

INTENSITY MODULATED RADIATION THERAPY (IMRT)

This Model Policy¹ addresses coverage for Intensity Modulated Radiation Therapy (IMRT).

DESCRIPTION

Intensity Modulated Radiation Therapy (IMRT) is a technology for delivering highly conformal external beam radiation to a well-defined treatment volume with radiation beams whose intensity varies across the beam. IMRT is particularly useful for delivering a highly conformal radiation dose to targets positioned near sensitive normal tissues.

TREATMENT


IMRT Treatment Planning

IMRT treatment plans are tailored to the target volumes and are geometrically more accurate than conventional or three-dimensional conformal radiation therapy plans. IMRT planning defines the necessary field sizes, gantry angles and other beam characteristics needed to achieve the desired radiation dose distribution.

IMRT treatment planning (i.e., inverse treatment planning) is a multi-step process:

1. **Imaging:** Three-dimensional image acquisition of the target region by simulation employing CT, MR, PET scanners or similar image fusion technology is an essential prerequisite to IMRT treatment planning. If respiratory or other normal organ motion is expected to produce significant movement of the target region during radiotherapy delivery, the radiation oncologist may additionally elect to order multi-phasic treatment planning image sets to account for motion when rendering target volumes.
2. **Contouring:** Defining the target and avoidance structures is in itself a multi-step process:
 - a. The radiation oncologist reviews the three-dimensional images and outlines the treatment target on each slice of the image set. The summation of these contours defines the Gross Tumor Volume (GTV). For multiple image sets, the physician may outline separate GTVs on each image set to account for the effect of normal organ motion upon target location and shape. Some patients may not have GTVs if they have had previous treatment with surgery or chemotherapy, in which case treatment planning will be based on CTVs as described below.
 - b. The radiation oncologist draws a margin around the GTV to generate a Clinical Target Volume (CTV) which encompasses the areas at risk for microscopic disease (i.e., not visible on imaging studies). Other CTVs may be created based on the estimated volume of residual disease. For multiple image sets, the physician may draw this margin around an aggregate volume containing all image set GTVs to generate an organ-motion CTV, or Internal Target Volume (ITV).
 - c. To account for potential daily patient set-up variation and/or organ and patient motion, a final margin is then added to create a Planning Target Volume (PTV).

¹ ASTRO model policies were developed as a means to efficiently communicate what ASTRO believes to be correct coverage policies for radiation oncology services. The ASTRO Model Policies do not serve as clinical guidelines and they are subject to periodic review and revision without notice. The ASTRO Model Policies may be reproduced and distributed, without modification, for noncommercial purposes.

- 
- d. Any combination of the GTV, CTV, ITV or PTV may be contoured depending on the clinical situation and the intent of treatment.
 - e. Nearby normal structures that could potentially be harmed by radiation (i.e., “organs at risk”, or OARs) are also contoured.
 3. **Radiation Dose Prescribing:** The radiation oncologist assigns specific dose requirements for the PTV which typically includes a prescribed dose that must be given to at least 90-95% of the PTV. This is often accompanied by a minimum acceptable point dose within the PTV and a constraint describing an acceptable range of dose homogeneity. Additionally, PTV dose requirements routinely include dose constraints for the OARs (e.g., upper limit of mean dose, maximum allowable point dose and/or a critical volume of the OAR that must not receive a dose above a specified limit). A treatment plan that satisfies these requirements and constraints should maximize the potential for disease control and minimize the risk of radiation injury to normal tissue.
 4. **Dosimetric Planning and Calculations:** The medical physicist or a supervised dosimetrist calculates a multiple static beam and/or modulated arc treatment plan to deliver the prescribed radiation dose to the PTV and simultaneously satisfy the normal tissue dose constraints by delivering significantly lower doses to nearby organs. Dose-volume-histograms are prepared for the PTV and OARs. Here, an arc is defined as a discrete complete or partial rotation of the linear accelerator gantry during which there is continuous motion of the multi-leaf collimator to deliver an optimized radiation dose distribution within the patient. The essential feature of an IMRT plan is that it describes the means to deliver treatment utilizing non-uniform beam intensities. Each radiation beam or arc is, in effect, a collection of numerous “beamlets,” each with a different level of radiation intensity; the summation of these “beamlets” delivers the characteristic highly conformal IMRT dose distribution. The physicist and dosimetrist perform basic dose calculations on each of the modulated beams or arcs. These patient specific monitor unit computations verify through an independent second dose calculation method the accuracy of the calculations.
 5. **Patient Specific Dose Verification:** The calculated beams or arcs are then delivered either to a phantom or a dosimetry measuring device to confirm that the intended dose distribution for the patient is physically verifiable and that the intensity modulated beams or arcs are technically feasible. Additional information can be found in the ASTRO QA White Paper (General Reference #13), which critically evaluates guidance and literature on the safe delivery of IMRT, with a primary focus on recommendations to prevent human error and methods to reduce or eliminate mistakes or machine malfunctions that can lead to catastrophic failures.

Documentation of all aspects of the treatment planning process is essential.

IMRT Treatment Delivery

The basic requirement for all forms of IMRT treatment delivery is that the technology must accurately produce the calculated dose distribution described by the IMRT plan. IMRT treatment delivery may be accomplished via various combinations of gantry motion, table motion, slice-by-slice treatment (tomotherapy) and multi-leaf collimator (MLC) or solid compensators to modulate the intensity of the radiation beams or arcs.

The highly conformal dose distribution produced by IMRT results in sharper spatial dose gradients than conventional or three-dimensional conformal radiation therapy. Consequently, small changes in patient position or target position within the body can cause significant changes in the dose delivered to the PTV and to the organs at risk; thus reproducible patient immobilization is required for precision IMRT. Imaging techniques such as stereoscopic kilovoltage or megavoltage X-ray, ultrasound, or cone beam or megavoltage CT scan (collectively referred to as Image Guided Radiation Therapy or IGRT) may be utilized to account for daily motion of the PTV to accurately deliver the treatment.

