Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum

Orientation and Professional Curriculum

Rotation Director: Watchman
Rotation Mentors: Watchman
Rotation Location(s): MSKCC Main Campus

Duration: 2 Weeks

Learning Objectives

1. The resident will be able to describe expectations required for clinical practice including
    a. Basic safety, patient care
2. The resident will demonstrate knowledge of the six core competencies
3. The resident will be able to describe what a professional medical physicist is and the expectations of one.
4. The resident will be able to discuss ethical obligations of a medical physicist and be able to discuss solutions to ethical scenarios
5. The resident will be able to discuss the qualities of leadership and different leadership models
6. The resident will be able to discuss fundamental financial concepts in radiation oncology

Key Topics

1. Orientation to Clinical Practice
    a. Expectations
2. Professional Curriculum
    a. Core Competencies
        i. Patient Care
        ii. Medical Knowledge
        iii. Practice-Based Learning and Improvement
        iv. Interpersonal and Communication Skills
        v. Professionalism
        vi. System-Based Practice
    b. Leadership
    c. Ethics
    d. Business and Finance
        i. Billing – CPT
        ii. Budgeting
        iii. SWOT Analysis
        iv. Alternative Payment Model

Required Readings

1. RSNA/AAPM Ethics modules
2. Read Assigned Leadership Book
3. AAPM Medical Physics Practice Guideline 10.a.: Scope of practice for clinical medical physics published in the Journal of Applied Clinical Medical Physics (JACMP). (2018).

4. AAPM Medical Physics Practice Guideline 3.a: Levels of supervision for medical physicists in clinical training published in the Journal of Applied Clinical Medical Physics (JACMP). Volume 16, Number 3 (2015). [ISBN: 978-1-936366-45-3]
5. Ehsan, S et al. "Redefining and Reinvigorating the Role of Physics in Clinical Medicine: A Report from the AAPM Medical Physics 3.0 Ad Ho Committee." Med Phys 45 (9) e783-89, 2018
6. Additional readings as assigned

Tasks/Checklist Requirements/ Competencies

1. Complete all MSKCC on-boarding curriculum
    a. If required (0+2)
2. Complete RSNA Modules
3. Complete Professionalism assignments
4. Meet with mentor as assigned and be prepared for the meeting

Evaluation Scheme:

Weekly Evaluation

1. Written weekly evaluations by mentor with resident achieving a marginal or greater score

Final Evaluation

1. Sign off by mentor

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Therapeutic Medical Physics Residency
Rotation Curriculum

Radiation Safety Curriculum

Rotation Director: Lawrence Dauer, PhD, CHP
Rotation Mentors: Brian Quinn, Bae Chu
Rotation Location(s): MSKCC Main Campus / Manhattan Campuses

Duration: 8 Weeks

Resident Professional Expectations

1. The resident will demonstrate a commitment to attainment of radiation safety knowledge and identify personal strengths and weaknesses in the attainment of radiation safety knowledge and, if indicated, demonstrate the ability to address weaknesses.
2. The resident will demonstrate responsible behaviors consistent with the highest ethical standards: honesty, respect, confidentiality, reliability, dependability, civility and punctuality.

Learning Objectives

1. The resident will be able to complete and discuss radiation surveys in a variety of contexts.
2. The resident will be able to complete and discuss patient dose monitoring.
3. The resident will be able to develop a radiation safety program.
4. The resident will be able to use and discuss the different aspects of radiation safety equipment.
5. The resident will be able to discuss and design laboratory radiation safety programs.
6. The resident will be able to complete external and internal dosimetry assessments for both clinical and occupational scenarios.
7. The resident will be able to demonstrate the ability to develop radiation shielding using NCRP methods.
8. The resident will be able to discuss and implement radioactive waste management methods.
9. The resident will be familiar with environmental radiation protection practice.
10. The resident will be able to develop and implement radiation safety training programs.
11. The resident will be able to demonstrate knowledge of federal, state and city laws/regulations related to the safe use of radiation producing machines and radioactive material.

Key Topics and Tasks

1. ***Radiation safety surveys**:* Appropriate selection of radiation instrumentation including energy response, efficiency, sensitivity and geometry. Performing radiation measurements and evaluation of radiation measurements with regard to purpose of survey and regulatory requirements. Radiation measurements in diagnostic and therapeutic radiation settings. Surveys for removable contamination. Radiation safety features of equipment and treatment room.
2. ***Patient dose monitoring**:* In-air measurements of exposure and exposure rates from equipment and measurements with phantoms using ionization chambers, patient dose measurement, calculation of skin entrance dose, internal organ dose, effective dose equivalent, risk estimation, evaluation of potential for deterministic effects, calibration and quality assurance of dosimeters and automated dosimetry systems.
3. ***Additional experiences:*** Design of radiation safety program, presentation of radiation safety in-service education, shielding design, consultation regarding radiation safety, patient doses

and image quality improvement.

4. ***Clinical radiation safety**:* Observation of inpatient therapy measurements/patient education. Observe brachytherapy implants (temporary/permanent) measurement/patient education. Review patient instruction booklets.
5. ***Radiation safety instrumentation – hands-on understanding*:** Understand operational differences/pros/cons for portable equipment. Tour the installed waste monitors. Perform wipe tests/leak tests.
6. ***Laboratory radiation safety:*** Assist in research laboratory radiation safety audits. Review the authorized user permitting process and inventory control.
7. ***External dosimetry system**:* Discuss monitoring program objectives and administration. Identify and discuss occupational dose limits. Review dosimetry reports (SDE, LDE, DDE, ALARA levels).
8. ***Shielding design:*** Understand NCRP methodology. Identify important points in Linac/PET shielding applications. Review ongoing shielding design packages and installations (depending on current construction projects); review design of existing facilities. Understand contribution to shielding requirements of head leakage, workload determination, broad beam transmission measurements, interpretation of regulatory requirements.
9. ***Radioactive waste management:*** Tour the decay-in-storage area. Review shipping manifests. Review DOT shipping course materials.
10. ***Environmental protection**:* Discuss regulatory limits on releases (air, water, etc.). Understand typical background levels.
11. ***Training:*** Discuss clinical desk in-service topics – nurses, doctors, and patients. Review laboratory desk training package – researchers.

Required Readings/Training

1. Khan –Chapters 15 and 16
2. NCRP Reports 116, 147, 151, 155.
3. ICRP Report 103, 118
4. Health Physics Journal Articles as assigned
5. CFR and State Regulations as assigned
6. Additional reading as determined by the rotation mentor

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Tasks/Checklist

Topic	*Radiation Safety Section Contact*	*Notes*
Clinical Desk		Check in with clinical team daily until all required cases are observed. Accompany clinical team in clinic.
Management of Therapy Patients	Bae Chu	
Observe 2 Inpatient therapy measurement/patient education (as available)	Medical Health Physics Clinical Team: Bae, Kassia, Brian S, Joaquin	
Observe 2 Outpatient therapy measurement/patient education		
Review Radioactive Precautions on Patient Eduction web pages: **Search “LDR”, “Radioactive”, etc**	https://www.mskcc.org/cancer-care/patient-education	
Observe 3 Y90 Spheres Case	Medical Health Physics Clinical Team	
Observe IORT Case (as available)		
Radiation Safety Instrumentation		Schedule with indicated contact
Hands On Operation and Theory	Dan Chiappetta	
Perform a Wipetest/leaktest	Brian Serencsits	
Laboratory		Schedule with indicated contact
Assist a Research Laboratory Audit	Kyle Machon/ Brian Serencsits	
Review the PI permitting process		
External Dosimetry		Schedule with indicated contact
Discuss Monitoring Program Objectives and Administration	Daniel Miodownik	
Identify and Discuss Occupational Limits		
Review Landauer Reports (SDE, LDE, DDE, ALARA Levels)		

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Topic	Radiation Safety Section Contact	Notes
Regulatory and Licensing		Schedule with indicated contact
Regulatory Requirements	Matt Williamson	
Shielding Design (especially NCRP 151)		Schedule with indicated contact
NCRP methodology (new and old)	Larry Dauer	
Identify Important Points in Diagnostic/LINAC/PET Shielding Applications		
Review Ongoing Shielding Design Packages and Installations (if applicable)		
Radioactive Waste Management		Schedule with indicated contact
Tour the Decay in Storage area	Bae Chu	
Review Shipping Manifest		
Review Shipping Course Materials		
Environmental Protection		Schedule with indicated contact
Discuss Regulation of environmental releases (air, water, etc.)	Brian Quinn	
Training		Schedule with indicated contact
Discuss Clinical Desk Inservice topics – nurses, doctors, patients	Bae Chu Daniel Miodownik	

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Topic	*Radiation Safety Section Contact*	*Notes*
Review Laboratory Desk Training package – researchers	Brian Serencsits Dan Chiappetta	
Literature Review: Resident folder in H:\Public		Resources available on network drive.
Khan – Radiation Safety	Larry Dauer	
NCRP –116, 147, 151; ICRP – 103, 118		
Health Physics Society Journal		
Dose Quantities and Estimation		
ICRP Dose and Risk Quantities/Units		
Internal Dosimetry Approaches		

Final Evaluation

1. Multiple choice exam is given to identify areas of improvement before final evaluation
2. Oral exam and evaluation, mentor team has a checklist of required knowledge
3. Sign off by rotation director

Therapy Physics Residency Program
Faculty Evaluation of Resident

Resident Name	**NAME**			
Rotation Name	**Medical Health Physics - Radiation Safety**			
Inclusive Dates of Rotation	**DATES**			
Faculty Name / Signature	**Lawrence T. Dauer /**			
Evaluation Criteria	**Not Competent**	**Marginally Competent**	**Fully Competent**	**Explanatory Notes**
Radiation Safety - Medical Health Physics				
• Medical Health Physics Procedures				
○ Identifies and locates institutional radiation safety administrative policies, medical staff rules, and procedures.			✓	
• Medical Health Physics Instrumentation				
○ Understand radiation detector design considerations (detection mechanisms, sensitivity, detection element size, energy dependence, dose and dose rate range, and stability of readings).			✓	
○ Reviews the advantages and disadvantages of each detector type in relation to different uses.			✓	
○ Demonstrates ability to use variety of available medical health physics instrumentation.			✓	

• Contamination Control				
○ Lists federal, state, and city regulatory requirements related to receipt of radionuclides, disposal of radioactive waste, and daily checks for contamination.			✓	
○ Demonstrates familiarity with and reviews the records required in the Radiation Oncology and Radiation Therapy Physics area.			✓	
○ Demonstrates the ability to use health physics instrumentation to perform surveys for contamination control, radionuclide package receipt, and radioactive waste disposal.			✓	
○ Demonstrates the ability to perform wipe tests for contamination.			✓	
• Shielding Design for Radiation Therapy Facilities				
○ Demonstrates familiarity with shielding design concepts and describes what information is required to perform shielding calculations and site planning and construction supervision.			✓	
○ Demonstrates knowledge of radiation exposure limits pertaining to staff and the general public for shielding.			✓	
○ Discusses shielding considerations for LINAC, HDR Brachytherapy, CT SIM, PET/CT, General Radiology, Fluoroscopy, and radioactive material use areas. IMRT.			✓	
○ Performs shielding calculations for a LINAC suite. (NCRP-151)			✓	

• Radiation Exposure to Personnel and the Public				
○ Demonstrates knowledge of radiation exposure limits to staff and the general public.			✓	
○ Describes radiation signage required for therapy facilities.			✓	
○ Explain risks of radiation exposure, LNT, source of information on secondary cancers from therapy.			✓	
○ Know the major natural sources of background radiation and know the major man-made sources of radiation exposure in U.S.			✓	
○ Demonstrate knowledge of external radiation exposure protection principles (including: time, distance, shielding, planning).			✓	
○ Understand the use of personnel monitoring systems, procedures, and reports, including declared pregnant workers.			✓	
• Radiation Protection Programs				
○ Discuss the role and responsibility of a radiation safety officer and radiation safety committee.			✓	
○ Discuss the significance of ACR, ASTRO, AAPM, NCRP, and ICRP recommendations.			✓	
○ Understand written directive requirements for Brachytherapy.			✓	
• Radiation Incidents				
○ Describes action plan for controlling the spread of contamination after a spill.			✓	
○ Describes the procedure for decontamination after a spill of radioactive material (or participates in response to a spill).			✓	
• Medical Events				
○ Demonstrates knowledge of the definition of a medical event under federal, state, and city regulations and the rules for reporting a medical event.			✓	
• Dose to Embryo/Fetus				
○ Demonstrates knowledge of the definition of medical event with regard to unplanned fetal exposure and how to determine if an event is reportable.			✓	
○ Demonstrates familiarity with the resources related to fetal dose calculations and protection in therapy.			✓	
○ Recognizes the applicable fetal dose guidance documents (NCRP Report No. 174; etc.).			✓	
• Radiation Safety Guidance				
○ Familiarity with the recommendation organizations such as the National Council on Radiation Protection and Measurements (NCRP), International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA), and the Joint Commission, and FDA for radiation and ultrasound safety.			✓	
○ Familiarity with the published literature (especially MSKCC-based) related to medical health physics/radiation protection.			✓	
○ Demonstrates knowledge of the principles of radiation protection: justification, optimization, and limitation.			✓	
○ Complete assigned readings for this rotation.			✓	

• Radiation Safety Regulations				
○ Demonstrates familiarity with federal, state, and city regulations relevant to imaging and nuclear medicine radiation protection and transportation of radioactive material.			✓	
○ Understands what an agreement state is and how they regulate.			✓	
○ Demonstrates familiarity with the contents and requirements of a radioactive materials license.			✓	
○ Participates in audits of areas that use radiation for compliance with regulations and recommendations.			✓	
• Waste and Effluent Management				
○ Understand effluent requirements, decay in storage concept, shipping manifesting, DOT and other regulatory requirements on waste transportation and disposal.			✓	

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Therapeutic Medical Physics Residency
Rotation Curriculum
Dosimetry

Rotation Director: Michael Lovelock
Rotation Mentors: as assigned
Rotation Location(s): MSKCC Main Campus / Manhattan Campuses

Duration: Ongoing through year 2

Resident Professional Expectations

1. The resident will demonstrate punctuality.
2. The resident will be present for all assignments
    a. Should a resident not be able to attend assignment enough notification with faculty should be given
3. The resident will communicate effectively with faculty, staff and physicians.
4. The resident will demonstrate professional curtesy with all oncology and physics team members.
    a. This will include use of equipment and return of facility to clinical readiness
5. The resident will support the radiation therapists.

Learning Objectives

1. The resident will be able to independently conduct daily, monthly and annual linac QA.
2. The resident will be able to develop a quality assurance program for all equipment used in clinical and quality assurance activities.
3. The resident will be able to conduct quality assurance activities in a large practice and small practice environment.
4. The resident will be able to discuss and use all quality assurance tools covered in this rotation.
5. The resident will develop treatment machine skills in treatment, physics and service modes.

Required Readings/Training

1. Report of the Task Group #51, Protocol for Clinical Dosimetry of High-Energy Photon and Electron Beams (Reprinted from Medical Physics, Vol. 26, Issue 9)
2. Report of the Task Group #53 Quality Assurance for Clinical Radiotherapy Treatment Planning (Reprinted from Medical Physics, Vol. 25, Issue 10)
3. Report of the Task Group #62 Diode in Vivo Dosimetry for Patients Receiving External Beam Radiation Therapy
4. Guidance document on delivery, treatment planning, and clinical implementation of IMRT: Report of the IMRT subcommittee of the AAPM radiation therapy committee. Medical Physics, Vol. 30, Issue 8
5. Dosimetry Task Group #70 Recommendations for clinical electron beam dosimetry: Supplement to the recommendations of Task Group 25 Medical Physics, Vol 36, Issue 7
6. Report of the Task Group #74 Report of AAPM Therapy Physics Committee Task Group 74: In- air output ratio, S_C, for megavoltage photon beams, Medical Physics, Vol 36, Issue 11
7. Dosimetry Task Group #70 Recommendations for clinical electron beam dosimetry: Supplement to the recommendations of Task Group 25, Medical Physics, Vol 36, Issue 7

8. Accelerator beam data commissioning equipment and procedures: Report of the TG-106 of the Therapy Physics Committee of the AAPM. Medical Physics, Vol 35, Issue 9
9. Report of Task Group 142 : Quality assurance of medical accelerators Medical Physics, Vol 36, Issue 9.
10. Report of Task Group 100 of the AAPM: Application of Risk Analysis Methods to Radiation Therapy Quality Management Programs. Medical Physics, Vol 43(7) July 2016.
11. AAPM Medical Physics Practice Guideline 8.a.: Linear accelerator performance tests published in the Journal of Applied Clinical Medical Physics (JACMP). Volume 18, Number 4 (2017).
12. Others as assigned.

Key Topics and Tasks

1. Complete assignments for sign off in document below.

MSKCC Physics Residency: Radiation Therapy Rotation

Dosimetry Group Progress Checklist

	Start date
Resident:	8/13/2018

Notes

1. Tasks can be competed at the earliest opportunity, prior to the milestone date. Tasks do not have to be completed in sequence.

2. There are sets of questions for each of the milestone dates. Short, concise responses are required. Email your answers to your current mentor and to Michael Lovelock. Your mentor will review your responses with you. Your responses form part of your Dosimetry Group record.

3. You are required to perform one or more end to end tests using an anthropomorphic phantom to quantify dosimetric and geometric accuracy of dose delivery. (See AAPM MPPG 9a). At the 12 month milestone, schedule with you mentor the setup and CT scan of the phantom. Over the next few weeks you need to setup the phantom in the CT simulation suite, scan ther phantom, plan the the dose distribution , deliver the treatment, and then using film dosimetry, analyse the results, and write a short report suitable for departmental review.

4. There will be two oral sessions with members of the Dosimetry Group to review your progress. These will be scheduled after the 12 and 21 month milestones

	Milestone Date	Physicist Initial	Signoff Date
Tasks to be Completed within 6 months:	**2/13/2019**		
Shadow therapists for morning QA (at least 5 sessions on different machines)			
Perform monthly QA for the CT simulation suite. Operate CT scanner for phantom scans.			
Perform monthly linac QA inclusive of imaging systems			
Perform patient specifc QA using EPID			
Perform patient specifc QA using mapcheck			

Tasks to be Completed within 12 months:	**8/13/2019**		
Perform Daily QA of Calypso			
Perform Daily QA of ExacTrac			
Perform Daily QA of AlignRT			

Perform TBI/TSET QA		
Perfrom monthy and annual QA of a kV therapy unit		
Perform radiochromic fim analysis		
Assist in Annual QA and associated data analysis of a Linac including imaging, TG51 procedure including handcalculations for photons and electrons		
Under the supervision of a qualified medical physicist, able to calibrate the morning QA device		
Run the automatic QA process on a TrueBeam (MPC).		
Perform an ISOCAL calibration or verification on a TrueBeam		
Schedule with your mentor one or more end-to-end tests (localization and dosimetry) of anthropomorphic phantom(s)		
Calibrate OSLDs		

Tasks to be Completed within 18 months:	**2/13/2020**		
Independently perform the Annual QA of a CT simulation suite			
Under the supervision of a qualified medical physicist, able to use the Profiler			

Tasks to be Completed within 21 months:	**5/13/2020**		
Independently perform annual QA, including dosimetry of the Linac imaging systems			
Complete end-to-end test of the anthropomorhpic phantom and submit report			

Final Evaluation

1. Written exam (timed closed book)
    a. Oral if written final exam is <80%
        i. Oral exam score ≥3 on 5 point scale

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
Imaging

Rotation Director: Lawrence Rothenberg
Rotation Mentors: as assigned
Rotation Location(s): MSKCC Main Campus and other locations as assigned

Duration: Ongoing for 1 year

Resident Professional Expectations

1. The resident will exhibit professional standards of MSKCC
2. The resident will complete reading and imaging QA assignments on time and as assigned
3. The resident will proactively coordinate training sessions with imaging faculty to ensure all obligations are met in conjunction with their other rotations

Learning Objectives

1. The resident will be able to develop an imaging quality assurance program.
2. The resident will be able to conduct imaging quality assurance activities in a large practice and small practice environment.
3. The resident will be able to discuss and use all imaging quality assurance tools covered in this rotation.

