overexposures to patients by CT Scanners effective January 1, 2011. Effective July 2012, all patient reports must contain dose information for the CT scans performed in all facilities by all scanners - regardless of vintage of the scanner. The bill requires accreditation of all CT scanners in the state by January 1, 2013, six months after the other provisions of the bill are effective. The bill requires that the radiation dose be recorded on the scanned image and in a patient's health records, and that radiation overdoses be reported to patients, treating physicians, and the state Department of Public Health (DPH). Among its reporting provisions, SB 1237 will require, for example, that medical facilities report to the DPH whenever the radiation dose for a given scan exceeds 20% of the prescribed dose, or whenever the wrong anatomic area is scanned. A physicist must work with every institution to develop and review their protocols to verify compliance with the reference values used by the accrediting bodies. Standard values of patient doses as calculated by the physicist are acceptable for reporting purposes. At a minimum, standard doses should be determined and reported for pediatric and adult patients for each type of exam (body part scanned). The legislation was introduced in February by State Sen. Alex Padilla (D-Pacoima) following a series of serious radiation overdoses that prompted outrage among patients and a raft of lawsuits. Last fall the California Department of Public Health learned that over an 18-month period some 260 patients at Cedars-Sinai Medical Center in Los Angeles who underwent CT perfusion scans were exposed to radiation doses eight times higher than

normal. Dose levels are established for triggering reporting requirements to the Department of Health Services. All information regarding overdoses except patient information is public.

Educational Objectives:

1. Attendees will be aware of the exposure levels of CT scans that require reporting to the Department of Health Services.
2. Atendees will be aware of the different values of doses displayed on CT scanners and how they relate to each other.
3. Attendees will be aware of the methods acceptable for use in calculating estimated patient doses for CT scans
4. Attendees will be aware of the reporting requirements for physicians of the estimated doses for individual patient scans

Young Investigator Symposium
Room: Ampitheater

MO-F-Ampitheater-01

Comprehensive Approach to Coregistration of Autoradiography and Microscopy Images Acquired From a Set of Sequential Tissue Sections

M Axente *, J He , C Bass , G Sundaresan , J Hirsch, C Thadigiri , J Zweit , A Pugachev, VA Commonwealth University, Richmond, VA

Purpose: Develop an objective methodology for deformable coregistration of digital-autoradiography (DAR) and microscopy images acquired from sequential tissue sections, in the context of histopathological PET tracer validation. **Method and Materials:** Tumor-bearing mice were injected with ^{18}F-FLT and other markers including Hoechst (blood flow surrogate). After sacrifice, tumors were excised, frozen and sectioned. Multiple stacks of sequential 8μm sections were collected from each tumor. Selected sections (reference) were used for DAR to image ^{18}F-FLT uptake distribution. Sections adjacent to references were used to acquire histopathological data. Hoechst images were acquired for each section. To correct for deformations induced by tissue processing and image acquisition, Hoechst image of each non-reference section was warped onto the reference Hoechst using elastic registration. This transformation was then applied to other images acquired from the same tissue section. This way, all microscopy images were coregistered to the reference Hoechst image. The Hoechst to DAR image registration was done using rigid point set registration based on external markers visible in both images. **Results:** Registration error was evaluated using sets of independent landmarks. The mean error of Hoechst to DAR (same section) registration was 30.8±20.1μm. The error of Hoechst-based deformable registration of histopathological images was 23.1±17.9μm. Total registration error was 44.86μm. This supersedes current rigid registration methods with reported errors of 100-200μm. **Conclusion:** Deformable registration of DAR and histopathology images acquired from sequential sections is feasible and accurate when performed using corresponding Hoechst images. Continuing Education: PET tracer validation, image-guided radiotherapy, deformable registration, digital autoradiography, immunofluorescent microscopy

MO-F-Ampitheater-02

Development of Tetrahedron Beam Computed Tomography for Image Guided Radiotherapy

Xiaochao Xu[1] *, Joshua Kim[2, 1] , Tiezhi Zhang[1] , (1) William Beaumont Hospital, Royal Oak, MI, (2) Oakland University, Royal oak, MI