Documentation Requirements

Documentation in the patient's medical records must support:

1. The reasonable and necessary requirements as outlined under the "Indications and Limitations of Coverage and/or Medical Necessity" section of this policy.
2. The prescription which defines the goals and requirements of the treatment plan, including the specific dose constraints to the target and nearby critical structures.
3. A note of medical necessity for IMRT by the treating physician.
4. Signed IMRT inverse plan that meets prescribed dose constraints for the planning target volume (PTV) and surrounding normal tissue.
5. The target verification methodology must include the following:
 - a. Documentation of the clinical treatment volume (CTV) and the planning target volume (PTV).
 - b. Documentation of immobilization and patient positioning.
6. Independent basic dose calculations of monitor units have been performed for each beam before the patient's first treatment.
7. Documentation of fluence distributions (re-computed and measured in a phantom or dosimetry measuring device) is required.
8. Documentation supporting identification of structures that traverse high-and low-dose regions created by respiration is indicated when billing for respiratory motion management simulation.

INDICATIONS AND LIMITATIONS OF COVERAGE AND/OR MEDICAL NECESSITY

Indications For Coverage

As IMRT technology was introduced and the appropriate clinical applications were being established, earlier versions of this model policy identified specific disease sites for which IMRT was considered a standard option. The maturation and dissemination of IMRT capabilities with improved clinical outcomes has expanded to the point that a definitive list of "approved sites" driven solely by diagnosis codes (ICD-9 or ICD-10) is no longer sufficient. However, it is important to note that normal tissue dose volume histograms (DVHs) or dosimetry must be demonstrably improved with an IMRT plan to validate coverage. Therefore, coverage decisions must extend beyond ICD-9 and ICD-10 codes to incorporate additional considerations of clinical scenario and medical necessity with appropriate documentation. For some anatomical sites such as nasopharynx, oropharynx, hypopharynx, larynx (except for early true vocal cord cancer), prostate, anus and central nervous system, IMRT is commonly performed. In all cases, documentation of the medical necessity is required.

IMRT is considered reasonable and medically necessary in instances where sparing the surrounding normal tissue is of added clinical benefit to the patient. Common clinical indications that frequently support the use of IMRT include:

1. Primary, metastatic or benign tumors of the central nervous system.
2. Primary, metastatic tumors of the spine where spinal cord tolerance may be exceeded by conventional treatment.
3. Selected extracranial primary, metastatic or benign lesions.
4. Reirradiation that meets the requirements for medical necessity.

IMRT offers advantages as well as added complexity over conventional or three-dimensional conformal radiation therapy. Before applying IMRT techniques, a comprehensive understanding of the benefits and consequences is required. In addition to satisfying at least one of the four selection criteria noted above, the radiation oncologist's decision to employ IMRT requires an informed assessment of benefits and risks including:

- Determination of patient suitability for IMRT allowing for reproducible treatment delivery.
- Adequate definition of the target volumes and organs at risk.
- Equipment capability, including ability to account for organ motion when a relevant factor.
- Physician and staff training.
- Adequate quality assurance procedures.

On the basis of the above conditions demonstrating medical necessity, disease sites that may support the use of IMRT include the following:

- Primary, metastatic or benign tumors of the central nervous system including the brain, brain stem and spinal cord.
- Primary or metastatic tumors of the spine where the spinal cord tolerance may be exceeded with conventional treatment or where the spinal cord has previously been irradiated.
- Primary, metastatic, benign or recurrent head and neck malignancies including, but not limited to those involving:
 - Orbits,
 - Sinuses,
 - Skull base,
 - Aero-digestive tract, and
 - Salivary glands.
- Thoracic malignancies.
- Abdominal malignancies when dose constraints to small bowel or other normal tissue are exceeded and prevent administration of a therapeutic dose.
- Pelvic malignancies, including prostatic, gynecologic and anal carcinomas.
- Other pelvic or retroperitoneal malignancies.

The final determination of the appropriateness and medical necessity for IMRT resides with the treating radiation oncologist who should document the justification for IMRT for each patient.

ICD-10-CM Codes that may be Associated with Medical Necessity

Note: Diagnosis codes are based on the current ICD-10-CM codes that are effective at the time of the Model Policy publication. Any updates to ICD-10-CM codes will be reviewed by ASTRO, and coverage should not be presumed until the results of such review have been published/posted. These ICD codes may support medical necessity under this Model Policy.

System	Site	ICD-10-CM Codes
Head and Neck	Lip	C00.0 - C00.9
	Tongue	C01 - C02.9
	Major salivary glands	C07 - C08.9
	Gum	C03.0 - C03.9
	Floor of mouth	C04.0 - C04.9
	Other parts of the mouth	C05.0 - C06.9
	Oropharynx	C09.0 - C10.9
	Nasopharynx	C11.0 - C11.9
	Hypopharynx	C12 - C13.9
	Nasal cavities, middle ear and accessory sinuses	C30.0 - C31.9
	Larynx	C32.0 - C32.9
Digestive Organs and Peritoneum	Esophagus	C15.3 - C15.9
	Stomach	C16.0 - C16.9
	Small intestine	C17.0 - C17.9
	Colon	C18.0 - C18.9
	Rectum, rectosigmoid, anus	C19 - C21.8
	Liver, intrahepatic bile ducts	C22.0 - C22.9
	Gallbladder, extrahepatic bile ducts	C23 - C24.9
	Pancreas	C25.0 - C25.9
	Retroperitoneum, peritoneum	C45.1 C48.0 - C48.8
Respiratory and Intrathoracic Organs	Trachea, bronchus and lung	C33 - C34.92
	Pleura	C38.4 C45.0
	Thymus, heart and mediastinum	C37 - C38.8 C45.2