Required Readings/Training

1. Report of Task Group 100 of the AAPM: Application of Risk Analysis Methods to Radiation Therapy Quality Management Programs. Medical Physics, Vol 43(7) July 2016.
2. AAPM Medical Physics Practice Guideline 2.a: Commissioning and quality assurance of X-ray–based image-guided radiotherapy systems published in the Journal of Applied Clinical Medical Physics (JACMP). Volume 15, Number 1 (2014). [ISBN: 978-1-936366-31-6]
3. ACR Guidance Document on MR Safe Practices: 2013. Journal of Magnetic Resonance Imaging 37:501-530 (2013).
4. Phantom Test Guidance. ACR MRI Accreditation Program. American College of Radiology.

Key Topics and Tasks

1. Review appropriate AAPM Task Group Reports of relevant Diagnostic Imaging Devices
2. Complete Annual Compliance Tests on
    a. 2 or more CT scanners
    b. 2 or more ultrasound units
    c. 2 or more mobile C-arm fluoroscopy units
    d. At least 1 MRI scanner
    e. At least 1 PET/CT scanner

Final Evaluation

1. Mentor sign off on task list

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THERAPY PHYSICS RESIDENCY PROGRAM FACULTY EVALUATION OF RESIDENT – IMAGING ROTATION				
Resident name				
Rotation name	**Computed Tomography**			
Inclusive dates of rotation				
Faculty name				
Evaluation Criteria	**Not Completed**	**Marginally Completed**	**Fully Completed**	**Explanatory Notes**
Patient care	*(residents should provide information that is appropriate, accurate and relevant to diagnosis of health problems)*			
1. Observes and understands annual compliance testing of a computed tomography scanner.				
2. Observes and understands annual compliance testing of a second computed tomography scanner.				
3. Observes and understands annual compliance testing of additional computed tomography scanners.				
4. Understands calculation of CTDI for computed tomographic examinations.				
Medical knowledge	*(residents should be knowledgeable, scholarly, and committed to lifelong learning)*			
5. Explains the complete computed tomographic imaging chain from production of X-rays to image reconstruction.				
6. Explains the physical meaning of Hounsfield Units.				
7. Explains how specifics of imaging protocol affect patient dose and diagnostic benefits of examination.				
Practice-based learning and improvement	*(residents should investigate and evaluate patient care practices, appraise and assimilate scientific evidence and improve patient care practices)*			
8. Assists with analysis of results of testing and observes unexpected findings including image artifacts.				
9. Assists with investigation of equipment performance and image quality problems.				
10. Recognizes and corrects personal errors.				
Interpersonal and communication skills	*(residents should demonstrate effective information exchange with physicians, technologists, service personnel, and professional associates)*			
11. Works effectively with others as a member of a health care team.				

12. Assists with production of written reports				
13. Listens effectively and follows directions				

THERAPY PHYSICS RESIDENCY PROGRAM FACULTY EVALUATION OF RESIDENT – IMAGING ROTATION				
Resident name				
Rotation name	**ULTRASOUND**			
Inclusive dates of rotation				
Faculty name				
Evaluation Criteria	**Not Completed**	**Marginally Completed**	**Fully Completed**	**Explanatory Notes**
Patient care	*(residents should provide information that is appropriate, accurate and relevant to diagnosis of health problems)*			
1. Observes and understands annual physics quality control testing of a general ultrasound unit and associated transducers.				
2. Observes and understands annual physics quality control testing of a second general ultrasound unit and associated transducers.				
3. Observes and understands annual physics quality control testing of additional general ultrasound units and associated transducers.				
4. Reviews historical QC data for units from at least one section of DI scanners (general, breast, IR, head and neck, O.R./ICU)				
5. Is familiar with all the areas in DI using ultrasound and the primary exams performed in each area.				
Medical knowledge	*(residents should be knowledgeable, scholarly, and committed to lifelong learning)*			
6. Explains the complete ultrasound imaging chain from production of vibrations to image reconstruction.				
7. Explains the sources of contrast in ultrasound imaging.				
8. Explains how specifics of imaging protocol affect the diagnostic benefits of examination.				
9. Understands and can explain the principles of ultrasound safety and ALARA with respect to FDA regulations.				
10. Understands and can explain modern clinical ultrasound techniques, some common commercial names and their use/benefit in the clinic, including power doppler, tissue harmonic imaging, spatial/frequency compound imaging, panoramic imaging, phase aberration correction, 1.5D and 2D scanhead				

technology, 3D image acquisition, and broadband technology.				
Practice-based learning and improvement	*(residents should investigate and evaluate patient care practices, appraise and assimilate scientific evidence and improve patient care practices)*			
11. Observes analysis of results of testing and recognition of unexpected findings including image artifacts.				
12. Observes equipment performance and image quality problem evaluation.				
13. Recognizes and corrects personal errors.				
Interpersonal and communication skills	*(residents should demonstrate effective information exchange with physicians, technologists, service personnel, and professional associates)*			
14. Works effectively with others as a member of a health care team.				
15. Assists with production of written reports that are accurate, concise, and grammatically correct.				
16. Listens effectively and follows directions.				

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THERAPY PHYSICS RESIDENCY PROGRAM FACULTY EVALUATION OF RESIDENT – IMAGING ROTATION				
Resident name				
Rotation name	**FLUOROSCOPY**			
Inclusive dates of rotation				
Faculty name				
Evaluation Criteria	**Not Completed**	**Marginally Completed**	**Fully Completed**	**Explanatory Notes**
Patient care	*(residents should provide information that is appropriate, accurate and relevant to diagnosis of health problems)*			
1. Observes annual compliance testing of a mobile fluoroscopic system.				
2 Observes annual compliance testing of a second mobile fluoroscopic system.				
3. Observes operation of fluoroscopic systems with appropriate regard for radiation safety.				
4. Determines entrance exposure rate for fluoroscopic examinations.				
5. Estimates patient ionizing radiation dose and risk for fluoroscopic examinations.				
Medical knowledge	*(residents should be knowledgeable, scholarly, and committed to lifelong learning)*			
6. Explains the complete fluoroscopic imaging chain from production of X-rays to image formation.				
7. Explains how operator choices affect patient dose and image quality.				
8. Explains methods of exposure control in fluoroscopic systems that use image intensifiers and digital receptors.				
Practice-based learning and improvement	*(residents should investigate and evaluate patient care practices, appraise and assimilate scientific evidence and improve patient care practices)*			
9. Assists with analysis of results of testing and observes unexpected findings.				
10. Observes Investigation of equipment performance and image quality problems.				
11. Recognizes and corrects personal errors.				
Interpersonal and communication skills	*(residents should demonstrate effective information exchange with physicians, technologists, service personnel, and professional associates)*			
12. Works effectively with others as a member of a health care team.				
13. Assists with production of written reports that are accurate, concise, and grammatically correct.				

14. Listens effectively and follows directions.				

THERAPY PHYSICS RESIDENCY PROGRAM FACULTY EVALUATION OF RESIDENT – IMAGING ROTATION				
Resident name				
Rotation name	**NUCLEAR MEDICINE – PET, SPECT, GAMMA CAMERA**			
Inclusive dates of rotation				
Faculty name				
Evaluation Criteria	**Not Completed**	**Marginally Completed**	**Fully Completed**	**Explanatory Notes**
Patient care	*(residents should provide information that is appropriate, accurate and relevant to diagnosis of health problems)*			
1. Assists with performance of annual compliance testing of a nuclear medicine gamma camera.				
2. Assists with performance orf annual compliance testing of a positron emission tomography scanner.				
3.Assists with performance of QC tests and calibrations of nuclear medicine imaging systems, dose calibrators, and counting systems.				
4. Estimates patient and conceptus ionizing radiation doses and risk for nuclear medicine examinations.				
5. Is familiar with radiopharmacy and radiation safety and protection procedures and associated regulations.				
6. Computes exposure factors related to radiation safety of release of a radioactive patient.				
Medical knowledge	*(residents should be knowledgeable, scholarly, and committed to lifelong learning)*			
7. Explains the complete nuclear medicine imaging chain from the ionizing radiation source to image reconstruction.				
8. Understands the use and characteristics of radionuclides for nuclear medicine imaging and therapy.				
9. Explains how uptake and clearance of radionuclides affects patient dose and benefits of examination.				
Practice-based learning and improvement	*(residents should investigate and evaluate patient care practices, appraise and assimilate scientific evidence and improve patient care practices)*			
10. Assists with analysis of results of testing and recognition of unexpected findings.				
11. Assists with investigation of equipment performance and image quality problems.				
12. Recognizes and corrects personal errors.				

Interpersonal and communication skills	*(residents should demonstrate effective information exchange with physicians, technologists, service personnel, and professional associates)*			
13. Works effectively with others as a member or leader of a health care team.				
14. Assists with production of written reports that are accurate, concise, and grammatically correct.				
16. Listens effectively and follows directions.				
Professionalism	*(residents should carry out responsibilities, adhere to ethical principles and show sensitivity to a diverse patient population)*			
17. Responsive to the needs of patients that supersedes self-interest.				
18. Respects patient privacy and confidentiality.				
19. Commitment to excellence and ongoing professional development.				
Systems-based practice	*(residents should be aware of the system of health care and effectively call on system resources to provide optimal care)*			
20. Understands how their professional practices affect other health care professionals.				
21. Utilizes system resources effectively to provide care that is of optimal value.				

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THERAPY PHYSICS RESIDENCY PROGRAM FACULTY EVALUATION OF RESIDENT – IMAGING ROTATION				
Resident name				
Rotation name	**MAGNETIC RESONANCE IMAGING**			
Inclusive dates of rotation				
Faculty name				
Evaluation Criteria	**Not Completed**	**Marginally Completed**	**Fully Completed**	**Explanatory Notes**
Patient care	*(residents should provide information that is appropriate, accurate and relevant to diagnosis of health problems)*			
1. Assists with annual testing of a magnetic resonance imaging system. - Observes and understands Annual Evaluations and Quality Control Testing of an MRI System including RF Coil Evaluations.				
2. Assists with daily quality control tests of a magnetic resonance imaging system.				
4. Assists with quality control tests on RF coils.				
5. Analyzes phantom images with all other requirements of ACR MR accreditation program.				
a) Learn how to complete ACR Data Form for Weekly (Daily) MRI Equipment Quality Control. b) Understand the meaning of data and parameters measured and entered on ACR Form during Weekly (Daily) QC MRI Testing. c) To be able to complete ACR MRI Accreditation Program Visual Checklist Form during observation of Annual Evaluations.				
6. Practices MR safety. - Comply with MSKCC MRI Safety Training and with any other MRI Safety requirement before accessing an MRI Suite for the first time.				
7. Reviews plans for siting of a magnetic resonance imaging system.				
8. Uses information technology to retrieve and store patient demographic, examination, and image information.				
Attend MRI Clinical Observation Sessions at sites available at the time of scheduling				

Medical knowledge	*(residents should be knowledgeable, scholarly, and committed to lifelong learning)*				
9. Explains the complete magnetic resonance imaging chain from production of signal to image reconstruction.					
10. Explains the role of k-space mapping in MR imaging.					
11. Explains how specific pulse sequences affect contrast in MRI and diagnostic benefits of examination.					
12. Uses information technology to investigate clinical, and technical questions.					
Practice-based learning and improvement	*(residents should investigate and evaluate patient care practices, appraise and assimilate scientific evidence and improve patient care practices)*				
13. Assists with analysis of results of testing and recognizes unexpected findings including image artifacts.					
14. Assists with investigation of equipment performance and image quality problems.					
15. Recognizes and corrects personal errors.					
Interpersonal and communication skills	*(residents should demonstrate effective information exchange with physicians, technologists, service personnel, and professional associates)*				
16. Works effectively with others as a member or leader of a health care team.					
17. Assists with production of written reports that are accurate, concise, and grammatically correct.					
18. Listens effectively.					
Professionalism	*(residents should carry*				

	out responsibilities, adher to ethical principles and show sensitivity to a diverse patient population)			
20. Responsive to the needs of patients that supersedes self-interest.				
21. Respects patient privacy and confidentiality.				
22. Commitment to excellence and ongoing professional development.				
Systems-based practice	*(residents should be aware of the system of health care and effectively call on system resources to provide optimal care)*			
24. Understands how professional practices affect other health care professionals.				

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
Radiation Oncology Informatics

Rotation Director: Watchman
Rotation Mentors: Watchman
Rotation Location(s): MSKCC Main Campus

Duration: 4 Weeks full time
Clinical assignment when opportunity is available

Resident Professional Expectations

1. The resident will exhibit professional standards of MSKCC
2. The resident will complete reading assignments prior to weekly meetings with mentor

Learning Objectives

1. The resident will be able to discuss imaging informatics standards.
2. The resident will be able to discuss DICOM-RT Standards.
3. The resident will be able to discuss and work with Record and Verify systems.
4. The resident will be able to develop and run imaging workstation quality assurance.
5. The resident will be able to discuss and implement treatment record design and maintenance.
6. The resident will understand the roles of the different members of the medical/radiation oncology informatics team.

Required Readings/Training

1. Starkschall, G and Siochi, A. Informatics in Radiation Oncology. CRC Press 2013, ISBN: 9781439825822
2. RA Soichi et al. AAPM Report 201. "Information Technology Resource Management in Radiation Oncology". OURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 10, NUMBER 4, FALL 2009. https://doi.org/10.1120/jacmp.v10i4.3116
3. Assessment of Display Performance for Medical Imaging Systems: Executive Summary of AAPM TG18 Report. https://aapm.onlinelibrary.wiley.com/doi/epdf/10.1118/1.1861159
4. https://www.aapm.org/IHERO/
5. https://www.dicomstandard.org/
6. M Law, B Lui. "DICOM-RT and its Utilization in Radiation Therapy". Radiographics Vol. 29 No. 3 Pg. 655-667.
7. Bushberg , JT et al. "Chapter 5: Medical Imaging Informatics" The Essential Physics of Medical Imaging. 3rd Edition, Lippincott Williams & Watkins ©2012

Key Topics and Tasks

1. PACS systems and their integration
2. HL7
3. DICOM standards
4. DICOM in radiation therapy (DICOM-RT)
5. Information acquisition from PACS/images
6. Quality/maintenance of imaging workstations
7. Evaluation of viewing conditions

8. Image registration, fusion, segmentation, processing
9. Quantitative analysis
10. Record and verify systems
11. Treatment record design/maintenance
12. IHE – Radiation Oncology (IHE-RO)
13. Network integration/management, and roles of physics and information technology staff

In addition to the Radiation Oncology specific informatics discussions the residents will meet with or have lectures from the following:

- PACS and RIS systems and their integration (Radiology Workflow) Brenda Maxworthy
- What is HL7 (Health Level Seven International) (Daniel LaFontaine)
- DICOM standards (Brad Beattie)
- Information acquisition from PACS/images (Daniel LaFontaine)
- Informatics variations among modalities (Daniel LaFontaine)
- Dose reporting features – Dose watch (Usman Mahmood)
- Use of IHE (Integrating Healthcare Enerprise) radiology profiles (Brenda Maxworthy)
- Open source software resources (Krishna Juluru)
- How do radiologists read scans (Krishna Juluru)
- Quality/maintenance of imaging workstations (Andreas Ruuge)
- Evaluation of viewing conditions (Andreas Ruuge)
- Image registration, fusion, segmentation, processing (Aditya Apte)
- Quantitative analysis (Amita Dave)
- Kinetic modeling/computer analysis (Brad Beattie)
- Radiomics / Texture Analysis (Aditya Apte)
- Deep Learning (Harini Veeraraghavan)
- Artificial Intelligence (Anyi Li)

These meetings/lectures will be given annually and the resident will provide documentation of attendance.

Final Evaluation

1. Oral Exam
    a. Oral exam score ≥3 on 5-point scale

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
Commissioning

Rotation Director: Michael Lovelock
Rotation Mentors: S. Gary Lim
Rotation Location(s): Location TBD based on machine location

Duration: 4 Weeks full time
Additional assignments given when available

Resident Professional Expectations

1. The resident will demonstrate punctuality.
2. The resident will be present for all assignments
    a. Should a resident not be able to attend assignment enough notification with faculty should be given
3. The resident will communicate effectively with faculty, staff and physicians.
4. The resident will demonstrate professional curtesy with all oncology and physics team members.
    a. This will include use of equipment and return of facility to clinical readiness
5. The resident will support the radiation therapists.

Learning Objectives

1. The resident will understand and be able to acquire needed beam data.
2. The resident will be able to manage beam data.
3. The resident will understand process of beam modelling.
4. The resident will be able to evaluate image import and quality in the commissioned system.
5. The resident will be able to discuss and implement the process of commissioning.

Required Readings/Training

1. Report of Task Group 142 : Quality assurance of medical accelerators Medical Physics, Vol 36, Issue 9.
2. Report of Task Group 100 of the AAPM: Application of Risk Analysis Methods to Radiation Therapy Quality Management Programs. Medical Physics, Vol 43(7) July 2016.
3. AAPM Medical Physics Practice Guideline 8.a.: Linear accelerator performance tests published in the Journal of Applied Clinical Medical Physics (JACMP). Volume 18, Number 4 (2017).
4. AAPM Medical Physics Practice Guideline 2.a: Commissioning and quality assurance of X-ray–based image-guided radiotherapy systems published in the Journal of Applied Clinical Medical Physics (JACMP). Volume 15, Number 1 (2014). [ISBN: 978-1-936366-31-6]
5. Report of Task Group#119 IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119, Medical Physics, Vol 32, Issue 11
6. Report of the Task Group #53 Quality Assurance for Clinical Radiotherapy Treatment Planning (Reprinted from Medical Physics, Vol. 25, Issue 10)
7. Report of the Task Group #51, Protocol for Clinical Dosimetry of High-Energy Photon and Electron Beams (Reprinted from Medical Physics, Vol. 26, Issue 9)
8. Report of the Task Group #51, Protocol for Clinical Dosimetry of High-Energy Photon and Electron Beams (Reprinted from Medical Physics, Vol. 26, Issue 9)

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Key Topics and Tasks

1. Complete the commissioning report and include all data
    a. See report after evaluation

Final Evaluation

1. Oral Exam
    a. Passing ≥3 on a 5 point scale.

Linear accelerator commissioning report

Machine name:

SN:

Machine type: Varian

Energies:

Photons:

Electrons:

Acceptance Date:

Clinical release date:

Commissioning Personnel:

Contents:

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Release of a New Treatment Machine

Department of Medical Physics

Name of Machine:

Serial Number:

Site

Request for Clinical Release

Requested and Certified by:

Signature:

Approval for Release

Dosimetry Approval

Signature:

Treatment Planning Approval:

Signature:

Regional Lead Approval:

Signature:

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Date of Release for Clinical Service:

SRS Clinical Release:

Description:

Acceptance Certificate

Water Tank measurements

PDDs

Beam Quality Photons: PDD at d=10 cm, 20 cm

Machine	
Date of measurement	
Physicists	
Water tank	
Field detector	
Reference detector	
SSD	
Data processing	
Reference data	

Photons (Tolerance 1% - TG142)							
Energy	Field Size (cm)	**%DD (10 cm)**		**%DD (20 cm)**		**% Difference from 245-TB3**	
						%DD (10 cm)	%DD (20 cm)
6 MV	3×3						
	10×10						
	30×30						
6FFF	3×3						
	10×10						
	30×30						

Beam Quality Electrons R50

Electrons (Tolerance 1 mm – TG142)				
Energy	Field Size (cm)	R50 (mm)		
6 MeV	6×6			
	10×10			
	25×25			
9 MeV	6×6			
	10×10			
	25×25			
12 MeV	6×6			
	10×10			

	25×25			

Profiles

Measurement data extracted from OmniPro Accept/myQA Accept using the profile analysis template "Varian" for photons and electrons.