Purpose: Cone-beam computed tomography (CBCT) is an important online imaging modality for image-guided radiotherapy and intervention. But its image quality is significantly inferior to diagnostic CT due to excessive scatters, suboptimal detector performance and approximate cone reconstruction artifact. We are developing a novel Tetrahedron Beam Computed Tomography (TBCT) system which circumvents the inherent problems of CBCT and potentially can achieve similar image quality as diagnostic CT scanners. **Method and Materials:** A TBCT benchtop system has been built with a 75-pixel field emission x-ray tube. A 5-row CT detector array was built using silicon photodiodes and $CdWO_4$ scintillators. The linear source and linear detector are aligned perpendicular and parallel to rotation plane respectively. The x-ray beams are collimated to fan-shape by a group of multi-slot collimators. FDK and iterative TBCT image reconstruction algorithms were developed. **Results:** Due to its scatter rejection geometry, the use of high-performance discrete x-ray detectors and iterative image reconstruction algorithm, TBCT image quality is superior to that of CBCT. Phantom scans produced excellent images without noticeable artifact. **Conclusion:** A TBCT benchtop system has been successfully built. The multiple pixel field emission x-ray tube is fully functioning but a higher tube current is desired for future clinical systems. Iterative image reconstruction was able to remove approximate image reconstruction artifacts. TBCT would significantly improve online image quality. Clinical implementation of TBCT would improve precision of image-guided radiotherapy and intervention. Due to its diagnostic image quality, TBCT can also be used as mobile diagnostic CT scanners.

MO-F-Ampitheater-03

Dual-Energy Dual Cone-Beam CT for Image Guided Radiotherapy

H Li[1] *, W Giles[1] , J Roper[1] , J Bowsher[1] , F Yin[1] , (1) Duke University Medical Center, Durham, NC

Purpose: To investigate the dual-energy cone-beam CT (CBCT) imaging using a recently developed dual CBCT system and explore the feasibility of a novel interventional imaging technique for IGRT. **Method and Materials:** A dual-detector CBCT system with two large flat panels has been developed in our laboratory. Two imaging chains were arranged orthogonally to each other on one optical bench. The designed source-to-detector distances and source-to-isocenter distances are 150 cm and 100 cm, respectively. The detectors are 40cm x 30cm in size with 194μm-pixels (Varian Paxscan 4030CB). Prereconstruction basis material decomposition is implemented using conic-surface equations and calibrated using aluminum and acrylic step-wedges. The scan data are processed into basis material density images and monochromatic projections, and then submitted for FDK reconstruction. Phantom studies have been carried out for qualitative evaluation and validation. Quantitative analysis is still in progress for the dual-energy imaging. **Results:** Preliminary results have demonstrated the validity of dual-energy CBCT technique in large flat-panel detectors. Basis material decomposition, monochromatic image and linearly mixed images are possible ways to utilize the information from a dual-energy scan. **Conclusion:** Single polychromatic CBCT reconstruction suffers in beam hardening and poor soft tissue contrast. The dual-energy system offers potential advantages to solve these inherent problems for IGRT and provides the potential for functional imaging. Future work will quantitatively investigate the technique, scatter effect, cross-scatter effect and combinations of imaging parameters in a dual cone-beam CT system. **Conflict of Interest:** This work is partially supported by a research grant from Varian Medical Systems.

MO-F-Ampitheater-04

Assessment of Margins for Set-Up Errors in Head-And-Neck IMRT

S Lacey*, J Antolak, D Pafundi, D Brinkmann, M Herman, B Barney, Y Garces, R Foote, Mayo Clinic, Rochester, MN