System	Site	ICD-10 Codes
Bone, connective tissue and skin	Bone	C40.00 - C41.9
	Connective and other soft tissue	C47.0 - C49.9
	Skin	C43.0 - C44.99 D03.0 - D03.9
	Kaposi's sarcoma	C46.0- C46.9
	Merkel cell carcinoma	C4A.0 - C4A.9 D3A.00 - D3A.8 C7B.00 - C7B.1
Breast	Female breast	C50.011 - C50.019 C50.111 - C50.119 C50.211 - C50.219 C50.311 - C50.319 C50.411 - C50.419 C50.511 - C50.519 C50.611 - C50.619 C50.811 - C50.819 C50.911 - C50.919 D05.00 - D05.92
	Male breast	C50.021 - C50.029 C50.121 - C50.129 C50.221 - C50.229 C50.321 - C50.329 C50.421 - C50.429 C50.521 - C50.529 C50.621 - C50.629 C50.821 - C50.829 C50.921 - C50.929
Genitourinary organs	Cervix	C53.0 - C53.9
	Uterus	C55 C54.0 - C54.9
	Ovary and adnexa	C56.1 - C57.4
	Other female genital organs	C51.0 - C52 C57.7 - C57.9
	Prostate	C61
	Testis	C62.00 - C62.90
	Penis and other male genital organs	C60.0 - C60.9 C63.00 - C63.9
	Bladder	C67.0 - C67.9
	Kidney	C64.1 - C66.9 C68.0 - C68.9



System	Site	ICD-10 Codes
Other sites	Eye	C69.00 - C69.92
	Brain, other parts of nervous system	C70.0 - C72.9
	Endocrine glands	C73 C74.00 - C75.9
	Benign neoplasms of brain, cranial nerves and meninges	D32.0 - D33.3
	Benign neoplasms of pituitary, pineal, aortic body and other paraganglia	D35.2 - D35.6
Malignant neoplasm of other and ill-defined sites	Various regions	C76.0 - C76.8 C45.7
Secondary and unspecified malignant neoplasm of lymph nodes	Lymph node metastases	C77.0 - C77.9
Secondary malignant neoplasm of respiratory, digestive and other specified sites	Metastatic disease other than lymph node metastases	C78.00 - C80.1 C45.9
Lymphatic and hematopoietic tissue	Non-Hodgkin's lymphoma	C82.00 - C86.6 C91.40 - C91.42 C96.A C96.0 - C96.9 C96.Z
	Hodgkin's lymphoma	C81.00 - C81.99
	Multiple myeloma	C90.00
Reirradiation	Various regions	T66.XXXA*

*ICD-10-CM T66.XXXA (Effects of Radiation, Unspecified) may only be used where prior radiation therapy to the site is the governing factor necessitating IMRT in lieu of other radiotherapy. An ICD diagnosis code for the anatomic diagnosis must also be used.

Limitations of Coverage

IMRT is not considered reasonable and medically necessary unless at least one of the criteria listed in the “Indications of Coverage” section of this policy is present.

Clinical scenarios that would not typically support the use of IMRT include:

1. Where IMRT does not offer an advantage over conventional or three-dimensional conformal radiation therapy techniques that deliver good clinical outcomes and low toxicity.
2. Clinical urgency, such as spinal cord compression, superior vena cava syndrome or airway obstruction.
3. Palliative treatment of metastatic disease where the prescribed dose does not approach normal tissue tolerances.
4. Inability to accommodate for organ motion, such as for a mobile lung tumor.
5. Inability of the patient to cooperate and tolerate immobilization to permit accurate and reproducible dose delivery.

PHYSICIANS’ CURRENT PROCEDURAL TERMINOLOGY (CPT®)/HCPCS

Note: CPT is a trademark of the American Medical Association (AMA)

CPT®/HCPCS codes

CPT Code for IMRT Treatment Planning

77301	Intensity Modulated Radiation Therapy (IMRT) plan, including dose-volume histograms for target and critical structure partial tolerance specifications. <i>This code is typically reported only once per course of IMRT.</i>
+77293	Respiratory motion management simulation (List separately in addition to code for primary procedure). <i>This is an add-on code and cannot be billed on its own. It should be billed with either CPT code 77295 or 77301.</i>

CPT Codes for IMRT Treatment Delivery

77385	Intensity modulated radiation treatment delivery (IMRT), includes guidance and tracking, when performed; simple <i>Use with any of the following: prostate, breast, and all sites using physical compensator based IMRT.</i>
77386	Intensity modulated radiation treatment delivery (IMRT), includes guidance and tracking, when performed; complex <i>Includes all other sites if not using physical compensator based IMRT.</i>
G6015	Intensity modulated treatment delivery, single or multiple fields/arcs, via narrow spatially and temporally modulated beams, binary, dynamic MLC, per treatment session <i>Report in freestanding centers under the Medicare Physician Fee Schedule to payers that do not accept CPT codes 77385 or 77386.</i>
G6016	Compensator-based beam modulation treatment delivery of inverse planned treatment using three or more high resolution (milled or cast) compensator convergent beam modulated fields, per treatment session <i>Report in freestanding centers under the Medicare Physician Fee Schedule to payers that do not accept CPT codes 77385 or 77386.</i>

Medical Radiation Physics, Dosimetry and Treatment Devices

Basic Radiation Dosimetry

Basic radiation dosimetry is a separate and distinct service from IMRT planning and should be reported accordingly. The radiation dose delivered by each IMRT beam must be individually calculated and verified before the course of radiation treatment begins. Thus, multiple basic dosimetry calculations (up to 10) are typically performed and reported on a single day. Supporting documentation should accompany a claim for more than ten (10) calculations on a single day.