Machine	
Date of measurement	
Physicists	
Water tank	
Field detector	
Reference detector	
SSD	
Data processing	
Reference data	

Predefined parameters are:

- **Center**
- **Penumbra**
- **Field width**
- **Flatness:** defined as Variation over mean (80%). It´s calculates as $F = 100*|d_{max} - d_{min}|/(d_{max} + d_{min})$.
- **Symmetry:** defined as Point difference: max difference in dose between points on equal distance from central axis within flattened area:

$Symmetry = 100*max (|Point_L - Point_L|) / D_{cax}$

The flattened area is defined as 80% of FW.

Photon Symmetry. QA3 used for measurement. Tolerance 1% TG142

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Energy	dmax (cm)	Center	Gun	Target	Right	Left	Asymmetry (%)	
							Radial	Trans
6x	**1.5**							
6fff	**1.5**							

Symmetrized Photon Profile Flatness. Tolerance 1% TG142						
Energy	Field Size (cm)	Depth (cm)				% Difference (Machine - 245)
6 MV	3×3	1.4	Inline			
			Crossline			
		10	Inline			
			Crossline		6.11	
	10×10	1.4	Inline	0.75	0.65	-0.1
			Crossline			
		10	Inline			
			Crossline			
	30×30	1.4	Inline			
			Crossline			
		10	Inline			
			Crossline			

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Symmetrized Electrons Profile Flatness. Tol: 1% from baseline (444) TG142						
	Depth (cm)	Field Size (cm)				**Difference** **(Machine - 444)**
6E	1.2	6×6	Inline			
			Crossline			
		10×10	Inline			
			Crossline			
		25×25	Inline			
			Crossline			
9E	2.0	6×6	Inline			
			Crossline			
		10×10	Inline			
			Crossline			
		25×25	Inline			
			Crossline			
12 E	2.5	6×6	Inline			
			Crossline			
		10×10	Inline			
			Crossline			
		25×25	Inline			
			Crossline			

Electron Symmetry. QA3 used for measurement. Tolerance 1% TG142							
Energy	**dmax (cm)**	**Center**	**Gun**	**Target**	**Right**	**Left**	**Asymmetry (%)**

							Radial	Trans
6e	**1.5**							
9e	**2.0**							
12e	**2.5**							

Output Factors

Machine	
Date of measurement	
Physicists	
Water tank/solid water	
Detector (SN)	
Electrometer	
SSD	
Electrometer voltage bias	
Data processing	
Reference data	

Photons. Tolerance 2% < 4x4, 1% > 4x4. TG142					
Energy	Field Size (cm)	245 TB3	Measurement		% Diff (Machine/245)
			Raw reading	Output factor	
6 MV	3×3	0.877			
	10×10	1.000			
	30×30	1.100			
6FFF	3×3	0.895			
	10×10	1.000			
	30×30	1.072			

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Cone Factors

Electrons. Tolerance +/- 2%. TG142					
Energy	Field Size (cm)	245 TB3	Measurement		**% Diff (Machine/245)**
			Raw reading	Output factor	
6 MeV	6×6	0.937			
	10×10	1.000			
	15×15	1.003			
	20×20	1.046			
	25×25	1.072			
9 MeV	6×6	0.982			
	10×10	1.000			
	15×15	0.996			
	20×20	1.009			
	25×25	1.008			
12 MeV	6×6	0.959			
	10×10	1.000			
	15×15	1.003			
	20×20	1.002			
	25×25	0.990			

Percentage depth dose -SRS

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Measurement data extracted from OmniPro Accpet/myQA Accept

using the depth dose analysis template "AAPM TG-21" for photons and "AAPM TG-25" for electrons.

Machine	
Date of measurement	
Physicists	
Water tank	
Field detector	
Reference detector	
Setup	
Data processing	
Reference data	

Photon PDD. Tolerance: 10cm and 20 cm: 1% TG142								
Energy	MLC (cm) X, Y	Jaws (cm) X, Y	%DD (10 cm)		%DD (20 cm)		% Difference (Machine - 244)	
							%DD (10 cm)	%DD (20 cm)
6 MV	0.5 × 1.0	1.2 × 1.2						
	1 × 1	1.2 × 1.2						
	2 × 2	2.2 × 2.2						
	3 × 3	3.2 × 3.2						
6 FFF	0.5 × 1.0	1.2 × 1.2						
	1 × 1	1.2 × 1.2						
	2 × 2	2.2 × 2.2						
	3 × 3	3.2 × 3.2						

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Profiles - SRS

Measurement data extracted from OmniPro Accpet/myQA Accept using the profile analysis template "Varian" for photons.

Machine	
Date of measurement	
Physicists	
Water tank	
Field detector	
Reference detector	
Setup	
Data processing	
Reference data	

Symmetry 3% (MPPG9a)							
Energy	MLC (cm) X, Y	Jaws (cm) X, Y	Depth (cm)				Difference (Machine - 444)
6X	1 × 1	1.2 × 1.2	1.4	Inline			
				Crossline			
			10	Inline			
				Crossline			

	2 × 2	2.2 × 2.2	1.4	Inline			
				Crossline			
			10	Inline			
				Crossline			
	3 × 3	3.2 × 3.2	1.4	Inline			
				Crossline			
			10	Inline			
				Crossline			

Dynamic Wedges

Ratio of Wedge Profiles: machine # to Corresponding point calculated in Eclipse Tol 2%. TG142			
Field size (cm)	(X,Y)	45 deg IN	45 deg OUT
4 × 4	CAX		
10 × 10	CAX		
	(x,y) = 0, 3		
	(x,y) = 3, 0		
	(x,y) = 0, -3		
	(x,y) = 3, -3		
	(x,y) = 3, 3		
20 × 20	CAX		
	(x,y) = 0, 7		
	(x,y) = 7, 0		
	(x,y) = 0, -7		

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	(x,y) = 7,-7		
	(x,y) = 7, 7		

Ratio (%) of Wedge Factors: 243 / Eclipse (Tolerance 2%. TG142)

Wedge:	10 deg IN	15 deg IN	20 deg IN	25 deg IN	30 deg IN	45 deg IN	60 deg IN	45 deg IN, 50 MU	45 deg IN, 200 MU	45 deg OUT
CAX										

Annual QA Report

MSKCC Linac Annual Calibration — Year **2019** — **Room** **243**

Enter current values (record visual measurements to the nearest 0.5 mm.); if adjustments are made, copy the table and paste onto the right of the page.
Tolerances are consistent with TG40, TG142, MPPG#8 and MPPG#2a. Values in parenthesis indicate action levels at MSKCC. — *Fill in green cells
Each linac is associated with its own Aria QA test patient for various tests in the annual QA. — **Yellow cells indicate calculated values
Associated Aria test patient MRN: — ***Blue cells indicate calculated/lookup values

1. Field light centricity

Date: 11/6/2019 Physicist: SL *Tolerance : 1 mm shift*

For TrueBeam machines:

The centricity of the light source with collimator rotation can be checked by using the shadow of the crosshairs projected to a piece of paper at the base of the 25×25 electron cone at collimator angles of 90° and 270°. Record the radial and transverse shifts.

	Light bulb 1	Light bulb 2
Radial shift (mm)	< 0.5 mm	< 0.5 mm
Transverse shift (mm)	0.5 mm	0.5 mm

For C-series machines:

The centricity of the light source with collimator rotation can be checked by using an object with a right angle at one corner, suspended close to the crosshairs. The shadow of the object on the couchtop at 100 SSD is marked on a piece of paper at collimator angles of 90° and 270°. Record the radial and transverse shifts.

	Light bulb
Radial shift (mm)	
Transverse shift (mm)	

2. Crosshair Centricity and Skew vs Collimator Rotation

Date: 11/6/2019 Physicist: SL *Tolerance : 2 mm diamter for centricity; 1 mm for skew*

a) The projection of crosshairs is marked at collimator angles of 0°, 90°, and 270° at 100 cm. Record the diameter of the smallest circle at 100 cm.

0.5 mm diameter

b) Align the graph paper using a 1 cm MLC field (at collimator 0° only). Record the deviation of the crosshair to the graph paper over a 20 cm length.
The MLC file is located at: va_transfer\TDS\input\Physics\Monthly QA\MLC 40x1cm.mlc

0.5 mm

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4. Mechanical Isocenter vs Gantry Rotation

Date: 11/6/2019 Physicist: SL/TL *Tolerance : ±1 mm from baseline->* mm, from

Check the extension of the front pointer by rotating the gantry from 90° to 270°.
A second pointer, with a 2 mm diamter tip is secured horizontally off the end of the table top so that its tip is near the isocenter. The horizontal pointer is moved vertically and laterally, such that the center of the circle is defined by the horizontal pointer by rotating the gantry through 360°. The center of this circle is effectively the mechanical isocenter.
The degree of extension of the front point should be recorded for future reference. Record the diameter of the smallest circle, which includes all the pointer positions.
*Note: leave the horizontal front pointer in this position for the next two tests.

0.5 mm diameter

5. Crosshair Centricity vs Gantry Rotation

Date: 11/19/2019 Physicist: SL *Tolerance : 2 mm diameter*

The projection of the crosshairs, w.r.t. the horizontal front pointer, is observed at various gantry angles through 360° by placing a piece of graph paper just behind the pointer.
The center of the horizontal front pointer is the mechanical isocenter, the maximum crosshair shift is:

< 0.5 mm

6. Laser Alignment

Date: 11/19/2019 Physicist: SL *Tolerance : 1 mm*

For 100 cm wall lasers, check position w.r.t. the mechanical isocenter using the front pointer. For 130 cm lasers, measure the distance from the 100 cm lasers using a ruler.
For ceiling and sagittal lasers, align the graph paper using a 1 cm MLC field (at collimator 0° only). Record the shifts of the lasers with respect to the graph paper.
The MLC file is located at: va_transfer\TDS\input\Physics\Monthly QA\MLC 40x1cm.mlc

Lateral	**Left wall**		**Right Wall**	
	Vertical	**Horizontal**	**Vertical**	**Horizontal**
100 cm	0.5 mm	< 0.5 mm	0.5 mm	< 0.5 mm
130 cm	< 0.5	0.5 mm	0.5 mm	0.5 mm

Ceiling	**Transverse**	**Longitudinal**
	0.5 mm	< 0.5 mm
Sagittal	< 0.5 mm	

7. Optical Distance Indicator

Date: 11/19/2019 Physicist: SL *Tolerance : 1 mm @ isocenter (2 mm @ 80, 5 mm@ 130)*

Place the graph paper on the couch. To make sure the surface of the paper is at SSD 100 cm, rotate the gantry ±45° and adjust the couch height until the crosshair projection doesn't vary with respect to the line on the paper. Check and make sure the ODI is at 100 cm.
Attach a ruler to the couch (best to attach the ruler to a 5 cm slab phantom placed on the couch). Use the laser to guide you to adjust the couch up by 20 cm and down by 30 cm. Check the ODI at 80 cm SSD and 130 cm SSD.

Distance	**80 cm SSD**	**100 cm SSD**	**130 cm SSD**
ODI	79.9	99.9	130.0

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8. Gantry Angle Indicator

Date: 11/18/2019 Physicist: SL *Tolerance : 1.0° (0.5°)*

Place a level on the interface mount or on the accessory mount and obtain the true angle for the four orthogonal gantry angles. Check the digital readout.
Note: For machines which treat patients at extended distances, e.g. 130 cm, a 0.5° gantry misalignment will appear as a 0.26 cm translation of the isocenter (30 cm x tan 0.5°).
The calibration of the gantry angle at 0° and 180° should be more stringent, when possible, for these machines.

True angle with spirit level	180° cw	90°	0°	270°	180° ccw
Digital Indicator	180.0	89.9	359.9	269.9	180.0

9. Collimator Angle Indicator

Date: 11/18/2019 Physicist: SL *Tolerance : 1.0° (0.5°)*

Align the graph paper following the same setup procedure as for the ceiling/sagittal lasers. Adjust the collimator angle such that the MLC is parallel to the graph paper. This is the effective 0° collimator angle. Record the digital indicator reading. Rotate the collimator angle so that the MLC is aligned to the graph paper at 90° and 270°. Record the digital indicator readings.

	90°	0°	270°
Digital Indicator	90.0	0.0	270.0

10. Field size defined at 100 cm SAD by light field (JAWS)

Date: 11/29/2019 Physicist: SL *Tolerance : 2 mm or 1% of field width at isocenter (symmetric)*
1 mm (1 mm) on any side at isocenter (asymmetric)

Adjust the collimators to match several field sizes covering the clinical range. Record the digital readout. Do this for the upper and lower jaws (in symmetric and asymmetric modes).

Symmetric mode (cm)	Digital readout (cm)	
	Y	X
5×5	5.0	5.0
10×10	10.0	10.0
20×20	20.0	20.0
30×30	30.0	30.0

Asymmetric mode (cm)	Digital readout (cm)			
	Y1	Y2	X1	X2
-9 (Y)	-9.1	-9.0		
-4 (Y), -2 (X)	-4.1	-4.0	-1.9	-2.0
2	2.0	2.0	2.0	2.0
8	8.0	8.0	8.0	8.0
14	14.0	14.0	14.0	14.0
19	19.0	19.0	19.0	19.1

11a. Field size defined at 100 cm SAD by light field (MLC)

Date: 11/29/2019 Physicist: SL *Tolerance : 1 mm*

Load the "Leafcal2.mlc" file and start the autocycle mode. Record the leaf positions observed on the graph paper. Note: If leaf positions exceed tolerance, reintialize and recheck. If this does not correct the problem, verify that the gap and offset calibration values in the configuration file have not changed.

For TB : To reocrd the control parameters, in Service mode, select "MLC" tab. Select "Initialization" and then select "Calibrate". The values will appear in the pop-up window.
For C-series : The control parameters are located in files on the MLC workstation computer C:\Program Files (x86)\Varian\Oncology\Clinac\Controller\SysOffsets.txt

Setting (cm)	Carriage A	Carriage B	A leaves	B leaves
16.0	16.0	16.0	16.0	16.0
12.0	12.0	12.0	12.1	12.0
8.0	8.0	8.0	8.1	8.0
4.0	4.1	4.0	4.1	4.0
0.5	0.6	0.5		
-4.0	-4.0	-4.0		
-8.0	-8.0	-8.0		
12.0	-11.9	-12.0		
-16.0	-15.9	-15.9		

Control parameters (cm)			
TrueBeam		C-series	
A start	0.054	LfGpErr	
A stop	0.069	CntLnOfs	
B start	-0.004	Skew	
B stop	-0.019		

Reference: Control parameters (cm)			
TrueBeam		C-series	
A start		LfGpErr	
A stop		CntLnOfs	
B start		Skew	
B stop			

11b. Picket fence with gantry rotation

Date: 10/31/2019 Physicist: SL/TL *Tolerance : 1 mm (0.5 mm)*

Secure a piece a film on the block tray with 2 mm copper plate for buildup. Mount the block tray to the gantry. Deliver the plan “AbuttFld_film” using the Aria QA patient.
Four bands are delivered at gantry 0°, while one band is delivered at each of the following gantry angles: 90°, 180°, and 270°.
Observe any deviation of the leaves and the carriages between the bands.

Deviation: < 0.5 mm

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12a. Graticule Position

Date: 11/26/2019 Physicist: SL *Tolerance : 2 mm (1 mm)*

Check for either the electronic grid or physical grid, depending on the machine.

Electronic grid (digital graticule)

Align MV/kV iso concordance phantom with lasers. Acquire a MV image of the phantom at gantry 0^o.
Load image in the Aria/Eclipse system or at the machine console. Turn on the digital graticule.
Measure and record the distance/deviation from the center of the graticule to the center of the ball bearing (which is a surrogate of the isocenter).

Deviation < 0.5 mm

Physical grid (physical graticule)

Align the graph paper to the crosshair at gantry 0^o, at SSD 100 cm. Mount the physical graticule tray on the gantry.
Measure and record the distance/deviation from the center of the graticule to the center of the graph paper (crosshair).

Deviation mm

12b. Block Tray Position

Date: 11/26/2019 Physicist: SL *Tolerance : 2 mm*

Insert block tray. Measure deviation with the light field, at isocenter, between the machine crosshairs and the tray crosshairs.

Deviation: 1.0 mm **Check here if the blocking tray latches** Y

13. Electron Applicator Position

Date: 11/26/2019 Physicist: SL *Tolerance : 2 mm*

Find the center of the field with the standard insert (i.e. align the field edges symmetrically about an origin indicated on graph paper), and record the deviation from the crosshairs. Verify that interlock is present without insert (Y/N).

Cone	Radial (cm)	Transverse (cm)	Insert interlock
6×6	1 mm	0.5 mm	V
10×10	< 0.5 mm	0.5 mm	V
15×15	0.5 mm	0.5 mm	V
20×20	0.5 mm	1 mm	V
25×25	0.5 mm	0.5 mm	V

14. Radiation Isocenter vs Gantry Rotation

Date: 11/19/2019 Physicist: SL/TL *Tolerance : ±1 mm from baseline->* mm, from

*Note: check calibrations of MLC before performing this test.

a) Attach the front pointer and mark the mechanical isocenter with a pen on a film. A "star" pattern exposure is created on the film by repeatedly exposing (in the transverse plane) a 3 mm slit field (MLC-defined) at several gantry angles differing by 40^o. Set collimator angle to 0^o. The MLC file can be found in TDS/input/Physics/Annual QA/3mm_starshot.mlc.
Draw the center-lines of these fields. Measure the diameter of the smallest circle which intersects all the center-lines.

0.8 mm

b) Record the deviation of the radiation and mechanical isocenters, i.e. the center of the circle w.r.t. the pen mark.

0.3 mm

15. Radiation Isocenter vs Collimator Rotation

Date: 11/19/2019 Physicist: SL/TL *Tolerance : ±1 mm from baseline->* mm, from

*Note: check calibrations of MLC before performing this test.

a) Attach the front pointer and mark the mechanical isocenter with a pen on a film. A "star" pattern exposure is created on the film by repeatedly exposing a 3 mm MLC-defined slit field perpendicular to the central axis of the beam. The MLC file can be found in TDS/input/Physics/Annual QA/3mm_starshot.mlc. The collimator is rotated 30^o between each of the 6 exposures.
Draw the center-lines of these fields. Measure the diameter of the smallest circle which intersects all the center-lines.

0.3 mm

b) Record the deviation of the radiation and mechanical isocenters, i.e. the center of the circle w.r.t. the pen mark.

0.8 mm

16. Patient Support Assembly (PSA) Isocenter

Date: 11/19/2019 Physicist: SL/TL *Tolerance : ±1 mm from baseline->* mm, from

a) The movement of the PSA isocenter is determined by attaching the front pointer assembly or observing the crosshair projection and rotating the couch through 180^o marking the position every 45^o on graph paper secured to the tabletop. Record the diameter of the smallest circle, which includes all the crosshair projections.

0.3 mm

b) Record the deviation of the PSA isocenter from the gantry/collimator isocenter.