Purpose: To measure the setup uncertainty for curative head and neck cancer patients undergoing intensity modulated radiation therapy (IMRT), to assess the degree of daily intra-fraction motion, and to determine whether our 5-mm CTV-PTV expansion margins can be reduced. **Method and Materials:** Nine patients receiving post-operative bilateral IMRT to the head and neck were fitted with dental molds containing gold fiducial markers. Daily orthogonal kV images were used for treatment positioning, and the patient position was corrected along the three Cartesian directions by matching bony anatomy near isocenter. Imaging was repeated at the completion of each treatment fraction to assess intrafraction motion. Images were compared off-line to the digitally reconstructed radiographs used for treatment and two sets of proposed shifts were recorded by separately matching bony anatomy near isocenter and the gold fiducial markers. **Results:** The required margins, as calculated by the van Herk margin recipe, for aligning bony anatomy near isocenter were 1.3 mm SI, 2.3 mm LR, and 2.5 mm AP. Based on aligning the fiducial markers the calculated margins were 7.4 mm SI, 6.9 mm LR, 8.5 mm AP. The average measured intrafraction displacement was 2.3 mm and 2.1 mm for bony anatomy and fiducial markers, respectively. **Conclusion:** The reported measurements indicate that the current 5-mm margin is adequate near isocenter. The larger margins calculated based on fiducial markers are attributed to angular setup uncertainties. Based on this data, we are currently investigating an alternative immobilization technique to reduce angular setup uncertainties and intrafraction rotations.

MO-F-Ampitheater-05

Target Tracking Using DMLC for Volumetric Modulated Arc Therapy

B Sun[1] *, D Rangaraj[2] , (1) Washington University in St. Louis, St. Louis, Missouri, (2) Washington University Saint Louis, Saint Louis, Missouri

Purpose: Target tracking using DMLC is a promising approach for intrafraction motion management in radiation therapy. The purpose of this work is to develop a DMLC tracking algorithm capable of delivering VMAT to the targets that experience 2D rigid motion in the beam's eye view. **Methods:** The problem of VMAT delivery to moving targets is formulated as a control problem with constraints. The relationships between gantry speed, gantry acceleration, MLC leaf-velocity, dose rate, and target motion are derived. An iterative search algorithm is developed to find solutions for efficient delivery of a specific VMAT plan to the moving target using. The delivery of five VMAT lung plans is simulated. The planned and delivered fluence maps are calculated and compared. **Results:** The simulation demonstrates that the 2D tracking algorithm is capable of delivering the VMAT plan to a moving target fast and accurately without violating the machine constraints and the plan integrity. The average delivery time is only 30 seconds longer than that of no-tracking delivery, 95.6 s versus 66 s. The fluence maps are normalized to 200 MU and the average RMS error between the desired and the delivered fluence is 2.1 MU, compared to 14.8 MU for no-tracking and 3.6 MU for 1D tracking. **Conclusions:** An optimal MLC tracking algorithm for VMAT delivery is proposed aiming at shortest delivery time while maintaining treatment plan invariant. The inconsequential increase of treatment time due to DMLC tracking is clinically desirable, which makes VMAT with DMLC tracking attractive in treating moving tumors.

MO-F-Ampitheater-06

Yields of Positron-Emitting Nuclei (10C, 11C, and 15O) Induced by Protons and Carbon Ions: A Simulation Study with Geant4

A Lau[1] *, S Ahmad[1] (1) University of Oklahoma Health Sciences Center, Oklahoma City, OK

Purpose: To investigate the yields and the yield-depth distributions of positron-emitting nuclei (PEN) ^{10}C, ^{11}C, and ^{15}O induced by protons and carbon ions in PMMA through detection of annihilation gamma rays using Geant4 Monte Carlo Toolkit. **Method and Materials:** An application utilizing various physics packages (low and standard electromagnetic, parameterized and Binary Cascade inelastic and parameterized elastic) was constructed with Geant4 Monte Carlo Toolkit. A phantom (9 cm x 9 cm x 30 cm) consisting of PMMA ($C_5H_8O_2$, density 1.18 g/cm^3) was irradiated with 70, 110 MeV protons and 204 A, 212.12 A MeV carbon-ions. Beams (1 cm FWHM; 0.2% Gaussian energy spread FWHM) were used. In each simulation the energy deposited was recorded for every 0.1 mm increment of depth in the phantom. The resulting PEN and their yield were recorded at the production point and the point of decay in increments of 1 mm. **Results:** The overall percentage yields and the yield-depth distributions of PEN per incident particle for both protons and carbon ions were obtained. **Conclusion:** Our yields of PEN are in excellent agreement with other simulations (FLUKA and MCHIT) and existing experimental data. However, we found in our simulation overestimation of the percentage yields of ^{10}C with incident carbon ions and underestimation of the percentage yields of ^{11}C for 110 MeV incident protons when compared to existing experimental data**.** The application built in this study thus can predict the amount of PEN as well as their yield-depth distributions.