CPT® Code for IMRT Dosimetry

77300	Basic radiation dosimetry calculation central axis depth dose calculation, TDF, NSD, gap calculation, off axis factor, tissue inhomogeneity factors, calculation of non-ionizing radiation surface and depth dose, as required during course of treatment, only when prescribed by the treating physician <i>This code can generally be billed once for each IMRT beam or arc up to a limit of ten. This code is used to report dosimetry calculations that arrive at the relationship between monitor units (or time) and dose, and the physician's verification, review and approval. The documentation should contain the independent check of each field, separate from the computer-generated IMRT plan.</i>
--------------	--

Treatment Devices

There are several categories of treatment devices used in conjunction with the delivery of IMRT radiotherapy. Immobilization treatment devices are commonly employed to ensure that the beam is accurately on target. In addition, the radiation oncologist is responsible for the design of treatment devices that define the beam geometry. The beam or arc aperture, the dose constraints per beam, the couch and gantry angles for each beam position or arc start/stop location, and the coverage requirements all must be evaluated in order to guide the generation of the multi-leaf collimator (MLC) segments. CPT® code 77338 was established to report multileaf collimator (MLC) design and construction for IMRT. It captures the physician work associated with design and fabrication of the device, the practice expense associated with staff (physicists and dosimetrists) and the equipment used to design, analyze and fabricate the device. While 77334 was previously billed once for each gantry angle, 77338 is billed only once per IMRT plan. There is no separate accounting for gantry angles or other beam arrangements. CPT code 77334 may be used in the IMRT process of care to report the immobilization device constructed at time of the simulation. Additional IMRT plans during a course of care merit additional reporting of 77338.

CPT Codes for IMRT Treatment Devices

77332	Treatment devices, design and construction; simple <i>Simple treatment devices include simple multi-use shaped blocks, bolus and passive, multiuse devices.</i>
77333	Treatment devices, design and construction; intermediate <i>Intermediate treatment devices include pre-cast or pre-made standard-shaped blocks, stents, and special bolus and bite blocks.</i>
77334	Treatment devices, design and construction; complex <i>Complex treatment devices include custom-fabricated cast blocks, immobilization devices, wedges, compensators and eye shields.</i>
77338	Multi-leaf collimator (MLC) device(s) for intensity modulated radiation therapy (IMRT), design and construction per IMRT plan <i>Report once per IMRT plan.</i>

Image Guided Radiation Therapy

Image Guided Radiation Therapy (IGRT) utilizes imaging technology to modify treatment delivery to account for changes in the position of the intended target. IGRT is indicated for use in patients whose tumors are located near or within critical structures and/or in tissue with inherent setup variation. The new IMRT delivery codes (77385 and 77386) include the technical component of guidance and tracking if performed. The G-codes listed below can be used to report the professional component of IGRT in instances where a payer does not accept 77387-26.

CPT® and HCPCS Codes for IGRT

77387	Guidance for localization of target volume for delivery of radiation treatment delivery, includes intrafraction tracking, when performed
G6001	Ultrasonic guidance for placement of radiation therapy fields <i>Report under the Medicare Physician Fee Schedule to payers that do not accept CPT code 77387.</i>
G6002	Stereoscopic X-ray guidance for localization of target volume for the delivery of radiation therapy <i>Report under the Medicare Physician Fee Schedule to payers that do not accept CPT code 77387.</i>
77014	Computed tomography guidance for placement of radiation therapy fields <i>Report under the Medicare Physician Fee Schedule to payers that do not accept CPT code 77387.</i>

ADDITIONAL INFORMATION

Per CMS, payment for the services identified by CPT codes 77014, 77280, 77285, 77290, 77295, 77306, 77307, 77321, and 77331, are included in the payment for CPT code 77301 (IMRT planning). These codes should not be reported in addition to CPT code 77301, when provided prior to, or as part of, the development of the IMRT plan. They may, however, be reported as needed during the course of IMRT treatment delivery (i.e., with CPT codes 77385, 77386, G6015 or G6016). Additionally, CPT codes 77280-77290 Simulation aided field settings should not be reported for verification of the treatment field during the course of IMRT.

CPT® Code	CPT Code Descriptor
77014	Computed tomography guidance for placement of radiation therapy fields
77280	Therapeutic radiology simulation-aided field setting; simple <i>Criteria for level: Single treatment area. 77280 may be performed and reported separately from the IMRT plan to report verification of the field after the planning process is complete and prior to the initial treatment.</i>
77285	Therapeutic radiology simulation-aided field setting; intermediate <i>Criteria for level: Two separate treatment areas.</i>
77290	Therapeutic radiology simulation-aided field setting; complex <i>Criteria for level: Any of these factors present: Three or more treatment areas, or any number of treatment areas if the following are involved: particle therapy, rotation or arc therapy, complex blocking, custom shielding blocks, brachytherapy simulation, hyperthermia probe verification, and/or any use of contrast materials.</i>
77295	3-dimensional radiotherapy plan, including dose-volume histograms <i>May be reported once per treatment course per treatment volume.</i>
77321	Special teletherapy port plan, particles, hemibody, total body <i>Use for particle beam isodose planning. Use for electrons, protons and neutron therapy; half body or total body therapy.</i>
77331	Special dosimetry (e.g., TLD, microdosimetry) (specify), only when prescribed by the treating physician <i>Explanation of medical necessity may be required.</i>
77370	Special medical radiation physics consultation <i>The radiation oncologist makes a direct request to the qualified medical physicist for a special consultative report or for specific physics services for an individual patient.</i>



REFERENCES

The medical literature regarding Intensity Modulated Radiation Therapy is extensive. The following list comprises a compilation of selected peer reviewed publications from the last 10 years reporting clinical outcomes in patients treated with IMRT, organized by disease site.