0.8 mm

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17. PSA Rotation Alignment

Date: 11/20/2019 Physicist: SL *Tolerance : absolute position at 0°:1°(0.2°); relative position: 0.5°*

The MLC file is located at: va_transfer\TDS\input\Physics\Monthly QA\MLC 40x1cm.mlc
Rotate the gantry to 0°. Rotate the PSA to 0°.
PSA top is placed at the isocenter height. Align the graph paper using a 1 cm MLC field (at collimator 0° only). Shift the PSA about 40 cm longitudinally, and check that the graph paper is still parallel to the MLC. If it is not, adjust the PSA rotation until a 40 cm longitudinal shift causes no lateral shift. This is the true 0° alignment of the PSA, and the floor marker should indicate this.
The PSA is then rotated to other angles between 90° and 270° while the digital readouts and the floor protractor indicators are observed if available.
Note: while 1.0° is recommended by MPPG#8, this will result in a 0.7 cm lateral shift when the couch is shifted 40 cm longitudinally. This is not a problem if the tabletop is shifted back laterally, however, this is often not apparent to the therapists. For this reason, at MSKCC, we will try to maintain the alignment within 0.2° at 0° couch angle, which would correspond to a 0.14 cm lateral shift for a 40 cm longitudinal shift.

	270°	0°	90°
Digital Indicator	270.0	359.9	89.9

18. Table Top Sag

Date: 12/27/2019 Physicist: SL *Tolerance : ±1 mm from baseline->* mm, from

Measure the sag at the isocenter with the tabletop at isocenter height, at 140 cm longitudinal position, and ~200 lb distributed evenly (e.g. a volunteer).

2.0 mm

19. PSA Vertical Motion

Date: 11/20/2019 Physicist: SL *Tolerance : absolute position at 0 cm : 2 mm; relative position: 1 mm*

The accuracy of the vertical position is assessed by measuring vertical displacements and observing the digital indicator.
The digital readout should indicate 0.0 ± 0.2 cm when the tabletop is at isocenter height (align with lasers).

Measured distance from 0 cm	Digital indicator (cm)
-35.0	965.07
-20.0	980.02
0.0	999.97
20.0	19.92
40.0	39.88
52.0	51.84

20. PSA Longitudinal Motion

Date: 11/20/2019 Physicist: SL *Tolerance : absolute position at 140 cm : 2 mm; relative position: 1 mm*

The accuracy of the longitudinal position is assessed by measuring longitudinal displacements and observing the digital indicator.
The absolute position of the tabletop should be 140.0 when the 0 detent is aligned with the lateral lasers.

Measured distance from ref (cm)	Digital indicator (cm)
-10.0	129.90
0.0	139.92
10.0	149.87

21. PSA Lateral Motion

Date: 11/20/2019 Physicist: SL *Tolerance : absolute position at 0 cm : 2 mm; relative position: 1 mm*

The accuracy of the lateral position is assessed by measuring lateral displacements and observing the digital indicator.
The digital readout should indicate 0.0 ± 0.2 cm when the tabletop is centered.

Measured distance from iso (cm)	Digital indicator (cm)
-10.0	990.04
0.0	0.10
10.0	10.03

22a-b. Output Calibration and Energy Check

See TG 51 worksheet tab (and chamber/electrometer cross calibration worksheet tab if applicable).

23. Monitor System Reproducibility

Date: 11/20/2019 Physicist: SL *Tolerance : 0.5% S.D.*

The reproducibility of the monitor system is assessed by determining the coefficient of variation (relative standard deviation) of measured output for three sequential 100 MU runs.
These measurements can be extracted from the monthly output measurements.

	6x	6FFF	6e	9e	12e
M1	20.5	20.18	21.52	21.79	22.04
M2	20.48	20.15	21.44	21.79	22.03
M3	20.49	20.17	21.45	21.8	22.03
Coefficient of variation	0.05%	0.08%	0.20%	0.03%	0.03%

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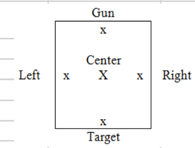
24. Morning dosimeter calibration check

Date: 12/23/2019 Physicist: SL *Tolerance : 1%*

Setup the morning checker as per morning setup procedure. Verify the calibration relative to the machine output. Reference dose from monthly output on: 12/23/2019

	Center	Gun	Target	Right	Left	Reference dose	Center/Ref dose
6x	99.81	102.39	102.49	102.83	102.64	100.07	0.997
6fff	99.61	81.15	80.77	81.03	80.99	99.83	0.998
6e	100.92	98.43	99.38	98.88	98.61	101.11	0.998
9e	100.77	102.61	103.60	103.13	103.09	100.28	1.005
12e	100.06	102.51	103.26	102.78	102.96	100.76	0.993



25a. Monitor System Linearity (Dose linearity vs Dose)

Date: 11/21/2019 Physicist: SL *Tolerance : ±2%*

The linearity of the monitor system is assessed using an ion chamber on the central axis of a 10×10 cm field for the range of MU settings currently allowable. The results normalized to the number of monitor units used for routine calibration, 100 MU, are calculated.
Depth = 2 cm, SCD = 130 cm (or other appropriate distance, so that all measurements are on one range of the electrometer)

Energy/Rep rate		**10 MU**	**100 MU**	**500 MU**
6X	M	12.200	12.230	61.190
(600 MU/min)	M_MU/M_100	0.998		5.003
6E	M	0.995	9.935	49.770
(600 MU/min)	M_MU/M_100	0.100		5.010
9E	M	1.264	12.640	63.260
(600 MU/min)	M_MU/M_100	0.100		5.005
12E	M	1.245	12.480	62.430
(600 MU/min)	M_MU/M_100	0.100		5.002

Energy/Rep rate		**50 MU**	**500 MU**	**3000 MU**
6FFF (1400	M	5.970	59.600	357.740
MU/min)	M_MU/M_500	0.100		6.002

25b. Monitor System Linearity (Dose linearity vs Rep Rate)

Date: 11/21/2019 Physicist: SL *Tolerance : ±2%*

The linearity of the monitor system is assessed using an ion chamber on the central axis of a 10×10 cm field for the range of rep rate settings currently allowable. The results normalized to the rep rate used for routine calibration, 600 MU/min for flattened x-rays, 1400 MU/min for 6FFF, and 2400 MU/min for 10FFF, are calculated.
Depth = 2 cm, SCD = 130 cm (or other appropriate distance, so that all measurements are on one range of the electrometer)

Energy/MU		**100 MU/min**	**600 MU/min**
6X (100 MU)	M	12.010	12.030
	M/M_600	0.998	

Energy/MU		**400 MU/min**	**6FFF: 1400 MU/min,**
6FFF (500 MU)	M	59.680	59.590
	M/M_1400	1.002	

26a. DMLC output (gap width) check

Date: 11/22/2019 Physicist: SL *Tolerance : Within 3% of target ratio (i.e. < 0.2 mm gap)*

Measure the output for the scanned field before and after reinitializing the MLC. Measure the output for a 10×10 cm2 reference field size defined by the jaws (MLC retracted).
Calculate the ratio of the scanned field to the reference field outputs.

File: \TDS\input\Physics\Monthly QA\OUTPUT12.mlc Energy: 6 MV Dose: 100 MU Dose rate: 600 MU/min
SAD: 100 cm Depth: 1.4 cm Backup: 10 cm Field size: 10x10 cm

	TB (M120)	TB (HD MLC)	C-series (M120)
Target ratio (MPK)	1525	1375	1575
Targe ratio (A12)	1540	1389	1590

	Reference	**Before reinitialization**	**After reinitialization**	**Reference**
	20.25	3.13	3.12	20.25
	20.26	3.12	3.12	20.25
	20.26	3.12	3.12	20.26
Average	20.257	3.123	3.120	20.253
Ratio		0.1542	0.1540	

MyQA Input	
Ratio	
Before	**After**
1541.88	1540.49

26b. Beam Holdoff Functionality

Date: 11/22/2019 Physicist: SL *Tolerance : Functioning*

Same setup as 26a, dose = 5 MU Record the output. Check if the holdoff is being applied

Reading 0.15 **Functioning (Y/N)** Y

26c. DMLC output vs Gantry and Collimator Angles

Date: 11/4/2019 Physicist: SL/ML *Tolerance : max/min ≤5% (3%)*

Reinitialize the MLC. Position a cylindrical chamber in air at isocenter. For each gantry angle, measure the open field and the scanned field outputs.
At gantry angles of 90° and 270°, also measure output for collimator angles of 90°. Calculate the ratio of the scanned field to the reference field outputs.

File: \TDS\input\Physics\Monthly QA\DMLCvsGantry.dcm Energy: 6 MV Dose: 100 MU Dose rate: 600 MU/min
SAD: 100 cm Spokus in air w/buildup Field size: 10x10 cm

Gantry Angle	**Reference**	**DMLC**		**DMLC/Reference**	
	0°	**0°**	**90°**	**0°**	**90°**
0°	22.43	3.52		0.1569	
90°	22.29	3.53	3.51	0.1584	0.1575
270°	22.58	3.54	3.53	0.1568	0.1563
180°	22.42	3.56		0.1588	
0°		3.52			

Max/Min
1.6

MyQA Input	
DMLC/Reference	
0°	**90°**
1569.33	
1583.67	1574.70
1567.76	1563.33
1587.87	

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27a. Enhanced dynamic wedge: Wedge factors and profiles vs field sizes

Date: 11/29/2019 Physicist: SL *Tolerance :* *2%*

Measure with MapCheck with SAD setup. *Backup: 5-10 cm* *Buildup: 5 cm* *Gantry and collimator at 0°* *100 MU*

6X					Wedge factor					
					30° OUT			60° IN		
		Open field	30° OUT	60° IN	M	TPS	M/TPS	M	TPS	M/TPS
10 × 10	CAX	90.180	76.570	59.070	0.849	0.852	0.997	0.655	0.657	0.997
	Y = 3 cm	90.450	70.800	77.290	0.783	0.784	0.998	0.855	0.857	0.997
20 × 20	CAX	96.350	65.410	40.180	0.679	0.684	0.993	0.417	0.418	0.998
	Y = 7 cm	98.100	56.270	76.090	0.574	0.575	0.998	0.776	0.776	1.000

27b. Enhanced dynamic wedge: Wedge factors for all angles

Date: 11/29/2019 Physicist: SL *Tolerance :* *2%*

Same setup as 27a.

	CAX	Open field	10°	15°	20°	25°	30°	45°	60°
6X	IN	89.720	85.450	83.250	81.020	78.800	76.600	69.070	59.070
	OUT		85.420	83.190	81.000	78.850	76.570	69.070	58.970
	WF(IN)		0.952	0.928	0.903	0.878	0.854	0.770	0.658
	WF(OUT)		0.952	0.927	0.903	0.879	0.853	0.770	0.657
	WF(TPS)		0.949	0.925	0.901	0.877	0.852	0.768	0.657
	WF(IN)/WF(TPS) (%)		0.36	0.31	0.23	0.15	0.21	0.24	0.21
	WF(OUT)/WF(TPS) (%)		0.32	0.24	0.20	0.21	0.17	0.24	0.04

MyQA input								
		10°	15°	20°	25°	30°	45°	60°
6x	WF(IN) (%)	95.2	92.8	90.3	87.8	85.4	77.0	65.8
	WF(OUT) (%)	95.2	92.7	90.3	87.9	85.3	77.0	65.7

28. Output vs Field size

Date: 11/25/2019 Physicist: SL/TL *Tolerance :* *2% for FS <4×4; 1% for FS ≥4×4 from baseline (photon baseline are from Eclipse v13 AAA calculations and electron baselines are from input data to TPS)*

Radiation dose is measured with the cc04 ion chamber on the central axis at 5 cm depth for photons and dmax for electrons for the range of clinically used field sizes. The measurements are normalized to a 10×10 field. These values are compared with the baseline. For electrons, also record the collimator sizes.

	6 MV Output factors			
Field size	**OF (Tables)**	**Meter reading**	**OF (Measured)**	**Measured/Tables**
3×3	0.880	849.65	0.881	1.001
4×4	0.905	875.33	0.907	1.002
10×10	1.000	964.88	1.000	
20×20	1.066	1024.10	1.061	0.996

	6 FFF Output factors			
Field size	**OF (Tables)**	**Meter reading**	**OF (Measured)**	**Measured/Tables**
3×3	0.897	841.82	0.898	1.001
4×4	0.921	864.96	0.923	1.002
10×10	1.000	937.10	1.000	
15×15	1.032	963.06	1.028	0.996

6 MeV Electron output factors

Cone	Collimator size prescribed	Collimator size observed	Insert	Depth (cm)	OF (Tables)	Meter reading	OF (Measured)	Measured/Tables
6x6	20×20	20 x 20	6x6	1.2	0.939	1045.00	0.943	1.005
10x10	22×22	22 x 22	10x10	1.2	1.000	1107.60	1.000	
15×15	20×20		15x15	1.2	0.999			
20×20	25×25		20x20	1.2	1.012			
25×25	30×30		25x25	1.2	1.008			

9 MeV Electron output factors

Cone	Collimator size prescribed	Collimator size observed	Insert	Depth (cm)	OF (Tables)	Meter reading	OF (Measured)	Measured/Tables
6x6	20×20		6x6	2.0	0.985			
10x10	20×20	20 x 20	10x10	2.0	1.000	1124.30	1.000	
15×15	20×20	20 x 20	15x15	2.0	0.995	1120.10	0.996	1.001
20×20	25×25		20x20	2.0	0.986			
25×25	30×30		25x25	2.0	0.964			

12 MeV Electron output factors

Cone	Collimator size prescribed	Collimator size observed	Insert	Depth (cm)	OF (Tables)	Meter reading	OF (Measured)	Measured/Tables
6x6	11×11		6x6	2.5	0.980			
10x10	15×15	15 x 15	10x10	2.5	1.000	1137.20	1.000	
15×15	19×19		15x15	2.5	1.003			
20×20	25×25	25 x 25	20x20	2.5	1.002	1143.40	1.005	1.003
25×25	30×30		25x25	2.5	0.951			

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29a. Flatness and Symmetry with ion chamber

Date: 12/12/2019 | Physicist: SL | *Tolerance : ±1% for symmetry; ±1% for flatness constancy (i.e. machine baseline)*

Electrometer: MAX801 | Chamber: A12 (2501)

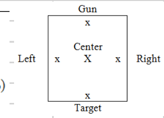
	x-rays	*FFF*	*electrons*	
Field size (cm)	*30×30*	*30×30*	*25×25*	*Backup: 10 cm*
Depth	*dmax*	*dmax*	*dmax*	*X-rays and FFF: SAD setup*
Off-axis distance	*10 cm*	*5 cm*	*8 cm*	*Electrons: SSD setup*
				SSD/SAD: 100 cm

Gantry and collimator: 0°
MU: 100

The flatness and symmetry is measured with an ion chamber by shifting the ion chamber (i.e. the by shifting the couch) to 5 different positions.

%Asymmetry: Radial $\frac{M_G - M_T}{(M_G+M_T)/2}$, Transverse $\frac{M_R - M_L}{(M_R+M_L)/2}$

%Unflatness: Radial $\frac{M_G+M_T}{2M_C}$, Transverse $\frac{M_L+M_R}{2M_C}$ (subtract 1, multiply by 100%)



Energy	dmax (cm)	Center	Gun	Target	Right	Left	Asymmetry (%) Radial	Asymmetry (%) Trans	Unflatness (%) Radial	Unflatness (%) Trans
6x	**1.5**	22.50	23.29	23.29	23.35	23.25	0.0	0.4	3.5	3.6
6fff	**1.5**	21.50	19.55	19.41	19.50	19.40	0.7	0.5	-9.4	-9.5
6e	**1.5**	23.39	23.26	23.21	23.32	23.28	0.2	0.2	-0.7	-0.4
9e	**2.0**	22.59	23.27	23.38	23.34	23.27	-0.5	0.3	3.3	3.2
12e	**2.5**	22.46	23.05	23.14	23.06	23.12	-0.4	-0.3	2.8	2.8

* Chamber meas repeated on 12/26/2019 to check consistency (see 243 Flat Symm worksheet 12262019.xls)

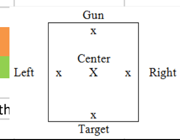
	Eclipse		Diff = (Measurement - Reference) Measurement - Eclipse	
	Unflatness (%)		Unflatness (%)	
	Radial	Trans	Radial	Trans
6x	3.2	3.3	0.3	0.3
6fff	-9.7	-9.8	0.3	0.3
6e	-0.5	-0.7	-0.2	0.3
9e	2.9	2.7	0.4	0.5
12e	2.3	2.3	0.5	0.5

%Asymmetry: Radial $\frac{M_G - M_T}{(M_G+M_T)/2}$, Transverse $\frac{M_R - M_L}{(M_R+M_L)/2}$

%Unflatness: Radial $\frac{M_G+M_T}{2M_C}$, Transverse $\frac{M_L+M_R}{2M_C}$ (subtract 1, multiply by 100%)

*Eclipse reference from calculations using AAA_v13623 and EMC_v13623_TEST (new EMC) (6EX, C-series and TrueBeam specific)

30a-c. Output and Profiles vs Gantry



Date: 11/1/2019 | Physicist: SL/TL | lerance : ±2% relative to gantry 0

Mount the morning checker or MapCheck to the gantry using the mounting device with | MU | Collimator size: 32 × 32

	Gantry	6x	6FFF	6e	9e	12e
Output	**0°**	270.53	254.58	272.01	265.24	262.12
	90°	270.64	254.52	272.09	265.10	261.85
	180°	270.31	254.90	271.69	265.16	263.18
	270°	270.50	254.60	270.08	265.42	261.64
Symmetry (G-T)	**0°**	-0.25	-0.63	-0.40	0.43	0.78
	90°	-0.68	-0.73	-0.17	0.15	0.70
	180°	-0.22	-0.47	-0.02	0.43	0.90
	270°	-0.35	-0.48	-0.24	0.67	0.90
Symmetry (L-R)	**0°**	-0.25	0.56	1.17	0.34	0.14
	90°	-0.31	0.92	0.84	0.31	-0.15
	180°	-0.51	0.82	0.89	0.35	0.06
	270°	-0.41	0.61	1.06	0.67	0.26
Flatness	**0°**	2.61	17.24	2.09	4.12	2.41
	90°	2.66	17.28	1.83	3.99	2.25
	180°	2.73	17.22	1.82	3.83	1.89
	270°	2.68	17.23	1.94	3.55	2.30

		Relative to 0° (%)				
	Gantry	6x	6FFF	6e	9e	12e
Output (ratio)	0°					
	90°	0.04	-0.02	0.03	-0.05	-0.10
	180°	-0.08	0.13	-0.12	-0.03	0.40
	270°	-0.01	0.01	-0.71	0.07	-0.18
Symmetry (G-T)	0°					
	90°	-0.43	-0.10	0.23	-0.28	-0.08
	180°	0.03	0.16	0.38	0.00	0.12
	270°	-0.10	0.15	0.16	0.24	0.12
Symmetry (L-R)	0°					
	90°	-0.06	0.36	-0.33	-0.03	-0.29
	180°	-0.26	0.26	-0.28	0.01	-0.08
	270°	-0.16	0.05	-0.11	0.33	0.12
Flatness	0°					
	90°	0.05	0.04	-0.26	-0.13	-0.16
	180°	0.12	-0.02	-0.27	-0.29	-0.52
	270°	0.07	-0.01	-0.15	-0.57	-0.11

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31. Portal Dosimetry Calibration

Date: 11/25/2019 Physicist: SL *Tolerance : 0.5%*

Calibrate MV panel for EPID dosimetry.

Acquire a test image (10 × 10 cm^2 open field) after calibration and note the mean dose of a 1 × 1 cm^2 ROI around the CAX. Record the CU per 100 MU.

Energy	Output/100 MU (CU)		MyQA Input
6FFF	1.001		100.12
6 MV	1.001		100.06

32. MV/kV isocenter and radiation isocenter concordance

Date: 11/5/2019 Physicist: SL *Tolerance : 1 mm*

Align the MV/kV iso concordance phantom with the lasers. Deliver the plan "MV kV iso" in the Course "Monthly QA" from the Aria test patient or run the XML file "TDS\input\Physics\Monthly QA\SysErrChk.xml" with 20 MU. Enter data below.