MO-F-Ampitheater-07

Treatment Planning Comparison: Flattening Filter Free (FFF) X-Rays Vs. Conventional Flattened X-Rays for Stereotactic Body Radiation Therapy (SBRT) of Stage 1A Non-Small Cell Lung Cancer (NSCLC)

y wang[1] *, N Golden[2] , J Ting[3] , (1) MIMA Cancer Center, Melbourne, FL, (2) MIMA Cancer Center, Melbourne, FL , (3) MIMA Cancer Center, Melbourne, Fl

INTRODUCTION: Excellent clinical outcomes have been proposed for stereotactic body radiation therapy (SBRT) of early stage NSCLC. With the adaptation of IMRT and RapidArc, the need of flattened X-rays becomes unnecessary. The utilization of photons of flattening filter free (FFF) is far more efficient and dose rate at the treatment target increases substantially. The FFF mode could make the breath-hold or respiratory-gating feasible in the SBRT lung treatment. This work investigates dosimetry performance of FFF X-rays for SBRT in the NSCLC treatment. METHODS: A linac with FFF has been in full clinical operations since July 2010. Dose rates for 6X flat, 10X flat, 6X-FFF and 10X-FFF is 600, 600, 1400, and 2400 MU/min respectively. We retrospectively re-planned ten early stage NSCLC patients with IMRT or RapidArc plans with conventional flattened and FFF X-rays. All optimization parameters were kept the same between two plans. Both plans were optimized using AAA in Varian Eclipse and were evaluated using DVH, isodose line, dose at organs at risk, total MUs and beam-on time. RESULTS AND CONCLUSIONS: Similar coverage and DVHs were obtained for both flat and FFF X-rays. Monitor units were found to be less, to almost equal, to much higher in some cases. Beam-on time of the FFF was less than ½ of the conventional flattened X-rays in all cases evaluated. The FFF delivers much higher dose to targets per unit time or per beam pulse. Organ motion management and patient comfort will be improved using the FFF mode for the SBRT delivery.

MO-F-Ampitheater-08

Plastic Scintillation Dosimetry for Measurement of Age-Related Macular Degeneration Radiosurgery Device

C Tien*[1], J Cantley[1], D Hintenlang[1], W Bolch[1], E Chell[2], (1) University of Florida, Gainesville, FL, (2) Oraya Therapeutics Inc, Newark, CA

Purpose: Age-related macular degeneration (AMD), the leading cause of severe vision loss and blindness among those over age 65, is a chronic, progressive disease of the macula. The performance of a plastic scintillation dosimeter (PSD) system was benchmarked for real-time dose monitoring and measurement of a diagnostic-energy (100 kVp) level stereotactic radiosurgery device, IRay^{TM}, developed for AMD treatment. **ethod and Materials:** The 0.4 mm^3 PSD was optically coupled to a plastic waveguide attached to a shielded photomultiplier tube. Dose linearity and percent-depth-dose in solid water was measured using a portable x-ray unit, in lieu of the off-site IRay^{TM}, and compared with an ion chamber. The calibration factor between counts and exposure was tested at high dose and high dose rates using a mobile c-arm fluoroscopy unit. **Results:** Real-timemeasurements were obtained with bins as small as 10 ms. A calibration factor (CF) from PSD percent-depth-dose to ion chamber percent-depth-dose was 1.06 at a depth of 1.5 cm in solid water, the typical macular target depth. High dose CF varied less than 1% from 0.862 to 15.26R. High dose rate CF remained linear with R^2 of 0.999 up to 16R. **Conclusion:** The IRay^{TM} can accommodate the small volume PSD in order to obtain linear dose measurements at high doses and high dose rates in addition to providing real-time monitoring of dose delivered. **Conflict of Interest (only if applicable):** This work was supported by Oraya Therapeutics.