General

1. 2015 *ASTRO Radiation Oncology Coding Resource*. Fairfax, Virginia: American Society for Radiation Oncology (ASTRO); 2015.
2. Bortfeld T, Schmidt-Ulrich R, De Neve W, Wazer DE. *Image-Guided IMRT*. Berlin, Germany: Springer; 2006.
3. Chao KSC, Apisarnthanarax S, Ozyigit G. *Practical Essentials of Intensity Modulated Radiation Therapy*. 2nd edition. Philadelphia, PA: Lippincott Williams & Wilkins; 2005.
4. DeVita VT, Hellman S, Rosenberg SA. *Radiation Oncology. Cancer, Principles & Practice of Oncology*. 9th edition. Philadelphia, PA: Lippincott William & Wilkins; 2011: 297-306.
5. Guerrero Urbano MT, Nutting CM. Clinical use of intensity-modulated radiotherapy: part I. *Br J Radiol*. 2004; 77(914): 88-96.
6. Guerrero Urbano MT, Nutting CM. Clinical use of intensity-modulated radiotherapy: part II. *Br J Radiol*. 2004; 77(915): 177-182.
7. Gunderson LL, Tepper, JE. Conformal Therapy and Intensity-Modulated Radiation Therapy: Treatment Planning, Treatment Delivery, and Clinical Results. *Clinical Radiation Oncology*. 3rd edition. Philadelphia, PA: Saunders; 2012: 287-316.
8. Halperin, EC, Perez, CA, Brady, LW. Intensity-Modulated Radiation Treatment Techniques and Clinical Applications. *Principles and Practice of Radiation Oncology*, 5th edition. Philadelphia, PA: Lippincott William & Wilkins; 2008: 239- 262.
9. Hartford AC, Galvin JM, Beyer DC, et al. American College of Radiology (ACR) and American Society for Radiation Oncology (ASTRO) Practice Guidelines for Intensity-Modulated Radiation Therapy (IMRT). *Am J Clin Oncol*. 2012; 35(6): 612-617.
10. Hoppe, RT, Phillips TL, Roach M. Three-Dimensional Conformal Radiotherapy and Intensity-Modulated Radiotherapy. *Leibel and Phillips Textbook of Radiation Oncology*, 3rd edition. Philadelphia, PA: Saunders; 2010: 170-192.
11. McCormick B, Hunt M. Intensity-modulated radiation therapy for breast: is it for everyone? *Semin Radiat Oncol*. 2011; 21: 51-54.
12. Mell LK, Mehrotra AK, Mundt AJ. Intensity-modulated radiation therapy use in the U.S., 2004. *Cancer*. 2005; 104(6): 1296-1303.
13. Moran JM, Dempsey M, Eishbruch A, et al. Safety consideration for IMRT: Executive Summary. *Pract Radiat Oncol*. 2011; 1: 190-195.
14. Mundt AJ, Roeske JC. *Intensity Modulated Radiation Therapy*. Hamilton, Ontario: BC Decker; 2005.
15. Bazan JG, Hara W, Hsu A, et al. Intensity-modulated radiation therapy versus conventional radiation therapy for squamous cell carcinoma of the anal canal. *Cancer*. 2011; 117(15): 3342-3351.
16. Call JA, Haddock MG, Quevedo JF, et al. Intensity-modulated radiotherapy for squamous cell carcinoma of the anal canal: efficacy of a low daily dose to clinically negative regions. *Radiat Oncol*. 2011; 6: 134.
17. Defoe SG, Beriwal S, Jones H, et al. Concurrent Chemotherapy and Intensity-modulated Radiation Therapy for Anal Carcinoma - Clinical Outcomes in a Large National Cancer Institute-designated Integrated Cancer Centre Network. *Clin Oncol (R Coll Radiol)*. 2012; 24(6): 424-431.
18. Devisetty K, Mell LK, Salama JK, et al. A multi-institutional acute gastrointestinal toxicity analysis of anal cancer patients treated with concurrent intensity-modulated radiation therapy (IMRT) and chemotherapy. *Radiother Oncol*. 2009; 93(2): 298-301.
19. Hodges JC, Das P, Eng C, et al. Intensity-modulated radiation therapy for the treatment of squamous cell anal cancer with para-aortic nodal involvement. *Int J Radiat Oncol Biol Phys*. 2009; 75(3): 791-794.
20. Kachnic LA, Tsai HK, Coen JJ, et al. Dose-painted intensity-modulated radiation therapy for anal cancer: a multi-institutional report of acutotoxicity and response to therapy. *Int J Radiat Oncol Biol Phys*. 2012; 82(1): 153-158.
21. Milano MT, Jani AB, Farrey KJ, et al. Intensity-modulated radiation therapy (IMRT) in the treatment of anal cancer: toxicity and clinical outcome. *Int J Radiat Oncol Biol Phys*. 2005; 63(2): 354-361.
22. Pepek JM, Willett CG, Wu QJ, et al. Intensity-modulated radiation therapy for anal malignancies: a preliminary toxicity and disease outcomes analysis. *Int J Radiat Oncol Biol Phys*. 2010; 78(5): 1413-1419.
23. Saarihahti K, Arponen P, Vaalavirta L, et al. The effect of intensity-modulated radiotherapy and high dose rate brachytherapy on acute and late radiotherapy-related adverse events following chemoradiotherapy of anal cancer. *Radiother Oncol*. 2008; 87(3): 383-390.
24. Salama JK, Mell LK, Schomas DA, et al. Concurrent chemotherapy and intensity-modulated radiation therapy for anal canal cancer patients: a multicenter experience. *J Clin Oncol*. 2007; 25(29): 4581-4586.
25. Zagar TM, Willett CG, Czito BG. Intensity-modulated radiation therapy for anal cancer: toxicity versus outcomes. *Oncology (Williston Park)*. 2010; 24(9): 815-23, 828.

Breast

26. Barnett GC, Wilkinson JS, Moody AM, et al. Randomized controlled trial of forward-planned intensity modulated radiotherapy for early breast cancer: interim results at 2 years. *Int J Radiat Oncol Biol Phys*. 2012; 82(2): 715-723.
27. Beckham WA, Popescu CC, Patenaude VV, et al. Is multi-beam IMRT better than standard treatment for patients with left-sided breast cancer? *Int J Radiat Onc Biol Phys*. 2007; 69(3): 918-924.
28. Bhatnagar AK, Beriwal S, Heron DE, et al. Initial outcomes analysis for large multicenter integrated cancer network implementation of intensity modulated radiation therapy for breast cancer. *Breast J*. 2009; 15(5): 468-474.
29. Bhatnagar AK, Brandner E, Sonnik D, et al. Intensity modulated radiation therapy (IMRT) reduces the dose to the contralateral breast when compared to conventional tangential fields for primary breast irradiation. *Breast Cancer Res Treat*. 2006; 96(1): 41-46.
30. Bhatnagar AK, Heron DE, Deutsch M, et al. Does breast size affect the scatter dose to the ipsilateral lung, heart, or contralateral breast in primary breast irradiation using intensity-modulated radiation therapy (IMRT)? *Am J Clin Oncol*. 2006; 29(1): 80-84.