Imaging mode	Deviation from radiation isocenter (mm)			
	X (+ Left)	Y (+ Posterior)	Z (+ Superior)	
CBCT (odd month: full fan, even month: half fan)	-0.88	-0.41	0.25	Half fan was used
Radiograph	-0.08	0.23	-0.01	

Record additional information for:

	X (Left-Rgt)	Y (Ant-Post)	Z (Sup-Inf)
Isocenter size (isocenter walk)	0.17	0.28	0.39

Panel alignment	X (+ Rght)	Y (+ Up)
MV	-0.17	0.00
kV	0.06	-0.01

33. VMAT QA

Date: 11/25/2019 Physicist: SL *Tolerance : Pass*

Aria QA test patient MRN: **#REF!** * Used 70000445

a) Dose-rate gantry speed (DRGS) test

Load Plan "RA_DRGS" in Course "Monthly QA" from Aria QA test patient in QA mode. Analyze in myQA.

Pass/Fail Pass

a) Dose-rate gantry speed (DRGS) test

Load Plan "RA_MLCspeed" in Course "Monthly QA" from Aria QA test patient in QA mode. Analyze in myQA.

Pass/Fail Pass

34. Couch Pitch and Roll

Date: 11/6/2019 Physicist: SL *Tolerance : Observed angle: 1°(0.5°)*
Observed shift: 0.5 mm

First zero the couch pitch and roll. Place sphere (MV/kV iso concordance test phantom) on the couch with lasers.
Set the pitch and roll to +3° for even months or -3° for odd months.
Record the pitch and roll using a level; record the shift in the sphere position using the service mode/XI tab tools.

Observed				
Pitch(°)	Roll(°)	LAT shift (mm)	LNG shift (mm)	VRT shift (mm)
3.0	3.0	0.10	0.30	0.10

MyQA Input		
Pitch(°)	Roll((°)	*absolute values
3.00	3.00	

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TG 51 Calibration Worksheet - 6MV Photons

Room 243TB6 **Energy** 6 Date ######### Initial TL/ML/SL

Temperature= 22 °C +273.2= 295.2 K Pressure= 772.3 mmHg

Chamber= A12 (198) **$N_{D,w}$=** 4.859 cGy/10nC r_{cav} = 0.305 cm

Electrometer= max 1284 **P_{elec} =** 1

Field Size = 10x10 cm^2 MU = 100 SSD = 100 cm d = 10cm

Eff. Depth = d + 0.6r_{cav} = **10.18** cm (assuming cylindrical chamber)

1. Beam Quality, k_Q

$\%DD(10)_x^*$ = 66.21 A 1.0146 B 0.777 C -1.666

k_Q = 0.99301

$$k_q = A + B \times 10^{-3} \times \%dd(10)_x + C \times 10^{-5} \times (\%dd(10)_x)^2$$

2. P_{TP}

$$P_{TP} = \frac{T}{P} \cdot \frac{760}{295.2}$$

P_{TP}= 0.984

3. P_{ION}

$$P_{ION} = \frac{1 - \left(\frac{V_H}{V_L}\right)}{\left(\frac{M_H}{M_L}\right) - \left(\frac{V_H}{V_L}\right)}$$

	M_H	**M_L**
M1	13.46	13.41
M2	13.45	13.41
M3		
<M>	13.455	13.41

V_H 300 V

V_L 150 V

P_{ION} = 1.003

4. P_{POL}

$$P_{POL} = \frac{|M_+ - M_-|}{2M}$$

	M_+	**M_-**
M1	13.46	13.47
M2	13.45	13.47
M3		
<M>	13.46	13.47

V_+ 300 V

V_- -300 V

P_{POL} = 1.001

5. P_{rp}

P_{rp} = 1.000

Dose at 10cm

$$D(10, SSD) = k_q N_{D,W}^{60Co} P_{ion} P_{TP} P_{elec} P_{pol} P_{rp} M$$

D(10)= 0.641 cGy

Dose at dmax and SAD = 100 cm

$$D(d_{max}) = \frac{D(10)}{\%DD(10)_{TPS}} \left(\frac{100 + d_{max}}{100}\right)^2$$

$\%DD(10)_{TPS}$ = 66.18 From TPS

dmax= 1.4

$D(d_{max})$ = 0.994 cGy

/ or lower beam which is obtained from annual water tank
photon beam above 10MV and FFF beams

Memorial Sloan Kettering Cancer Center

TG 51 Calibration Worksheet - 6FFF Photons

Room 243TB6 | **Energy** 6FFF | Date ######## | Initial TL/ML/SL

Temperature= 22 °C | +273.2= 295.2 K | Pressure= 772.3 mmHg

Chamber= A12 (198) | $N_{D,w}$= 4.859 cGy/10nC | r_{cav}= 0.305 cm

Electrometer= max 1284 | P_{elec} = 1

Field Size = 10x10 cm^2 | MU = 100 | SSD = 100 cm | d = 10cm

Eff. Depth = d + 0.6r_{cav} = **10.18** cm (assuming cylindrical chamber)

1. Beam Quality, k_Q

%DD(10)$_x^{**}$ = 64.17 | A 1.0146 | B 0.777 | C -1.666

k_Q = 0.99301

$$k_q = A + B\times10^{-3}\times\%dd(10)_x + C\times10^{-5}\times(\%dd(10)_x)^2$$

2. P_{TP}

$$P_{TP} = \frac{T}{P}\cdot\frac{760}{295.2}$$

P_{TP}= 0.984

3. P_{ION}

$$P_{ION} = \frac{1-\left(\frac{V_H}{V_L}\right)}{\left(\frac{M_H}{M_L}\right)-\left(\frac{V_H}{V_L}\right)}$$

	M_H	M_L
M1	12.67	12.58
M2	12.66	12.58
M3	12.66	
<M>	12.66	12.58

V_H 300 V

V_L 150 V

P_{ION} = 1.007

4. P_{POL}

$$P_{POL} = \frac{|M_+ - M_-|}{2M}$$

	M_+	M_-
M1	12.67	13.47
M2	12.66	13.47
M3	12.66	
<M>	12.66	13.47

V_+ 300 V

V_- -300 V

P_{POL} = 1.000

5. P_{rp}

P_{rp} = 1.002

Dose at 10cm

$$D(10,SSD) = k_q N_{D,W}^{60Co} P_{ion} P_{TP} P_{elec} P_{pol} P_{rp} M$$

D(10)= 0.609 cGy

Dose at dmax and SAD = 100 cm

$$D(d_{max}) = \frac{D(10)}{\%DD(10)_{TPS}}\left(\frac{100+d_{max}}{100}\right)^2$$

%DD(10)$_{TPS}$ = 63.1 From TPS

dmax= 1.4

D(d_{max}) = 0.992 cGy

ır lower beam which is obtained from annual water tank
oton beam above 10MV and FFF beams

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TG 51 Calibration Worksheet - 6 MeV Electrons

Room 243TB6 **Energy** 6 Date 11/14/2019 Initial TL/ML/SL

Temperature= 22 °C +273.2= 295.2 K Pressure= 772.3 mmHg

Chamber= A12 (198) **$N_{D,w}$=** 4.859 cGy/10nC r_{cav}= 0.305 cm

Electrometer= max 1284 **P_{elec} =** 1

Field Size = 10x10 cm^2 MU = 100 SSD = 100 cm R_{50}^{*} = 2.33 cm

d_{ref}= $0.6R_{50}$ - 0.1 = 1.30 cm

Eff. d_{ref} = d_{ref} + $0.5r_{cav}$ = 1.45 cm (cylindrical chamber)

1. Beam Quality, k_{R50}, P^{Q}_{gr}

k_{ecal}= 0.906 Table III of TG51

k'_{R50} = 1.028

$$k'_{R_{50}} = 0.9905 + 0.0710 \cdot e^{\frac{-R_{50}}{3.67}}$$

$$P^{Q}_{gr} = \frac{M(d_{ref} + 0.5 r_{cav})}{M(d_{ref})}$$

	M(d_{ref}+0.5r_{cav})	M(d_{ref})
M1	22.01	22.02
M2	22.01	22.00
M3		
<M>	22.01	22.01

P^{Q}_{gr} = 1.000

2. P_{TP}

$$P_{TP} = \frac{T}{P} \cdot \frac{760}{295.2}$$

P_{TP}= **0.984**

3. P_{ION}

$$P_{ION} = \frac{1 - \left(\frac{V_H}{V_L}\right)}{\left(\frac{M_H}{M_L}\right) - \left(\frac{V_H}{V_L}\right)}$$

	M_H	M_L
M1	22.02	22.03
M2	22.00	22.04
M3		
<M>	22.01	22.04

V_H 300 V

V_L 150 V

P_{ION} = 1.0135

4. P_{POL}

$$P_{POL} = \frac{|M_+ - M_-|}{2M}$$

	M_+	M_-
M1	22.02	22
M2	22.00	22.01
M3		
<M>	22.01	22.01

V_+ 300 V

V_- -300 V

P_{POL} = 0.9999

Dose at 10cm

$$D(d_{ref}) = k'_{R_{50}} k_{ecal} P^{Q}_{gr} N^{^{60}Co}_{D,w} P_{ELEC} P_{POL} P_{ION} P_{TP} M$$

$D(d_{ref})$= 0.993 cGy

Dose at dmax and SSD = 100 cm

$$D(d_{max}) = \frac{D(d_{ref})}{\%DD(d_{ref})_{TPS}}$$

$\%DD(d_{ref})_{TPS}$ = 99.0 From TPS

dmax= 1.2

$D(d_{max})$ = 1.004 cGy

*Obtained from annuel water tank scan using R_{50} = $1.029I_{50}$ - 0.06 (cm)

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TG 51 Calibration Worksheet - 9 MeV Electrons

Room 243TB6 **Energy** 9 Date 11/14/2019 Initial TL/ML/SL

Temperature= 22 °C +273.2= 295.2 K Pressure= 772.3 mmHg

Chamber= A12 (198) **$N_{D,w}$=** 4.859 cGy/10nC r_{cav}= 0.305 cm

Electrometer= max 1284 **P_{elec}** = 1

Field Size = 10x10 cm^2 MU = 100 SSD = 100 cm R_{50}^* = 3.57 cm

d_{ref}= $0.6R_{50} - 0.1$ = 2.04 cm

Eff. d_{ref} = d_{ref} + $0.5r_{cav}$ = 2.19 cm (cylindrical chamber)

1. Beam Quality, k_{R50}, P^Q_{gr}

k_{ecal}= 0.906 Table III of TG51

k'_{R50} = 1.017

$$k'_{R_{50}} = 0.9905 + 0.0710 \cdot e^{\frac{-R_{50}}{3.67}}$$

$$P^Q_{gr} = \frac{M(d_{ref} + 0.5r_{cav})}{M(d_{ref})}$$

	$M(d_{ref}+0.5r_{cav})$	**$M(d_{ref})$**
M1	22.32	22.33
M2	22.32	22.33
M3		
<M>	22.32	22.33

P^Q_{gr} = 1.000

2. P_{TP}

$$P_{TP} = \frac{T}{P} \cdot \frac{760}{295.2}$$

P_{TP}= 0.984

3. P_{ION}

$$P_{ION} = \frac{1 - \left(\frac{V_H}{V_L}\right)}{\left(\frac{M_H}{M_L}\right) - \left(\frac{V_H}{V_L}\right)}$$

	M_H	**M_L**
M1	22.33	22.03
M2	22.33	22.04
M3		
<M>	22.33	22.04

V_H 300 V

V_L 150 V

P_{ION} = 1.0136

4. P_{POL}

$$P_{POL} = \frac{|M_+ - M_-|}{2M}$$

	M_+	**M_-**
M1	22.33	22.35
M2	22.33	22.36
M3		
<M>	22.33	22.36

V_+ 300 V

V_- -300 V

P_{POL} = 1.0006

Dose at 10cm

$$D(d_{ref}) = k'_{R_{50}} k_{ecal} P^Q_{gr} N^{60Co}_{D,w} P_{ELEC} P_{POL} P_{ION} P_{TP} M$$

$D(d_{ref})$= 0.998 cGy

Dose at dmax and SSD = 100 cm

$$D(d_{max}) = \frac{D(d_{ref})}{\%DD(d_{ref})_{TPS}}$$

$\%DD(d_{ref})_{TPS}$ = 99.8 From TPS

dmax= 2.0

$D(d_{max})$ = 0.999 cGy

*Obtained from annual water tank scan using $R_{50} = 1.029 I_{50} - 0.06$ (cm)

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TG 51 Calibration Worksheet - 12 MeV Electrons

Room 243TB6 **Energy** 12 Date 11/14/2019 Initial TL/ML/SL

Temperature= 22 °C +273.2= 295.2 K Pressure= 772.3 mmHg

Chamber= A12 (198) **$N_{D,w}$=** 4.859 cGy/10nC r_{cav}= 0.305 cm

Electrometer= max 1284 **P_{elec} =** 1

Field Size = 10x10 cm² MU = 100 SSD = 100 cm R_{50}^{*} = 4.93 cm

d_{ref}= $0.6R_{50}$ - 0.1 = 2.86 cm

Eff. d_{ref} = d_{ref} + $0.5r_{cav}$ = 3.01 **cm** (cylindrical chamber)

1. Beam Quality, k_{R50}, P^{Q}_{gr}

k_{ecal}= 0.906 Table III of TG51

k'_{R50} = 1.009

$$k'_{R_{50}} = 0.9905 + 0.0710 \cdot e^{\frac{-R_{50}}{3.67}}$$

$$P^{Q}_{gr} = \frac{M(d_{ref} + 0.5r_{cav})}{M(d_{ref})}$$

	$M(d_{ref}+0.5r_{cav})$	$M(d_{ref})$
M1	22.48	22.53
M2	22.47	22.52
M3		
<M>	22.48	22.53

P^{Q}_{gr} = 0.998

2. P_{TP}

$$P_{TP} = \frac{T}{P} \cdot \frac{760}{295.2}$$

P_{TP}= **0.984**

3. P_{ION}

$$P_{ION} = \frac{1 - \left(\frac{V_H}{V_L}\right)}{\left(\frac{M_H}{M_L}\right) - \left(\frac{V_H}{V_L}\right)}$$

	M_H	M_L
M1	22.53	22.22
M2	22.52	22.22
M3		
<M>	22.53	22.22

V_H 300 V

V_L 150 V

P_{ION} = 1.0139

4. P_{POL}

$$P_{POL} = \frac{|M_+ - M_-|}{2M}$$

	M_+	M_-
M1	22.53	22.53
M2	22.52	22.53
M3		
<M>	22.53	22.53

V_+ 300 V

V_- -300 V

P_{POL} = 1.0001

Dose at 10cm

$$D(d_{ref}) = k'_{R_{50}} k_{ecal} P^{Q}_{gr} N^{^{60}Co}_{D,w} P_{ELEC} P_{POL} P_{ION} P_{TP} M$$

$D(d_{ref})$= 0.996 cGy

Dose at dmax and SSD = 100 cm

$$D(d_{max}) = \frac{D(d_{ref})}{\%DD(d_{ref})_{TPS}}$$

$\%DD(d_{ref})_{TPS}$ = 100.2 From TPS

dmax= 2.5

$D(d_{max})$ = 0.994 cGy

*Obtained from annual water tank scan using R_{50} = $1.029I_{50}$ - 0.06 (cm)

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Pre-Clinical Plan QA

Measurements were done using MapCheck and EPID Portal dosimetry.

All plans are in a single aria paient with MRN of ARIAupgrade_KOC_TB1

EPID

The EPID was calibrated prior to use (normalized to current machine output)

Acceptance is based on the EPID measurements being within tolerance.

- The gamma averaged over all fields must be > 95%
- The gamma for each field must be > 90%

MapCheck

mapcheck measurements were compared with historical data. All mapcheck measurements were found to be consistent with the historical record.

Machine	
Date of measurement	
Physicists	
MapCheck setup	
Portal dosimetry setup	
Data processing	

6X IMRT			
Plan	Field	MapCheck (2%/2mm, global)	Portal Dosimetry (3%/3mm, local)
Lung1	1		

	2		
	3		
	4		
	5		
Lung2	1		
	2		
	3		
	4		
	5		
	6		
	7		
Brain1	1		
	2		
	3		
	4		
	5		
	6		
Brain2	1		
	2		
	3		
	4		
	5		
	6		
GI	1		
	2		

	3		
	4		
	5		
	6		
	7		

6X VMAT			
Plan	Field	MapCheck (2%/2mm, global)	Portal Dosimetry (3%/3mm, local)
PS_VMAT_6x	1		
	2		
	3		
	4		
GI_VMAT_6x	1		
	7		
HN_VMAT_6x	1		
	2		
	3		
	4		
WA_VMAT_6x	1		
	2		
	3		
	4		

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6FFF IMRT			
Plan	Field	MapCheck (2%/2mm, global)	Portal Dosimetry (3%/3mm, local)
Lung_6fff	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
brain_6fff	1		
	2		
	3		
	4		
	5		
	6		
pancreas_6fff	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		

Paraspin_6fff	1		
	2		
	3		
	4		
	5		
	6		

6FFF VMAT			
Plan	Field	MapCheck (2%/2mm, global)	Portal Dosimetry (3%/3mm, local)
lung_vmat6fff	1		
	2		
	3		
	4		
brainVMAT6fff	1		
	7		

LTbrainVM6fff	1		
	2		
RTbrainVM6fff	1		
	2		
PS_VMAT_6fff	1		
	2		
	3		
	4		

Radiation Survey

Table 2 - Exposure Guidelines

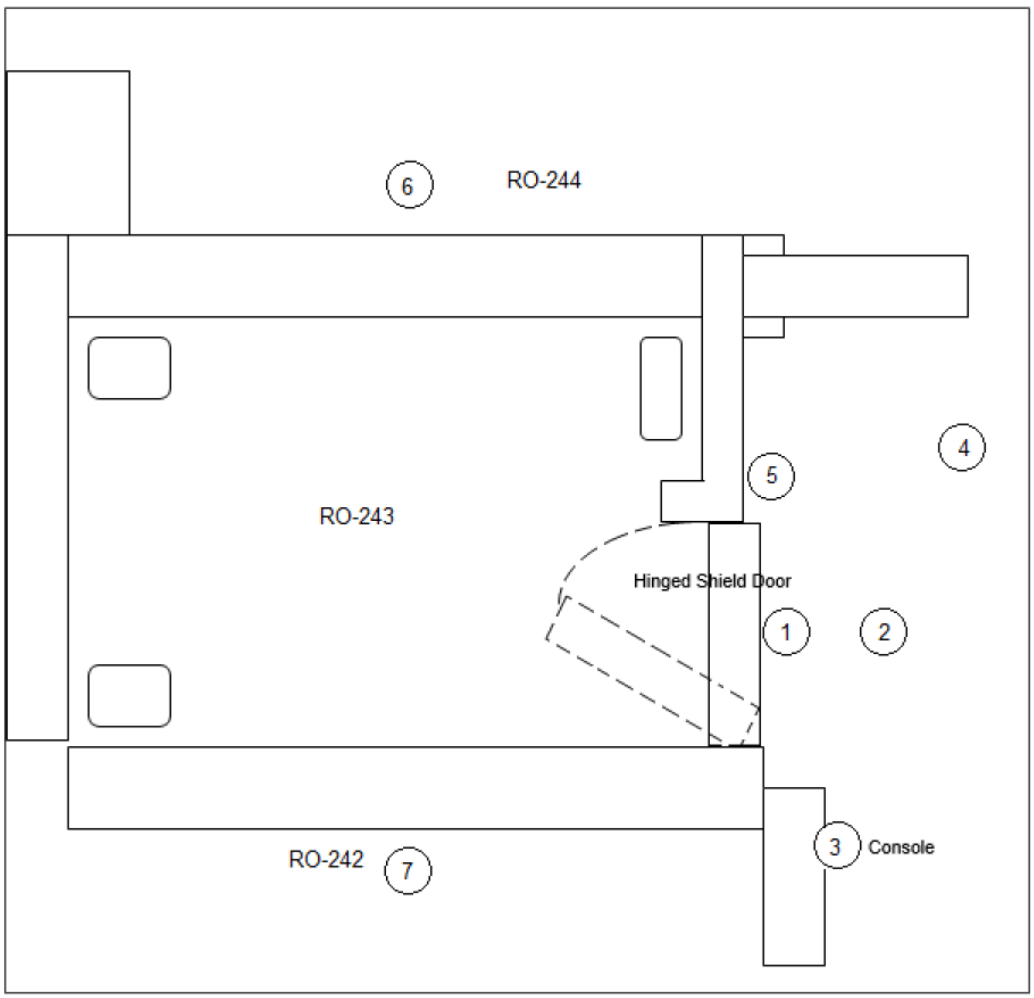
Member of the Public	Occupational
2 mrem in a week to uncontrolled areas (average)	10 mrem in a week
100 mrem in a year	5,000 mrem in a year
2 mrem in any hour	

Assumptions Made

A conservatively high x-ray workload of 1325 Gy/wk at an isocenter located 100 cm from target is assumed. Workload breakdown assumptions are based on conventional 3D, IMRT, and Hypo-RT (25, 300, 35 patients/week respectively). This workload is based on a high volume installation planning to use additional Intensity Modulated Radiation Therapy (IMRT) (Mechalakos, et al, 2002[2]; Saleh, et al, 2017[3]). The modulation factor is assumed to be 5, utilizing the methodology of Report Number 151 of the National Council on Radiation Protection (NCRP-151)[4], and based on latest literature (Saleh,et al, 2017).