MO-F-Ampitheater-09

Evaluations of the Dose Discrepancies Calculated On CT and Cone-Beam CT Using Pencil Beam Convolution and Analytical Anisotropic Algorithms

S Oyewale*, S Ahmad, I Ali, University of Oklahoma Health Sciences Center, Oklahoma City, OK

Purpose: To investigate differences in dose calculated using cone-beam CT (CBCT) and conventional CT (CT) using pencil beam convolution (PBC) and analytical anisotropic algorithms (AAA). **Methods**: CBCT images were acquired using on-board imaging system of Varian Trilogy. The clinical plans were calculated on CT and CBCT using PBC and AAA in Eclipse treatment planning system. The structures, beams and leaf sequences from clinical plans were preserved and transferred to CBCT. Treatment plans for 8 lungs, 1 lumbar spine, and 1 liver patient were used. Dose differences from 2D distributions on CT and CBCT slices were calculated. The gamma index was used to analyze dose distributions with tolerance criteria of (3%, 3 mm). **Results**: The data show that nearly 67% and 90% of patients had an average dose calculated on CBCT higher than on CT using PBC and AAA, respectively. The overall average of mean percentage dose difference (MPDD) between CT and CBCT from all patients in different planes was 0.5% (PBC) and 1.8% (AAA). The MPDD ranged from -13.2% to 7.9% (PBC) and -13.9% to 9.9% (AAA). The gamma analysis using AAA had lower or equal passing rates (84% of 139 cases) than PBC. **Conclusion**: The dose calculated was generally higher on CBCT than CT. The AAA dose showed larger deviations in CBCT compared to CT and accounts more for image artifacts inherent to CBCT than PBC. The discrepancies in dose between CBCT and CT were the largest in lung patients due to large variations in CBCT and CT numbers.

Joint Symposium
Room: Ampitheater
Imaging & Image Guidance

TU-A-Ampitheater-01
MVCT Image Guidance and QA
R Staton*, MD Anderson Cancer Center Orlando, Orlando, FL

The TomoTherapy system is capable of producing megavoltage computed tomography (MVCT) images using the same beam line components that are used for treatment procedures. Daily MVCT image guidance has become the standard for most TomoTherapy users. Establishing a QA program for image guided procedures is crucial to ensure the proper delivery of complex IMRT treatments. Geometric and image quality tests for MVCT imaging should be included in the QA program to guarantee accurate image guidance of patient positioning. MVCT images are mainly used for alignment of the patient. However, MVCT images can also be used for planning or adaptive planning calculations. MVCT images have been shown to be very useful for adaptive radiation therapy approaches. When used for dosimetric calculations, the imaging QA program should also include proper monitoring of the CT numbers since they can affect dosimetric results.

This lecture will provide an overview of MVCT imaging principles and recommended QA tests. QA procedures for geometric accuracy and image quality of MVCT images will be discussed.

Educational Objectives:
1. Understand the principles of MVCT imaging.
2. Understand the rationale for MVCT imaging QA procedures.
3. Understand the recommended components of a MVCT QA program.

TU-A-Ampitheater-02
Image Guidance Techniques on the CyberKnife
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The Accuray CyberKnife incorporates a non-isocentric, robot-mounted linear accelerator which uses image guidance not only to detect the presence and determine the magnitude of target motion, but also to correct for real-time motion in 6 dimensions (x, y, and z translations, roll, pitch, and yaw angles). The ability to continuously correct for motion during treatment allows for sub-millimetric targeting accuracy for targets that do not move with respiration, and 1.5 mm (or less) accuracy for those that do. The stereotactic image guidance system uses two orthogonal, ceiling-mounted, kilo-voltage x-ray tubes and a pair of planar amorphous silicon imagers recessed in the floor. Five different tracking methods are employed, with the robot correcting the aim of the x-ray beam to account for target motion throughout treatment. Three tracking methods rely on anatomic density differences in the images (Skull Tracking, X-Sight Lung Tracking, and X-Sight Spine Tracking). Two rely on fiducial markers (Fiducial Tracking and Synchrony). Of these five methodologies, Synchrony and X-Sight Lung Tracking are designed to track and correct for motion of targets that move with respiration. The other three methods assume target motion is decoupled from respiratory motion. A recently developed refinement to X-Sight Lung tracking - called Lung Optimized Treatment - will be described briefly. The hardware and software used for each of the tracking methods will be discussed, along with examples of common treatment sites appropriate for each methodology. Finally, quality assurance techniques, along with results from system end-to-end tests, will be presented for each approach.