17. Defoe SG, Beriwal S, Jones H, et al. Concurrent Chemotherapy and Intensity-modulated Radiation Therapy for Anal Carcinoma - Clinical Outcomes in a Large National Cancer Institute-designated Integrated Cancer Centre Network. *Clin Oncol (R Coll Radiol)*. 2012; 24(6): 424-431.
18. Devisetty K, Mell LK, Salama JK, et al. A multi-institutional acute gastrointestinal toxicity analysis of anal cancer patients treated with concurrent intensity-modulated radiation therapy (IMRT) and chemotherapy. *Radiother Oncol*. 2009; 93(2): 298-301.
19. Hodges JC, Das P, Eng C, et al. Intensity-modulated radiation therapy for the treatment of squamous cell anal cancer with para-aortic nodal involvement. *Int J Radiat Oncol Biol Phys*. 2009; 75(3): 791-794.
20. Kachnic LA, Tsai HK, Coen JJ, et al. Dose-painted intensity-modulated radiation therapy for anal cancer: a multi-institutional report of acutotoxicity and response to therapy. *Int J Radiat Oncol Biol Phys*. 2012; 82(1): 153-158.
21. Milano MT, Jani AB, Farrey KJ, et al. Intensity-modulated radiation therapy (IMRT) in the treatment of anal cancer: toxicity and clinical outcome. *Int J Radiat Oncol Biol Phys*. 2005; 63(2): 354-361.
22. Pepek JM, Willett CG, Wu QJ, et al. Intensity-modulated radiation therapy for anal malignancies: a preliminary toxicity and disease outcomes analysis. *Int J Radiat Oncol Biol Phys*. 2010; 78(5): 1413-1419.
23. Saarilahti K, Arponen P, Vaalavirta L, et al. The effect of intensity-modulated radiotherapy and high dose rate brachytherapy on acute and late radiotherapy-related adverse events following chemoradiotherapy of anal cancer. *Radiother Oncol*. 2008; 87(3): 383-390.
24. Salama JK, Mell LK, Schomas DA, et al. Concurrent chemotherapy and intensity-modulated radiation therapy for anal canal cancer patients: a multicenter experience. *J Clin Oncol*. 2007; 25(29): 4581-4586.
25. Zagar TM, Willett CG, Czito BG. Intensity-modulated radiation therapy for anal cancer: toxicity versus outcomes. *Oncology (Williston Park)*. 2010; 24(9): 815-23, 828.
- Breast**
26. Barnett GC, Wilkinson JS, Moody AM, et al. Randomized controlled trial of forward-planned intensity modulated radiotherapy for early breast cancer: interim results at 2 years. *Int J Radiat Oncol Biol Phys*. 2012; 82(2): 715-723.
27. Beckham WA, Popescu CC, Patenaude VV, et al. Is multi-beam IMRT better than standard treatment for patients with left-sided breast cancer? *Int J Radiat Oncol Biol Phys*. 2007; 69(3): 918-924.
28. Bhatnagar AK, Beriwal S, Heron DE, et al. Initial outcomes analysis for large multicenter integrated cancer network implementation of intensity modulated radiation therapy for breast cancer. *Breast J*. 2009; 15(5): 468-474.
29. Bhatnagar AK, Brandner E, Sonnik D, et al. Intensity modulated radiation therapy (IMRT) reduces the dose to the contralateral breast when compared to conventional tangential fields for primary breast irradiation. *Breast Cancer Res Treat*. 2006; 96(1): 41-46.
30. Bhatnagar AK, Heron DE, Deutsch M, et al. Does breast size affect the scatter dose to the ipsilateral lung, heart, or contralateral breast in primary breast irradiation using intensity-modulated radiation therapy (IMRT)? *Am J Clin Oncol*. 2006; 29(1): 80-84.
31. Coles CE, Moody AM, Wilson CB, et al. Reduction of radiotherapy-induced late complications in early breast cancer: the role of intensity-modulated radiation therapy and partial breast irradiation. Part I--normal tissue complications. *Clin Oncol (R Coll Radiol)*. 2005; 17(1): 16-24.
32. Coles CE, Moody AM, Wilson CB, et al. Reduction of radiotherapy induced late complications in early breast cancer: the role of intensity modulated radiation therapy and partial breast irradiation. Part II: Radiotherapy strategies to reduce radiation-induced late effects. *Clin Oncol (R Coll Radiol)*. 2005; 17: 98-110.
33. Correa CR, Litt HI, Hwang WT, et al. Coronary artery findings after left-sided compared with right-sided radiation treatment for early-stage breast cancer. *J Clin Oncol*. 2007; 25(21): 3031-3037.
34. Cozzi L, Fogliata A, Nicolini G, et al. Clinical experience in breast irradiation with intensity modulated photon beams. *Acta Oncol*. 2005; 44(5): 467-474.
35. Dayes I, Rumble R, Bowen J, et al. Intensity-modulated radiotherapy in the treatment of breast cancer. *Clin Oncol (R Coll Radiol)*. 2012; 24(7): 488-498.
36. De Neve W, De Gerssem W, Madani I. Rational Use of Intensity-Modulated Radiation Therapy: The Importance of Clinical Outcome. *Semin Radiat Oncol*. 2012; 22(1): 40-49.
37. Donovan E, Bleakley N, Denholm E, et al. Randomised trial of standard 2D radiotherapy (RT) versus intensity modulated radiotherapy (IMRT) in patients prescribed breast radiotherapy. *Radiother Oncol*. 2007; 82(3): 254-264.
38. Freedman GM, Anderson PR, Bleicher RJ, et al. Five-year local control in a phase II study of hypofractionated intensity modulated radiation therapy with an incorporated boost for early stage breast cancer. *Int J Radiat Oncol Biol Phys*. 2012; 84(4): 888-893.
39. Freedman GM, Anderson PR, Li J, et al. Intensity modulated radiation therapy (IMRT) decreases acute skin toxicity for women receiving radiation for breast cancer. *Am J Clin Oncol*. 2006; 29(1): 66-70.
40. Freedman GM, Li T, Nicolaou N, et al. Breast intensity-modulated radiation therapy reduces time spent with acute dermatitis for women of all breast sizes during radiation. *Int J Radiat Oncol Biol Phys*. 2009; 74: 689-694.
41. Harsolia A, Kestin L, Grills I, et al. Intensity-modulated radiotherapy results in significant decrease in clinical toxicities compared with conventional wedge-based breast radiotherapy. *Int J Radiat Oncol Biol Phys*. 2007; 68(5): 1375-1380.
42. Keller LMM, Sopka DM, Li T, et al. Five-year results of whole breast intensity modulated radiation therapy for treatment of early stage breast cancer: The Fox Chase Center experience. *Int J Radiat Oncol Biol Phys*. 2012; 84(4): 881-887.
43. Leonard C, Carter D, Kerscher J, et al. Prospective trial of accelerated partial breast intensity-modulated radiotherapy. *Int J Radiat Oncol Biol Phys*. 2007; 67(5): 1291-1298.
44. Lewin AA, Derhagopian R, Saigal K, et al. Accelerated partial breast irradiation is safe and effective using intensity-modulated radiation therapy in selected early-stage breast cancer. *Int J Radiat Oncol Biol Phys*. 2012; 82(5): 2104-2110.
45. McDonald MW, Godette KD, Butker EK, et al. Long-term outcomes of IMRT for breast cancer: a single-institution cohort analysis. *Int J Radiat Oncol Biol Phys*. 2008; 72(4): 1031-1040.