- The dose rate is expressed as 14 Gy min^{-1} for the purpose of evaluating shielding design goals.
- Assuming a 40-hour workweek, weekly x-ray beam on time is therefore assumed to be 1.57 hours for the purpose of this evaluation.
- For the purpose of demonstrating compliance with shielding design goals using
- conservative assumptions, the electron beam workload is conservatively assumed to be shared between the 9 MeV and 12 MeV beams, although electron beams of lower energies may be used.

FIGURE 1 - Room Layout



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W

Table 5: Survey Results - Total x-ray and electron									
Location	mrem/wk			mrem in any hour			mrem/yr		
	x-ray	electron	total	x-ray	electron	total	x-ray	electron	total
Door (contact)	0.58	0.061	**0.64**	N/A	N/A	N/A	30	3.2	**33**
Door (1-meter)	0.48	0.032	**0.51**	N/A	N/A	N/A	25	1.7	**27**
Control console (operator position)	0.094	0.021	**0.12**	N/A	N/A	N/A	4.9	1.1	**6.0**
244 Console	1.4	0.31	**1.7**	N/A	N/A	N/A	73	16	**89**
244 Console wall	0.36	0.07	**0.43**	N/A	N/A	N/A	19	3.6	**22**
244	0.064	0.0017	**0.066**	N/A	N/A	N/A	3.3	0.088	**3.4**
242	0.071	0.0017	**0.073**	N/A	N/A	N/A	3.7	0.088	**3.8**
Downstairs	0.094	0.0035	**0.10**	0.00013	0.0052	0.0053	4.9	0.18	**5.1**

All exposures well within guidelines, even assuming MSK 80 hr weeks.

MSKCC SBRT E2E Report

Tolerance: Dose Difference (DD) < 5.0% and Localization <= 1.0 mm

Summary:

The average dose difference is 32 cGy and the location accuracy is acceptable. This end to end test has meet the tolerances of MPPG9a.

Dose Analysis Sagittal plane

	TPS (cGy) (max dose)	ROI at 50% Max dose	<TPS> (cGy)	γ (3%, 2mm)	Dose Diff (cGy)	%Dose Diff

Sagittal	1965	983	1461	95%	-32	-2.2%

Localization Analysis

	A-P (mm)	**S-I (mm)**	**L-R (mm)**
Sagittal	0.2	1.0	
Coronal		0.4	0.6

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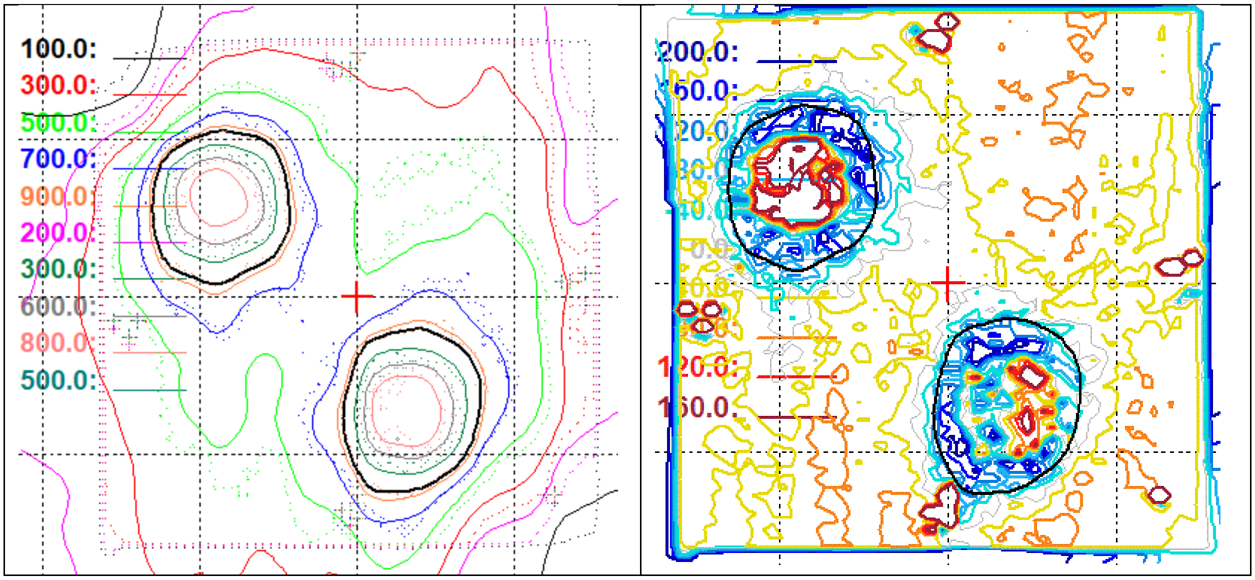
Film Distribution (Sagittal plane)

- Dashed line: film measurement
- Solid line: Eclipse



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Imaging Geometric Accuracy

Imaging Geometry QA

Machine: **243**

Date: 10/25/2019

Physicist: Lovelock

MV (Winston-Lutz) Analysis

File	Source Angle	Sphere Position X (+ Rght)	Sphere Position Y (+ Up)	Field Center Position X (+ Rght)	Field Center Position Y (+ Up)	Sphere - Field X (+ Rght)	Sphere - Field Y (+ Up)
WL-004	0	-0.11	-0.22	-0.11	0.22	0.00	-0.45
WL-000	180	0.00	-0.17	-0.22	-0.17	0.22	0.00
WL-003	90	0.28	-0.17	0.06	0.11	0.22	-0.28
WL-007	270	-0.34	-0.22	-0.45	0.06	0.11	-0.28

	X (Left-Rgt)	Y (Ant-Post)	Z (Sup-Inf)
Field Shift (Isocenter walk)	0.22	0.34	0.45

	X (+: Left)	Y (+: Post)	Z (+: Sup.)
Sphere Position (Lasers) with respect to Rad. Iso. *(Vec P)*	-0.11	0.06	-0.25

	X (+ Rght)	Y (+ Up)
MV Panel Alignment Average Position of Rad Iso.	-0.18	0.06

All units mm unless otherwise noted.

KV 2D (Radiographic) Analysis

File	Source Angle	Sphere Position X (+ Rght)	Sphere Position Y (+ Up)
WL-002	0	-0.03	-0.13
WL-006	180	0.10	-0.13
WL-001	90	0.23	-0.06
WL-005	270	-0.19	-0.19

MV KV concordances are in blue

	X (+: Left)	Y (+: Post)	Z (+: Sup.)
Sphere with respect to imaging origin: *(Vec S)*	-0.06	0.21	-0.13
Rad. Iso. (as seen by KV-KV imaging): *(S-P)*	0.05	0.15	0.12

	X (+ Rght)	Y (+ Up)
KV Panel Alignment Average Position of Rad Iso.	0.02	0.12

Half Fan Cone Beam Analysis

File: 19-10-16_12-08-57	X (+: Left)	Y (+: Post)	Z (+: Sup.)
Sphere with respect to HF imaging origin: *(Vec Q)*	-0.10	0.09	-0.28
Rad. Iso. (as seen by HF CBCT): *(Q-P)*	0.01	0.04	-0.03

Full Fan Cone Beam Analysis

File 19-10-16_12-16-25	X (+: Left)	Y (+: Post)	Z (+: Sup.)
Sphere with respect to FF imaging origin: *(Vec R)*	-0.25	0.09	-0.15
Rad. Iso. (as seen by FF CBCT): *(R-P)*	-0.14	0.03	0.10

KV Image Mechanicals / Safety / Image Quality

Test	Result
KV beam door interlock	Pass
Collision interlocks	Pass
Override of collision interlocks	Pass
Blade positions	Pass
Radiographic contrast resolution	pass
Radiographic high contrast spatial resolution	Pass
Radiographic uniformity	Pass
Fluoro contrast resolution	Pass
Fluoro high contrast spatial resolution	Pass
Fluoro uniformity	Pass
CBCT head contrast resolution	Pass
CBCT head geometric distortion	Pass
CBCT head geometric uniformity	Pass
CBCT head spatial resolution	Pass
CBCT head HU constancy	Pass
CBCT Pelvis contrast resolution	Pass
CBCT Pelvis geometric distortion	Pass
CBCT Pelvis geometric uniformity	Pass
CBCT Pelvis spatial resolution	Pass
CBCT Pelvis HU constancy	Pass
CBCT Spotlight contrast resolution	Pass
CBCT Spotlight geometric distortion	Pass
CBCT Spotlight geometric uniformity	Pass
CBCT Spotlight spatial resolution	Pass
CBCT Pelvis HU constancy	Pass

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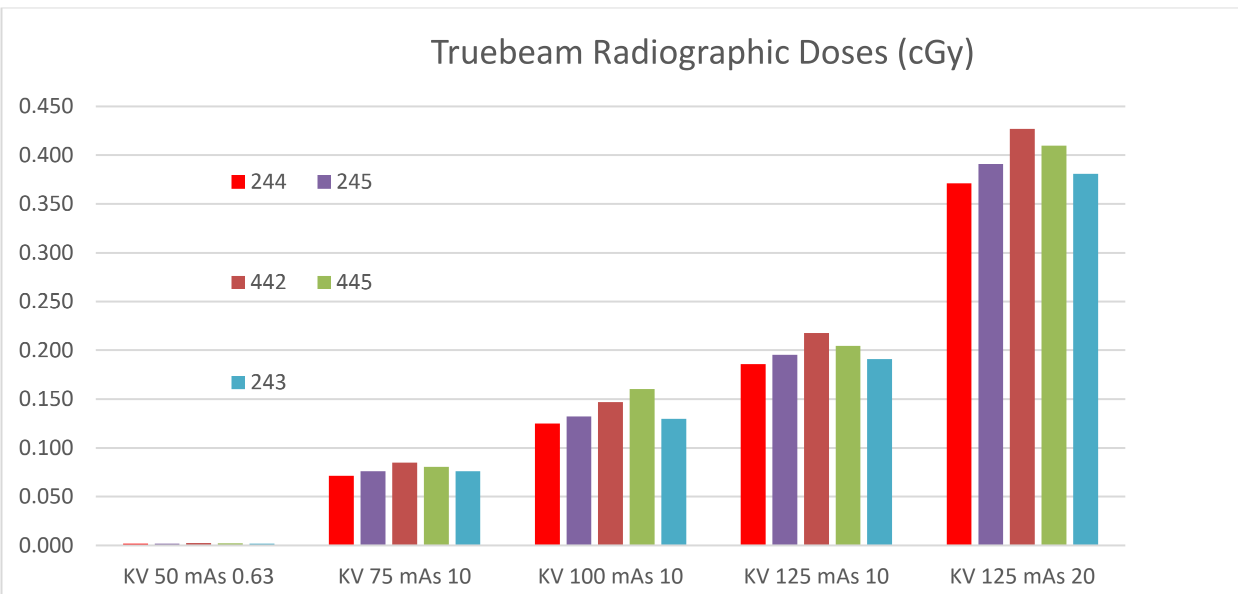
KV Dosimetry



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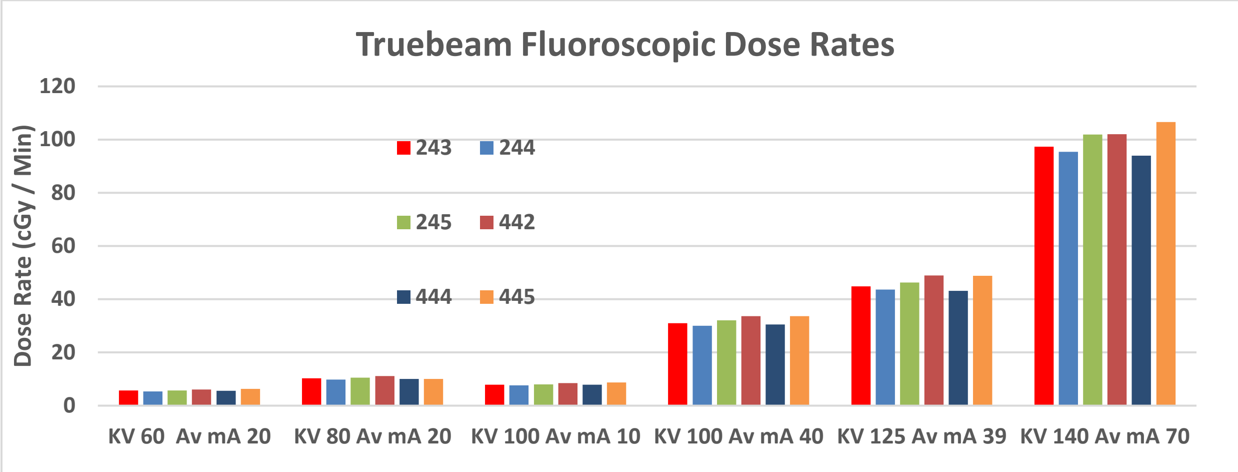

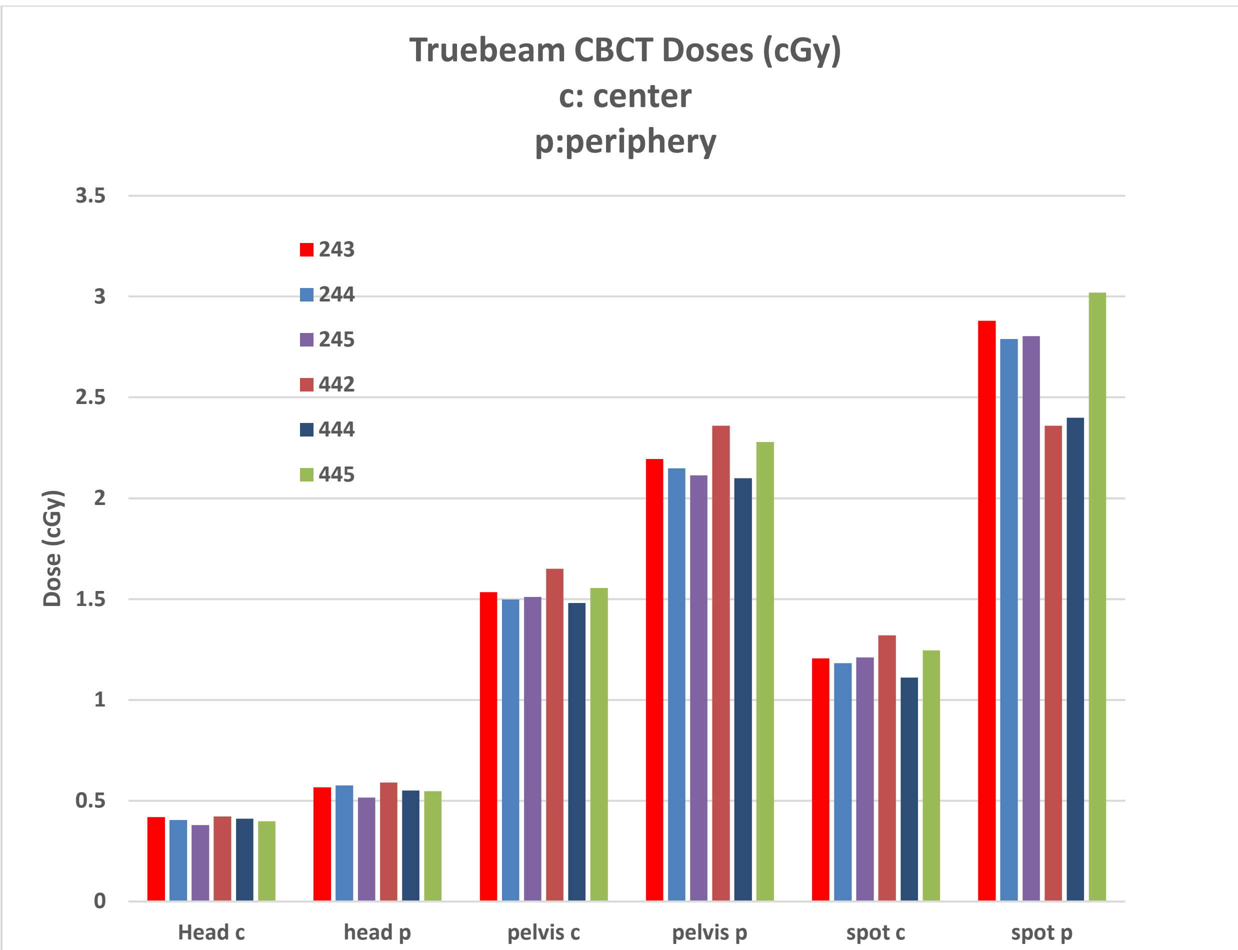

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IROC Electrons:

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IMAGING AND RADIATION ONCOLOGY CORE
Global Leaders in Clinical Trial Quality Assurance

IROC Houston QA Center
MD Anderson Cancer Center
8060 El Rio Street
Houston, TX 77054
Tel (713) 745-8989
Fax (713) 794-1364

RESULTS OF OSLD CHECK OF ELECTRON BEAM

v9.2

Institution:	Memorial Sloan-Kettering Cancer Center, New York, NY
RTF Number:	1823
Person irradiating dosimeters:	Robert Febo
Radiation Machine:	TrueBeam Serial 4238 (Rm 243)
Distance from target to surface:	100.0 cm

OUTPUT VERIFICATION:

Electron Energy	Date of Irradiation	IROC Houston measured dose at dmax:	Institution reported dose at dmax:	**Ratio of absorbed dose determined by IROC Houston to that stated by institution: OSLD/INST**
6 MeV	11/19/2019	103.1 cGy to water	101.2 cGy to water	**1.02**
9 MeV	11/19/2019	100.1 cGy to water	101.1 cGy to water	**0.99**
12 MeV	11/19/2019	100.0 cGy to water	100.7 cGy to water	**0.99**

Agreement within 5% is considered a satisfactory check.