Sam Session - Joint Symposium
Room: Ampitheater
Imaging & Image Guidance

TU-C-Ampitheater-01
Clinical Image Guidance and Imaging
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In recent years, image guidance systems have revolutionized the way clinicians localize and treat patients. Image guidance systems (IGS), along with advanced imaging techniques, are now used to plan and successfully execute therapies with speed, precision, and accuracy that had previously been unachievable. Moreover, the advancement of novel MRI imaging techniques, cone-beam CT, and various real-time tracking devices allow for intra-procedural adjustments to be made to account for patient/tissue motion. All of these aspects of imaging and image guidance systems make them an important part of a modern clinical practice. While these systems may improve patient therapies, the process required for an expert to employ an IGS clinically has become increasingly more complicated. The steps and additional quality assurance components are numerous. Typically, an image set (ie. CT, MRI, ultrasound, PET) is acquired and a therapeutic plan (ie. surgery, biopsy, radiation therapy) is created based off this image set. A reference within the scan (ie. tracking spheres, anatomic surfaces) can be used to relate the patient's coordinate system to that of the image set. Finally, a therapy is delivered with either patient positional confirmation throughout the process (ie. real-time tracking) or before/after in the case of imaging techniques that require longer acquisition times.

This lecture is an overview of the procedure required to employ an IGS in clinical practice for patient therapies with an emphasis on the increased demands on imaging.

Educational Objectives:
1. Understand the steps required to employ an image guidance system
2. Understand the additional necessary requirements on image modalities
3. Understand the core concepts behind image guidance quality assurance

TU-C-Ampitheater-02
Imaging Doses in Radiation Therapy From Kilovoltage Cone-Beam CT
D Hyer, University of Iowa, Iowa City, IA

Gantry mounted kilovoltage cone-beam computed tomography (kV-CBCT) systems are quickly gaining popularity for use in image-guided radiation therapy. These systems are capable of acquiring high resolution volumetric images of the patient at the time of treatment which can then be registered with the planning CT dataset to confirm proper alignment of the patient on the treatment table. To date, two such systems are commercially available, the X-ray Volumetric Imager (XVI, Elekta Oncology Systems, Crawley, UK) and the On-Board Imager (OBI, Varian Medical Systems, Palo Alto, CA).

While kV- CBCT is a very useful tool for positioning the patient prior to treatment, daily use in a high fraction therapy regimen results in an associated imaging radiation dose. In order to quantify the radiation dose associated with CBCT imaging, an in-house anthropomorphic phantom representing a 50th percentile adult male (J Appl Clin Med Phys 2009;10(3):195 -204) and a fiber-optic coupled (FOC) dosimetry system (Med Phys 2009;36(5):1711–16) were used to directly measure organ doses incurred during clinical protocols for the head, chest, and pelvis. For completeness, the dose delivered using factory installed protocols from both the XVI (v4.0) and the OBI (v1.4.13.0) were investigated. While these measurements provided a direct measure of organ doses, a practical method for estimating organ doses that could be performed with phantoms and dosimeters currently available at most clinics was also desired. To accomplish this goal, a 100 mm pencil ion chamber was used along with standard CT dose index (CTDI) acrylic phantoms to measure the cone-beam dose index (CBDI). A weighted CBDI (CBDIw), similar to the weighted CT dose index (CTDIw), was calculated to represent the average dose in the acrylic phantom. Organ dose conversion coefficients were then developed by comparing CBDIw to the previously measured organ doses. These conversion coefficients allow specific organ doses to be estimated quickly and easily using readily available clinical equipment.

This lecture will provide an overview of the methodology used to perform organ dose measurements in the anthropomorphic phantom as well as a summary of the results. The measured CBDI values will also be presented along with the organ dose conversion coefficients.

Educational Objectives:
1. Understand the doses associated with popular kV-CBCT imaging protocols.
2. Understand the methodology used to perform organ dose measurements in an anthropomorphic phantom.
3. Understand how to apply organ dose conversion coefficients to CBDI measurements in order to estimate CBCT organ doses.