46. Pignol J, Olivotto I, Rakovitch E, et al. Phase III randomized study of intensity modulated radiation therapy versus standard wedging technique for adjuvant breast radiation therapy. *Int J Radiat Oncol Biol Phys.* 2006; 66(3 Suppl): S1.

47. Pignol JP, Olivotto I, Rakovitch E, et al. A multicenter randomized trial of breast intensity-modulated radiation therapy to reduce acute radiation dermatitis. *J Clin Oncol.* 2008;

Central Nervous System

48. Milker-Zabel S, Zabel-du Bois A, Huber P, et al. Intensity-modulated radiotherapy for complex-shaped meningioma of the skull base: long-term experience of a single institution. *Int J Radiat Oncol Biol Phys.* 2007; 68(3): 858-863.

49. Narayana A, Chang J, Yenice K, et al. Hypofractionated stereotactic radiotherapy using intensity-modulated radiotherapy in patients with one or two brain metastases. *Stereotact Funct Neurosurg.* 2007; 85(2-3): 82-87.

50. Narayana A, Yamada J, Berry S, et al. Intensity-modulated radiotherapy in high-grade gliomas: clinical and dosimetric results. *Int J Radiat Onc Biol Phys.* 2006; 64(3): 892-897.

51. Paravati AJ, Heron DE, Landsittel D, et al. Radiotherapy and temozolomide for newly diagnosed glioblastoma and anaplastic astrocytoma: validation of Radiation Therapy Oncology Group-Recursive Partitioning Analysis in the IMRT and temozolomide era. *J Neurooncol.* 2011; 104(1): 339-349.

52. Pirzkall A, Debus J, Haering P, et al. Intensity modulated radiotherapy (IMRT) for recurrent, residual, or untreated skull-base meningiomas: preliminary clinical experience. *Int J Radiat Oncol Biol Phys.* 2003; 55(2): 362-372.

53. Reddy K, Damek D, Gaspar L, et al. Phase II trial of hypofractionated IMRT with temozolamide for patients with newly diagnosed glioblastoma multiforme. *Int J Radiat Oncol Biol Phys.* 2012; 84(3): 655-660.

54. Schroeder TM, Chintagumpala M, Okcu MF, et al. Intensity-modulated radiation therapy in childhood ependymoma. *Int J Radiat Oncol Biol Phys.* 2008; 71(4): 987-993.

55. Wang SJ, Choi M, Fuller CD, et al. Intensity-modulated Radiosurgery for patients with brain metastases: a mature outcomes analysis. *Technol Cancer Res Treat.* 2007; 6(3): 161-168.

56. Yamada Y, Lovelock M, Bilsky MH. Image-guided intensity-modulated radiation therapy of spine tumors. *Curr Neurol Neurosci Rep.* 2006; 6: 207-211.

Cervix

57. Ahmed R, Kim RY, Duan J, et al. IMRT Dose escalation for positive para-aortic lymph nodes in patients with locally advanced cervical cancer while reducing the dose to bone marrow and other organs at risk. *Int J Radiat Oncol Biol Phys.* 2004; 60(2): 505-512.

58. Albuquerque K, Giangreco D, Morrison C, et al. Radiation-related predictors of hematologic toxicity after concurrent chemoradiation for cervical cancer and implications for bone marrow-sparing pelvic IMRT. *Int J Radiat Oncol Biol Phys.* 2011; 79(4): 1043-1047.

59. Beriwal S, Gan GN, Heron DE, et al. Early clinical outcome with concurrent chemotherapy and extended-field, intensity-modulated radiotherapy for cervical cancer. *Int J Radiat Oncol Biol Phys.* 2007; 68(1): 166-171.