DEPTH DOSE VERIFICATION:

Electron Energy	Depth of OSL in falloff region	IROC-determined percentage depth-dose	Institution's depth for this depth dose	**IROC depth - Institution depth**
6 MeV	2.1 cm	66%	2.1 cm	**0 mm**
9 MeV	3.4 cm	55%	3.5 cm	**-1 mm**
12 MeV	4.8 cm	54%	4.9 cm	**-1 mm**

Agreement within 5 mm is considered a satisfactory check.

IROC Photons:

6 MV

OUTPUT VERIFICATION:

Date of Irradiation	IROC Houston measured dose at dmax:	Institution reported dose at dmax:	**Ratio of absorbed dose determined by IROC Houston to that stated by institution: OSLD/INST**
19-Nov-2019	101.5 cGy to water	100.4 cGy to water	**1.01**

Agreement within 5% is considered a satisfactory check.

6FFF

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
Treatment Planning – Team H

Rotation Director: Michalis Aristophanous
Rotation Mentors: Åse Ballangrud-Popovic
Rotation Location(s): MSKCC Main Campus

Duration: 3 months full time

Resident Professional Expectations

1. The resident will be proficient in all tasks performed by faculty in team H.

Team H Learning Objectives

		Contact
Techs	OSMS: commissioning and clinical use	GL
	Exactrac: commissioning and clinical use	ÅBP, ML
	SRS/SBRT machine requirements: MPPG9a	GL, ML
Cranial SRS and conventional Brain	**LINAC:**	
	Beam modelling for small fields	GL, ÅBP
	Spatial accuracy and dose tolerance, End-to-end testing	GL, ÅBP
	Immobilization and simulation; evaluate multiple options	ÅBP
	Image fusion and contours; MR only planning	ÅBP
	Treatment delivery, setup and motion monitoring	ÅBP
	Planning: DCA, VMAT, conventional brain IMRT/VMAT	ÅBP
	Plan evaluation; technique, lesion number/distribution, historic plans	ÅBP
	Rx dose, margins, outcome, previous treatment considerations	ÅBP
	Patient specific QA	ÅBP
	Plan checking	ÅBP
	Non-LINAC: Framed SRS in iPlan Review of SRS on non-LINAC machines: GammaKnife, CyberKnife, ZAP-X	ÅBP
Head & Neck	**Photons:**	
	CT simulation, immobilization, positioning	MA
	Image fusion and contours- target definition	MA
	Treatment planning: IMRT and VMAT	MA
	Plan evaluation- dose volume constrains	MA
	Rx dose, margins, outcomes: standard, HYPO, QUADSHOTS	MA
	Plan checking	MA
	Protons	?
Paraspinal	ECHO	LH, YZ
	CT simulation, immobilization, positioning	JM?
	Images and contours	JM?
	Treatment planning: ECHO vs VMAT	YZ
	Plan evaluation; ECHO vs Eclipse VMAT	YZ
	Rx dose, margins, outcomes	JM?

	Plan checking	YZ
CSI	Photons: supine and prone Use test cases in Development system	CDB/AK
	Protons	?
Projects	Cross planning system dose summation: 1. patient treated both on LINAC and MR-LINAC 2. patient treated both at MSK with photons and at proton center	ÅBP, MA

Cross Team Learning

Task	Deception	Requirement	Completion
Calcs	None planned cases	1st calc 2nd calc x?	Completed 1st calc sing-off Pending 2nd check
Previous treatment review/Gap	Prepare special physis consult for cases with previous treatment	H-team plans: 3 for each type (SRS/spi)	
Planning	Team H plans	2 plans/week -> 32	
Plan check	Check of all team H type plans	Observe 1 plan check for each plan type-> 3 2 plans/week x16 = 32	
Chart rounds	Attend weekly chart check with radiation oncology	Attend 1/week -> 16 Brain chart rounds SRS tumor board H&N chart rounds METS chart rounds METS volume review	
EOT	Observe EOT	4 plans/week = 64	
Weeklies	Observe weeklies	4 plans/week = 64	

Required Readings/Training

1. *Radiation Oncology* by Cox and Ang, chapters 8, 9, 33
2. *Treatment planning in Radiation Oncology* by Khan, chapters 21, 22, 23, 28
3. AAPM TG-29 and TG-30
4. *Radiation Oncology* by Cox and Ang, chapters 5-7, 10-14, 34, 35, 37 (suggested)
5. *OSMS: Book chapter (not yet published):* Chapter 20. Image Guidance for Frameless Radiosurgery Including Surface Mapping. Guang Li[1], Josh Yamada[2], and Ase Ballangrud[1]
6. Exactrac
7. MPPG9a
8. Additional readings as assigned by mentor

Key Topics and Tasks

1. See above list

Memorial Sloan Kettering Cancer Center

Final Evaluation

1. Oral Exam
    a. score ≥3 on 5-point scale
2. Written exam
    a. Score ≥80%

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
Motion Management

Rotation Director: Ellen Yorke, Lakshmi Santanam
Rotation Mentors: Linda Hong, Jeho Jeong, Ellen Yorke, Wei Lu, Sharif Elguindi, Grace Tang, Dosimetry Core faculty
Rotation Location(s): MSKCC Main Campus and 61st Street MSK building

Duration: 3 Weeks

Resident Professional Expectations

1. The resident will master and become independent for review of SBRT plans and setups.
2. Resident will also be able to perform Gator duties like binning, Gating setups, Align RT, DIBH

Learning Objectives

1. The resident will be able to demonstrate knowledge of motion management strategies in radiation therapy.
2. The resident will be able to conduct quality assurance activities related to motion management devices.

Observations:
Week 1- 3: Observe 4DCT QA on CT Sims (Flexible depending on QA schedule) Week 1- 3: Observe Monthly, Qurterly or Annual Motion Managment QA on LINACS (Flexible- QA schedule)

Required Readings/Training

1. Keall PJ, Mageras GS, Balter JM, et al. The management of respiratory motion in radiation oncology report of AAPM Task Group 76. *Med Phys.* 2006;33(10):3874-3900.
2. COMP report: CPQR technical quality control guidelines for CT simulators. P.Despres, S.Gaede
3. Ford EC,Mageras GS, Yorke E et al.,Respiration-correlated spiral CT: A method of measuring respiratory-induced anatomic motion for radiation treatment planning. *MedPhys.* 2003;30(1):88-97.
4. Vedam SS, Keall PJ, Kini VR,etal: Acquiring a four dimensional computed tomography dataset using an external respiratory signal.*PhysMedBiol*.2003; 48:45-62.
5. Keall P, 4-dimensional computed tomography imaging and treatment planning. *Semin Radiat Oncol.* 2004 Jan;14(1):81-90.
6. Hua Li, C.Noel, J Garcia-ramirez, clinical evaluations of an amplitude-based binning algorithm for 4DCT reconstruction in radiation therapy. *Med Phys.* 2012 Feb;39(2):922-32.
7. Liu HH, Balter P, Tutt T, et al. Assessing respiration-induced tumor motion and internal target volume using four-dimensional computed tomography for radiotherapy of lung cancer. *Int J Radiat Oncol Biol Phys.* 2007;68(2):531-540.
8. Boda-Heggemann J, Knopf AC, Simeonova-Chergou A, et al. Deep Inspiration Breath Hold-Based Radiation Therapy: A Clinical Review. *Int J Radiat Oncol Biol Phys.* 2016;94(3):478-492.
9. Hunt MA, Sonnick M, Pham H, et al. Simultaneous MV-kV imaging for intrafractional motion management during volumetric-modulated arc therapy delivery. *J Appl Clin Med Phys.* 2016;17(2):473-486.

10. Yorke E, Xiong Y, Han Q, et al. Kilovoltage imaging of implanted fiducials to monitor intrafraction motion with abdominal compression during stereotactic body radiation therapy for gastrointestinal tumors. *Int J Radiat Oncol Biol Phys.* 2016;95(3):1042-1049.
11. Guckenberger M, Wilbert J, Krieger T, et al. Four-dimensional treatment planning for stereotactic body radiotherapy. *Int J Radiat Oncol Biol Phys.* 2007;69(1):276-285.
12. Goharian M, Khan RFH Measurement of time delay for a prospectively gated CT simulator. *Med Phys*. 2010 Apr-Jun; 35(2): 123–127.
13. Kubo.H, Wang L Compatibility of varian 2100c gated operations with enhanced dynamic wedge and IMRT dose delivery. Med Phys 27(8):1732-1738
14. Varian RPM manual
15. AlignRT manual

Final Evaluation

1. Mentor sign off
    a. Aspect of this rotation will be further tested during Team R Oral exam

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
Treatment Planning – Team R

Rotation Director: Ellen Yorke, Lakshmi Santanam
Rotation Mentors: Linda Hong(Breast), Jeho Jeong(Lung), Ellen Yorke(Lung), Wei Lu(Abdomen), Sharif Elguindi(Abdomen), Grace Tang (Breast), Lakshmi Santanam (4DCT, Gating)
Rotation Location(s): MSKCC Main Campus and 61st Street MSK building

Duration: 3 months full time

Resident Professional Expectations
The resident will be trained in treatment planning. During the initial period, the resident will learn image acquisition (by a short simulation rotation), registration and fusion (MR/PET, 4D) and contouring. This will be followed by Eclipse training for isodose computations. The resident will master treatment planning for breast, thorax, Abdomen sites. Included will be an understanding of, irregular field and heterogeneity calculations and compensation techniques. They will also learn to perform IMRT and VMAT plans. During this rotation, physicists and dosimetrists(planners) will closely supervise the physics resident. Upon completing the planning rotation the resident will spend another 1-week rotation on the treatment machines to observe SBRT setups. This could be spread out during the 12weeks. Residents will by the end of 12 weeks, have observed the entire patient path from Simulation, planning, treatment delivery for all 3 sites.

Rotations:
Week 1: Simulation (4DCT, PET/CT)/ MIM Contouring
Week 2-3: Breast Planning Week 3-5: Lung /SBRT Planning Week 6-7 : Abdomen Planning

Assigned Readings
TG 101
TG-66,
TG 76
All reading material listed below

Site Reports and Comprehensions:
Week 3: Breast Planning Report for 3D, VMAT Week 5: Lung /SBRT Planning : Report for SBRT Planning Week 7 : Abdomen Planning : Report for abdomen ablative planning

Required Readings/Training

1. COMP report: CPQR technical quality control guidelines for CT simulators. P.Despres, S.Gaede
2. Stereotactic body radiation therapy: The report of AAPM Task Group 101
3. AAPM-RSS Medical Physics Practice Guideline 9.a. for SRS-SBRT.
4. ACR-ASTRO: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/SBRT-RO.pdf
5. AAPM Task Group #155, "Small Fields and NonEquilibrium Condition Photon Beam Dosimetry"
6. Langen K, Jones D. Organ motion and its management. *Int J Radiat Oncol Biol Phys.* 2001;50(1):265-278.
7. Guckenberger M, Wilbert J, Krieger T, et al. Four-dimensional treatment planning for stereotactic body radiotherapy. *Int J Radiat Oncol Biol Phys.* 2007;69(1):276-285.
8. Goharian M, Khan RFH Measurement of time delay for a prospectively gated CT simulator. *Med Phys*. 2010 Apr-Jun; 35(2): 123–127.

9. Kubo.H, Wang L Compatibility of varian 2100c gated operations with enhanced dynamic wedge and IMRT dose delivery. Med Phys 27(8):1732-1738
10. M. Fuss et al., "Stereotactic body radiation therapy: An ablative treatment option for primary and secondary liver tumors", Annals of Surgical Oncology, 11 (2) 130- 138 (2004). • K.K. Herfarth et al., "Stereotactic single-dose radiation therapy of liver tumors: Results of a phase I/II trial", Journal of Clinical Oncology, 19 (1) 164-170 (2001).
11. ESTRO ACROP consensus guideline on implementation and practice of stereotactic body radiotherapy for peripherally located early stage non-small cell lung cancer. Radiotherapy and Oncology 124(2017)11-17
12. Timmerman et al, Stereotactic Body Radiation Therapy for Operable Early-Stage Lung Cancer: Findings From the NRG Oncology RTOG 0618 Trial. JAMA Oncol 2018(Sep1;4(9)1263-1266
13. Pollom et al., Normal Tissue Constraints for Abdominal and Thoracic Stereotactic Body Radiotherapy. Semin Radiat Oncol 2017 27(3):197-208
14. Licheng Kuo, et al A VMAT planning technique for locally advanced breast cancer patients with expander or implant reconstructions requiring comprehensive postmastectomy radiation therapy. Medical Dosimetry 2019 44: 150-154.
15. Linda Hong, et al Electron postmastectomy chest wall plus comprehensive nodal irradiation technique using Electron Monte Carlo dose algorithm. Dosimetry 2018 43: 230-236.
16. L. Hong, et al INTENSITY-MODULATED TANGENTIAL BEAM IRRADIATION OF THE INTACT BREAST. Int. J. Radiation Oncology Biol. Phys., 1999, Vol. 44, No. 5, pp. 1155–1164.
17. Chen-Shou Chui, et al. INTENSITY-MODULATED RADIOTHERAPY TECHNIQUE FOR THREE-FIELD BREAST TREATMENT. Int. J. Radiation Oncology Biol. Phys., 2005, Vol. 62, No. 4, pp. 1217–1223.
18. Crane C, O'reilly E Ablative radiotherapy dsoes for loclly advacned pancreatic cancer, Cancer 23(6)Nov 2017. (review artricle) 350-354.
19. Crane C, Koay EJ Solutions that enable ablatvie radiotherpy for large liver tumors: fractionated dose painting, simultaneous integrated protection, motion mangement, and CT imgae guidance – review article. Cancer July(2016)1974-1986.
20. Eclipse Algorithm reference guide
21. AAPM #017 – TBI
22. Quantitative analyses of normal tisue effects in the clinic. Int. J. Radiation Oncology Biol. Phys 2010, 76(3) S1-S160

Key Topics and Tasks

1. Complete site-specific reports after completion of each site planning rotation.
2. Meet with the assigned faculty to review site specific planning techniques.

Final Evaluation

1. Oral Exam
    a. score ≥3 on 5-point scale

or

2. Written exam
    a. Score ≥80%

Therapeutic Medical physics Residency

Rotation Curriculum

Treatment Planning – Team G External Beam

Rotation Director: Antonio Damato

Rotation Mentor: David Aramburu Núñez,

Rotation Location(s): MSKCC Main Campus

Duration: 12 weeks full time

Resident Professional Expectations

1. The resident will exhibit professional standards of MSKCC
2. The resident will complete reading assignments prior to weekly meetings with mentor

Learning Objectives

1. The resident will be familiar with simulations and treatment floor setups for prostate patients
2. The resident will be familiar with MSK clinical workflow and general planning procedures for MRCAT and non-MRCAT prostate patients.
3. The resident will be able to perform independently MRCAT fusions and pass its sign off competency.
4. The resident will be able to perform independently prostate hypo and conventional planning.
5. The resident will be able to understand why different fractionations and dose constraints used for different prostate patients and toxicities related to the treatment.
6. The resident will be familiar with simulations and treatment floor setups for GU/GYN/PELVIS patients
7. The resident will be familiar with MSK clinical workflow and general planning procedures for GU/GYN/PELVIS patients.
8. The resident will be able to understand why Simultaneous integrated boost (SIB) or Cone Down (CD) schemes are selected for specific GYN patients and toxicities related to the treatment.
9. The resident will be able to perform independently GU/GYN/PELVIS planning.
10. The resident will be familiar with MSK clinical workflow and general planning procedures for extremity cases.
11. The resident will be familiar with simulations and treatment floor setups for extremity cases.

12. The resident will be able to perform independently planning for extremity cases.
13. The resident will understand the advantages and consequences of using different energies and treatment types for specific sites.
14. The resident will be able to answer any questions related to the plans by the MD or licensed medical physicist.
15. The resident will attend to Chart Rounds and will be able to answer any questions by the MD.

Required Reading/Training

1. H:\Medical Physics\Treatment Planning\EBTP INFO\aaaTREATMENT PLANNING PROCEDURES\PROCEDURES-ECLIPSE SITE SPECIFIC\prostate
2. H:\Medical Physics\Treatment Planning\EBTP INFO\aaaTREATMENT PLANNING PROCEDURES\PROCEDURES-ECLIPSE SITE SPECIFIC\GI-GYN
3. H:\Medical Physics\Treatment Planning\EBTP INFO\aaaTREATMENT PLANNING PROCEDURES\PROCEDURES-ECLIPSE SITE SPECIFIC\Extremity
4. Report No. 101 - Stereotactic body radiation therapy: The report of AAPM Task Group 101 (2010)
5. MRI for Radiotherapy Planning, Delivery, and Response Assessment Editors: Liney, Gary, van der Heide, Uulke (Eds.) (https://link.springer.com/book/10.1007%2F978-3-030-14442-5)

Key Topics and Tasks

1. Observe 3 simulations of each: Prostate CT and Prostate MRCAT
2. Perform MRCAT Setup for Post-op (at least 1), Post- brachy (at least 2), Intact prostate (at least 2).
3. Pass MRCAT Sign off Competency
4. Perform 5 Hypo and 5 conventional Prostate planning (at least 2 MVKV, at least 1 ECHO)
5. Competency in Hypo and Conventional Prostate Planning.
6. Observe 3 simulations for GU/GYN/PELVIS.
7. Perform 10 conventional GU/GYN/PELVIS planning. (at least 1 Bladder, at least 2 3DCRT, at least 2 IMRT, if not possible training cases will be available).
8. Observe 5 simulations for GU/GYN/PELVIS.
9. Perform 10 plans for extremity cases (if not possible, training cases will be available)
10. Attend 5 Chart Rounds (GU/GYN/SARCOMA)
11. Attend Team G monthly prostate meetings.
12. Attend New planner meetings.
13. Attend General Treatment planning meetings.

Final Evaluation

1. Oral Exam

a. Passing ≥3 average score out of 5

Therapeutic Medical Physics Residency
Rotation Curriculum
Treatment Planning – Team G Brachytherapy

Rotation Director: Antonio Damoto
Rotation Mentors: Gilad Cohen
Rotation Location(s): MSKCC Main Campus

Duration: 12 Weeks full time

Resident Professional Expectations

The resident attend QA procedures and clinical cases, as directed by the mentor, and keep track of his/her progress. The mentor will indicate relevant reading in line with clinical cases.

Every two weeks, the resident will meet with the mentor to evaluate the residents' progress, by means of an oral quiz.

Learning Objectives

While the resident will be exposed to procedure as they are performed at MSK, emphasis will also be given to the understanding of basic principles, and methodology. The learning objectives include:

- Ability to perform QA tasks independently
- Ability to perform clinical procedure (under supervision as required by regulations)
- Ability to apply learned techniques in other clinics with different platforms and implantation procedures

Required Readings/Training

1. Brachytherapy physics; AAPM summer school 1994
2. Brachytherapy physics; AAPM/ABS summer school 2005
3. MSKCC brachytherapy service Policy and Procedures (MSKCC staff)
4. Relevant publications (e.g. AAPM TG reports, ABS, and ICRU guidelines)

Key Topics and Tasks

Clinical Rotation – Brachytherapy	**Date**	**Clinical Rotation**
Learning exercises: (*to be done if new equipment is not purchased during the resident's training period.*)		
Review purchase, commissioning and acceptance testing of the brachytherapy treatment planning system and remote		
Participate in planning and treatment for:		
Prostate LDR		
Eye plaques		
Cervix HDR		
Prostate HDR		
Vaginal/Endometrial HDR		
IORT		
Other procedures as they are scheduled		
Handling of sealed radioactive sources (min # of Activities of each type required)		
Ordering / Source type:		
I-125, Pd-103 (5)		
Ir-192 HDR (none required standing order)		
Receiving/Source type		
All of the above (2)		
Calibration/Source type		
I-125, Pd-103, Cs-131 (5)		

Ir-192 HDR (3)		
Preparation for procedure / source type		
Eye plaques (2)		
Other permanent implants (as available)		
Storage - inventory-wipe test		
NA		
Shipment / source type:		
Ir-192 HDR (2)		
Disposal (waste storage) / source type:		
I-125, Pd-103, Cs-131 (2)		
Treatment planning (min # plans of each type completed)		
LDR prostate (5)		
LDR temporary implant (pending clinical schedule)		
Eye plaque (2)		
HDR Prostate (5)		
Interstitial HDR implant (pending clinical schedule)		
Intra-operative HDR implants (3)		
HDR gynecological implants (5)		
Treatment plan QA (min # for each plan type)		
LDR prostate (5)		
LDR temporary implant (pending clinical schedule)		
Eye plaque (2)		
HDR Prostate (5)		
Interstitial HDR implant (pending clinical schedule)		
Intra-operative HDR implants (3)		
HDR gynecological implants (5)		
HDR Quality Assurance		
Emergency response training (complete at least 1 session)		
Pre-treatment operational and safety checks (complete at least 5 check sessions)		
Participate in at least 2 source changes and subsequent QA/PM		
Treatment delivery (min # of each)		
Prostate HDR implants (2)		
Intra-operative HDR implants (2)		
Intraluminal HDR implants (2)		
Intracavitary HDR implants (2)		
treatment delivery (min # of each)		
Permanent LDR prostate (5)		
LDR temporary implant (if scheduled)		
LDR Eye plaque (2)		
Post implant evaluation and review of permanent implants (min # of ea)		
Prostate implants (5)		
Other permanent implants (pending clinical schedule)		

Memorial Sloan Kettering Cancer Center

Final Evaluation

1. Oral Exam
    a. score ≥3 on 5-point scale
2. Written exam
    a. Score ≥80%

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
Chart Check and Review

Rotation Director: Laura Cervino
Rotation Mentors: Cesar Della Biancia
Rotation Location(s): MSKCC Main Campus

Duration: 6 Weeks

Resident Professional Expectations

1. The resident will exhibit professional standards of MSKCC
2. The resident will demonstrate punctuality.
3. The resident will be present for all assignments
    a. Should a resident not be able to attend assignment enough notification with faculty should be given
4. The resident will communicate effectively with faculty, staff and physicians.

Learning Objectives

1. The resident will be able to independently review a treatment plan chart
2. The resident will be able to independently review weekly treatment chart audits
3. The resident will be able to independently complete end of treatment chart review
4. The resident will be able to discus the applications of checklists in chart review
5. The resident will be able to demonstrate understanding and ability in SPOC role
6. The resident will be able to assist as on-call physicist

Required Readings/Training

1. Report of the Task Group #275, Chart review
2. Medical Physics Practice Guideline 4.a: Development, implementation, use and maintenance of safety checklists published in the **Journal of Applied Clinical Medical Physics** (JACMP). Volume 16, Number 3 (2015). [ISBN: 978-1-936366-46-0]
3. AAPM Report No. 46 (TG 40) "Compressive QA for Radiation Oncology". https://www.aapm.org/pubs/reports/RPT_46.PDF

Key Topics and Tasks

1. Complete 5-10 chart check observations
2. Complete 10 independent check checks for presentation and sign off by faculty.
3. Complete weekly chart review as assigned
4. Complete End of Treatment chart check as assigned

Final Evaluation

1. Oral Exam
    a. Passing score ≥3 on 5 Pt scale
2. Oral Exam
    a. score ≥3 on 5-point scale
3. Written exam
    a. Score ≥80%

4. Completion of required number of plan checks

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
Regional Clinic

Rotation Director: As Assigned
Rotation Mentors: As Assigned
Rotation Location(s): As Assigned

Duration: 6 Weeks

Resident Professional Expectations

1. The resident will perform duties and act in expected professional manner as learned during orientation rotation.
2. The resident will comport themselves with any additional requirements as outlined by their outpatient rotation mentor.

Learning Objectives

1. The resident will be able to synthesize what was learned during their specialized main campus rotations (e.g. dosimetry, brachytherapy, external beam planning) into a comprehensive understanding of the role of a physicist at a small to medium sized (3-4 linacs) practice, where the physicist is generally responsible for all aspects of clinical physics on a day-to-day basis.
   To perform clinical physics functions, mainly machine QA, initial, weekly, and end-of treatment chart checks, brachytherapy (if available), and being the first line of contact for machine or patient-related issues on the linac or in the simulator as independently as possible within the bounds of NYC/NYS or NJ practice guidelines.

Required Readings/Training

1. MPPG 10a
2. Report of the Task Group #275

Key Topics and Tasks

1. Under the supervision of a (NYS defined) PMP:
   a. Complete 1 monthly linac QA for every month on the rotation
   b. Complete 1 CT simulator QA for every month on the rotation
   c. Complete initial, weekly, and EOT physics chart checks with a frequency equal to that of other physicists in the region.
   d. Serve as senior physicist on-call (SPOC) and first line of contact for linac/simulator calls to physics
   e. If brachytherapy available at the site,
      i. Perform 1 source exchange (if occurs during rotation)
      ii. Perform IVRT planning, delivery, daily HDR QA
   f. The resident will be able to perform patient specific dosimetry in vivo measurement

Final Evaluation

1. Oral Exam
   a. score ≥3 on 5-point scale

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
MR-Linac

Rotation Director: James Mechalakos
Rotation Mentors: Neelam Tyagi, Ergys Subashi
Rotation Location(s): MSKCC Koch Center

Duration: 4 Weeks

Resident Professional Expectations

1. The resident will perform duties and act in expected professional manner as learned during orientation rotation.
2. The resident will comport themselves with any additional requirements as outlined by their outpatient rotation mentor.

Learning Objectives

1. The resident will be able to demonstrate knowledge of MR Safety
2. The resident will be able to demonstrate knowledge of MR-Linac QA processes
3. The resident will be able to discuss adaptive radiotherapy and its applications
4. The resident will be able to discuss Synthetic CT used in planning
5. The resident will be able to demonstrate basic Mosaiq and Monaco skills

Required Readings/Training

1. Report of the Task Group #275
2. C Kontaxis, G H Bol, J J W Lagendijk and B W Raaymakers, "A new methodology for inter- and intrafraction plan adaptation for the MR-linac". Physics in Medicine & Biology, Volume 60, Number 19:7485-97
3. K Smit, B van Asselen, J G M Kok, A H L Aalbers, J J W Lagendijk and B W Raaymakers, " Towards reference dosimetry for the MR-linac: magnetic field correction of the ionization chamber reading". Physics in Medicine & Biology, Volume 58, Number 17: 5945-57
4. C Kontaxis, G H Bol, J J W Lagendijk and B W Raaymakers, "Towards adaptive IMRT sequencing for the MR-linac". Physics in Medicine & Biology, Volume 60, Number 6:2493-2509
5. D Winkel et al. "Adaptive Radiotherapy: The Elekta Unity MR-Linac Concept". Clin and Trans Rad Oncol V18, Pg. 54-59.
6. K Smit, B van Asselen, J G M Kok, A H L Aalbers, J J W Lagendijk and B W Raaymakers, " Towards reference dosimetry for the MR-linac: magnetic field correction of the ionization chamber reading". Physics in Medicine & Biology, Volume 58, Number 17:5945-57
7. X. Allen Li (Ed), "Adaptive Radiotherapy". CRC Press Francis & Taylor, Boca Raton, FL 2011
8. Additional readings as assigned

Key Topics and Tasks

1. Complete monthly MR-Linac QA
2. Complete an MR-Linac treatment plan in Monco
3. Complete transfer of pan to Mosaiq

Memorial Sloan Kettering Cancer Center

Final Evaluation

1. Oral Exam
    a. >3 average score on 5 pt scale.

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
Proton Therapy

Rotation Director: Haibo Lin, Ph.D
Rotation Mentors: Haibo Lin Ph.D, Minglei Kang Ph.D, Pingfang Tsai Ph.D, Weijun Xiong Ph.D, Qing Chen M.S, Francis Yu M.S, Lei Hu Ph.D, Anna Zhai M.S
Rotation Location(s): New York Proton Center

Duration: 8 Weeks

Resident Professional Expectations

1. The therapeutic medical physics residents in the department of medical physics at Memorial Sloan Kettering Cancer Center will be expected to achieve the following competencies associated with proton therapy.

Learning Objectives

1. The resident will be able to demonstrate knowledge of basic physics of proton therapy including interactions of protons with material, Bragg peak, etc
2. To learn the clinical rationale of proton therapy
3. To understand the major proton machine components such as cyclotron for proton acceleration, energy selection system, beamline for beam delivery, gantry, snout, nozzle and associated accessories.
4. To learn different proton delivery methods such as passive scattering and active scanning techniques, their pros and cons.
5. To Understand the root of uncertainties associated with proton therapy, especially for pencil beam scanning technique.
6. To learn quality assurance (QA) instruments used for proton therapy such as ion chambers, Multi-layer Ionization Chambers (MLICs), detector arrays, film dosimetry, scintillator detector.
7. To learn the TRS-398 protocol for absolute dose calibration protocol of proton beam
8. To learn NYPC proton machine QA protocols for daily, monthly and annual checks
9. To learn NYPC patient specific QA procedure for different treatment techniques e.g. Single Field Optimization (SFO) and Multi-field Optimization (MFO).
10. To learn basic treatment planning for proton therapy including SOF and MFO for various disease sites.
11. To learn how to evaluate a proton plan quality for different treatment sites.
12. To learn CT and MRI simulations for proton therapy and associated patient setup & immobilization for proton therapy
13. To learn basic protocol for CT HU - proton stopping power calibration
14. To understand the shielding requirements for proton therapy facilities
15. To participate ProBeam system commissioning (before center open) including beam data collection, TPS configuration, validation of TPS configuration, validation of CT calibration and end-to-end test.

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Required Readings/Training

Required Readings:

1. *ACR-ASTRO practice guideline for the performance of proton beam radiation therapy*. American College of Radiology, 2013. Available at: http://www.acr.org/w/media/7BEBF7E77E1141578 CB8722F997BDE9B.pdf.
2. *(TRS) no. 398. Absorbed dose determination in external beam radiotherapy.* An international code of practice for dosimetry based on standards of absorbed dose to water. Vienna: International Atomic Energy Agency Technical report series; 2000.
3. *Prescribing, Recording and Reporting Proton-Beam Therapy.* ICRU report 78. Oxford: Oxford University Press; 2007. Available at AAPM web site.
4. *Proton Beam Therapy*, Kooy and Adams, Ch 18 in *Treatment Planning in Radiation Oncology*, ed. Khan, Gibbons and Sperduto, 2016.
5. *Role of Protons Versus Photons in Modern Radiotherapy: Clinical Perspective*, Yip, Wand and DeLaney, Ch 19 in *Treatment Planning in Radiation Oncology*, ed. Khan, Gibbons and Sperduto, 2016.
6. *Intensity Modulated Proton Therapy*, Lomax Ch 10 in *Treatment Planning in Radiation Oncology*, ed. Khan, Gibbons and Sperduto, 2016.

Suggested Readings:

1. *Radiation Oncology: A physicists-eye view.* Goitein, M. 2008. New York: Springer. Chapters 10 & 11.
2. *Proton and Charged Particle Radiotherapy.* DeLaney and Kooy. Lippincott, Williams and Wilkins (2007)
3. *Proton Therapy Physics*, 2nd ed. H. Paganetti, 2018
4. *Eclipse treatment planning algorithm: proton therapy*
5. *Radiation safety issues relevant to proton therapy and radioisotope production medical cyclotrons* Mukherjee, B. 2012, *Radiation Protection and Environment*, Vol. 35, Issue 3&4, p126-134.
6. *Radiation Therapy with Light Ions.* Vatnitsky, S.M. and M.F. Moyers. 2013,. In *The Modern Technology of Radiation Oncology*: *Vol.* III, ed. J. VanDyk, 183-222. Madison: Medical Physics Publishing. (see Pat McDermott)

Key Topics and Tasks

1. Clinical Activity 1: ProBeam Daily QA
   a. Observe and perform the machine daily QA. Attach a copy of daily QA report.
2. Clinical Activity 2: ProBeam Monthly QA
   a. Observe and perform the monthly QA. Attach a copy of monthly QA report.
3. Clinical Activity 3: Patient Specific QA
   a. Observe and perform patient specific QA.
4. Clinical Activity 4: CT Monthly QA

   a. Observe and perform the CT monthly QA. Attach a copy of monthly QA report.
5. Clinical Activity 5: Imaging transfer and registration
   a. Observe and Perform CT imaging transfer and imaging registration.
6. Clinical Activity 6: Daily Physics support – early shift
   a. Observe and shadow early shift Physics of the Day (POD) for clinical supports.
7. Clinical Activity 7: Daily Physics support – late shift
   a. Observe and shadow late shift Physics of the Day (POD) for clinical supports.
8. Clinical Activity 8: Physics chart checks
   a. Observe and perform physics chart checks.
9. Clinical Activity 9: Proton simulation observation
   a. Observe proton patient simulation for various disease sites.
10. Clinical Activity 10: Proton treatment observation
    a. Observe proton treatment for various disease sites.
11. Clinical Activity 11: Proton treatment planning
    a. observe and perform proton treatment planning for different treatment sites.
12. Clinical Activity 12: Proton beam calibration – TRS 398
    a. Perform proton beam absolute dose calibration using IAEA TRS-398 protocol

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NYPC Proton Therapy Rotation Sign Off Sheet

Name of trainee:_____________________________________

Your signature indicates that you have read the reference

Required Reading

Reference	Signature	Date
ACR-ASTRO practice guideline		
(TRS) # 398. Absorbed dose determination in external beam radiotherapy		
Prescribing, Recording and Reporting Proton-Beam Therapy ICRU #78		
Proton Beam Therapy by Kooy and Adams: chapter 18 treatment planning		
Role of Protons Versus Photons in Modern Radiotherapy: Clinical Perspective: chapter 19 treatment planning		
Intensity Modulated Proton Therapy: chapter 10 Treatment planning		

Proton Therapy Rotation Sign Off Sheet (2 of #)

Name:_____________________________________

Clinical Activity 1: ProBeam Daily QA

The resident has observed the daily ProBeam machine QA

Medical Physicist Signature #1:__________________________________ Date:__________________

The resident has observed the daily ProBeam machine QA

Medical Physicist Signature #2:_________________________________ Date:__________________

The resident has *performed* daily ProBeam machine QA under my supervision

Medical Physicist Signature:_________________________________ Date:__________________

Clinical Activity 2: ProBeam Monthly QA

The resident has observed the monthly ProBeam machine QA

Medical Physicist Signature:_________________________________ Date:__________________

The resident has observed the monthly ProBeam machine QA

Medical Physicist Signature:_________________________________ Date:__________________

The resident has *performed* the Monthly ProBeam machine QA under my supervision

Medical Physicist Signature:_________________________________ Date:__________________

Clinical Activity 3: Patient Specific QA

The resident has observed the patient specific QA

Medical Physicist Signature:_________________________________ Date:__________________

The resident has observed the patient specific QA

Medical Physicist Signature:_________________________________ Date:__________________

The resident has *performed* the patient specific QA under my supervision

Medical Physicist Signature:_________________________________ Date:__________________

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Clinical Activity 4: CT Monthly QA

The resident has observed the CT monthly machine QA

Medical Physicist Signature:___________________________________ Date:___________________

The resident has observed the CT monthly machine QA

Medical Physicist Signature:___________________________________ Date:___________________

The resident has *performed* the CT Monthly machine QA under my supervision

Medical Physicist Signature:___________________________________ Date:___________________

Clinical Activity 5: Imaging transfer and registration

Observe and Perform the transfer of the CT imaging data set from CT console to Eclipse/Velocity and perform imaging registration.

Signature/Date	
Signature/Date	

Clinical Activity 6: Daily Physics support – early shift

Observe and shadow early shift Physics of the Day (POD) for clinical support.

Oversee the machine performance, communicate with physician, therapist and dosimetrist for problems/issues and provide clinical supports in plan review, QA check, chart check .etc. Perform the machine morning QA.

Signature/Date	
Signature/Date	
Signature/Date	
Signature/Date	
Signature/Date	
Signature/Date	

Signature/Date	
Signature/Date	
Signature/Date	
Signature/Date	
Signature/Date	

Clinical Activity 7: Daily Physics support – late shift

Observe and shadow late shift Physics of the Day (POD) for clinical support.

Oversee machine performance, communicate with physician, therapist and dosimetrist about the problems and provide clinical support in plan review, QA check, chart check .etc. Perform the machine QA and patient specific QA after patient treatment.

Signature/Date	
Signature/Date	
Signature/Date	
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Signature/Date	
Signature/Date	
Signature/Date	
Signature/Date	

Clinical Activity 8: Physics chart checks

Observe and perform physics chart checks with licensed Medical Physicist.

Signature/Date	
Signature/Date	
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Signature/Date	
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Signature/Date	
Signature/Date	

Clinical Activity 9: Proton simulation observation

Observe proton patient simulation for various disease sites.

Pediatric vs adult treatment; CNS, H&N, Brain, Prostate, CSI, Lung, breast Abdomen region.

Signature/Date	Disease site

Clinical Activity 10: Proton treatment observation

Observe proton treatment for various disease sites.

Pediatric vs adult treatment; CNS, H&N, Brain, Prostate, CSI, Lung, breast Abdomen region.

Signature/Date	Disease site

Clinical Activity 11: Proton treatment planning

observe and perform proton treatment planning for different treatment sites.

Pediatric vs adult treatment; CNS, H&N, Brain, Prostate, CSI, Lung, breast Abdomen region.

Signature/Date/observation	Disease site	*Signature/Date/planning*

Clinical Activity 12: Proton beam calibration – TRS 398

Perform proton beam absolute dose calibration using IAEA TRS-398 protocol.

Signature/Date		

Memorial Sloan Kettering Cancer Center

Therapeutic Medical Physics Residency
Rotation Curriculum
Supervised Independent Practice

Rotation Director: As assigned
Rotation Mentors: As assigned
Rotation Location(s): As Assigned

Duration: 8 Weeks

Residents will be assigned to a section/team and perform clinical duties as assigned within their scope of permit.

Resident Professional Expectations

1. The resident will act as a member of the assigned team completing all assignments in a timely manner.
2. The resident is expected to act independently within the scope and limits of their permit and section directors' assignments.

Learning Objectives

1. The resident will be able to demonstrate knowledge and ability to perform standard medical physics duties at the level of junior physicist.
2. Deficiencies identified from earlier rotations will be addressed and corrected.
3. The resident will develop confidence in clinical problem solving.
4. The resident will show competence in acting as an independent practitioner of therapeutics medical physics.

Required Readings/Training

1. As assigned by the rotation mentor or section chief.

Key Topics and Tasks

1. Assigned task per the clinical service.

Final Evaluation

1. Oral Exam (comprehensive)
    a. Average score ≥3 on 5-point scale

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Therapeutic Medical Physics Residency
Rotation Curriculum
Elective

Rotation Director: Christopher J. Watchman, PhD, DABR
Rotation Mentors: as assigned per the specifics of the elective rotation
Rotation Location(s): As Assigned

Duration: 4 Weeks

Resident Professional Expectations

1. The resident will choose an elective and coordinate with the assigned mentor.
2. The resident will complete all outstanding work related to clinical assignments, development projects and program requirements.
3. The resident will provide the program director with all completed work and forms.
4. The resident will leave with the program director, mentor and/or other faculty needed documentation and work product developed during their residency.

Learning Objectives

1. The resident will learn to complete and closeout employment with an employer.

Required Readings/Training

1. As assigned by mentor or director

Key Topics and Tasks

1. TBD based on resident's elective