60. Chen CC, Lin JC, Jan JS, et al. Definitive intensity-modulated radiation therapy with concurrent chemotherapy for patients with locally advanced cervical cancer. *Gynecol Oncol.* 2011; 122(1): 9-13.

61. Chen MF, Tseng CJ, Tseng CC, et al. Clinical outcome in posthysterectomy cervical cancer patients treated with concurrent Cisplatin and intensity-modulated pelvic radiotherapy: comparison with conventional radiotherapy. *Int J Radiat Oncol Biol Phys.* 2007; 67(5): 1438-1444.

62. Du XL, Tao J, Sheng XG, et al. Intensity-modulated radiation therapy for advanced cervical cancer: a comparison of dosimetric and clinical outcomes with conventional radiotherapy. *Gynecol Oncol.* 2012; 125(1): 151-157.

63. Esthappan J, Chaudhari S, Santanam L, et al. Prospective clinical trial of positron emission tomography/computed tomography image-guided intensity-modulated radiation therapy for cervical carcinoma with positive para-aortic lymph nodes. *Int J Radiat Oncol Biol Phys.* 2008; 72(4): 1134-1139.

64. Hasselle MD, Rose BS, Kochanski JD, et al. Clinical outcomes of intensity-modulated pelvic radiation therapy for carcinoma of the cervix. *Int J Radiat Oncol Biol Phys.* 2011; 80(5): 1436-1445.

65. Kidd EA, Siegel BA, Dehdashti F, et al. Clinical outcomes of definitive intensity modulated radiation therapy with fluorodeoxyglucose-positron emission tomography simulation in patients with locally advanced cervical cancer. *Int J Radiat Oncol Biol Phys.* 2010; 77: 1085-1091.

66. Macdonald DM, Lin LL, Biehl K, et al. Combined intensity-modulated radiation therapy and brachytherapy in the treatment of cervical cancer. *Int J Radiat Oncol Biol Phys.* 2008; 71(2): 618-624.

67. Simpson DR, Song WY, Moiseenko V, et al. Normal tissue complication probability analysis of acute gastrointestinal toxicity in cervical cancer patients undergoing intensity modulated radiation therapy and concurrent cisplatin. *Int J Radiat Oncol Biol Phys.* 2012; 83(1): e81-e86.

68. Van de Bunt L, van der Heide UA, Ketelaars M, et al. Conventional, conformal, and Intensity-modulated radiation therapy treatment planning of external beam radiotherapy for cervical cancer: The impact of tumor regression. *Int J Radiat Oncol Biol Phys.* 2006; 64(1): 189-196.

Esophagus

69. Kole T, Aghayere O, Kwah J, et al. Comparison of heart and coronary artery doses associated with intensity-modulated radiation therapy versus three-dimensional conformal radiotherapy for distal esophageal cancer. *Int J Radiat Oncol Biol Phys.* 2012; 83(5): 1580-1586.

70. La TH, Minn AY, Su Z, et al. Multimodality treatment with intensity modulated radiation therapy for esophageal cancer. *Dis Esophagus.* 2010; 23(4): 300-308.

71. Lin SH, Wang L, Myles B, et al. Propensity score-based comparison of long-term outcomes with 3-dimensional conformal radiotherapy vs intensity-modulated radiotherapy for esophageal cancer. *Int J Radiat Oncol Biol Phys.* 2012; 84(5): 1078-1085.

72. Mayo CS, Urie MM, Fitzgerald TJ, et al. Hybrid IMRT for treatment of cancers of the Lung and Esophagus. *Int J Radiat Oncol Biol Phys.* 2008; 71(5): 1408-1418.
73. Wang SL, Laio Z, Vaporciyan AA, et al. Investigation of clinical and dosimetric factors associated with postoperative pulmonary complications in esophageal cancer patients treated with concurrent chemo radiotherapy followed by surgery. *Int J Radiat Oncol Biol Phys.* 2006; 64(3): 692-699.
- Gynecologic**
74. Ferrigno R, Santos A, Martins LC, et al. Comparison of conformal and intensity modulated radiation therapy techniques for treatment of pelvic tumors. Analysis of acute toxicity. *Radiat Oncol.* 2010; 5: 117.
75. Georg P, Georg D, Hillbrand M, et al. Factors influencing bowel sparing in intensity modulated whole pelvic radiotherapy for gynaecological malignancies. *Radiother Oncol.* 2006; 80(1): 19-26.
76. Lujan AE, Mundt AJ, Yamada SD, et al. Intensity-modulated radiotherapy as a means of reducing dose to bone marrow in gynecologic patients receiving whole pelvic radiotherapy. *Int J Radiat Oncol Biol Phys.* 2003; 57(2): 516-521.
77. Mundt AJ, Mell LK, Roeske JC. Preliminary analysis of chronic gastrointestinal toxicity in gynecology patients treated with intensity-modulated whole pelvic radiation therapy. *Int J Radiat Oncol Biol Phys.* 2003; 56(5): 1354-1360.
78. Salama JK, Mundt AJ, Roeske J, et al: Preliminary outcome and toxicity report of extended-field, intensity-modulated radiation therapy for gynecologic malignancies. *Int J Radiat Oncol Biol Phys.* 2006; 65: 1170-1176.
79. Vandecasteele K, Tummers P, Makar A, et al. Postoperative intensity-modulated arc therapy for cervical and endometrial cancer: A prospective report on toxicity. *Int J Radiat Oncol Biol Phys.* 2012; 84(2): 408-414.
- Head and Neck**
80. Arcangeli G, Benassi M, Giovino G, et al. Analysis of Salivary Flow and Dose–Volume Modeling of Complication Incidence in Patients With Head-and-Neck Cancer Receiving Intensity- Modulated Radiotherapy. *Int J Radiat Oncol Biol Phys.* 2009; 73(4): 1252-1259.
81. Bhide S A, Bidmead A M, Clark C H, et al. Pre-trial quality assurance process for an intensity modulated radiation therapy (IMRT) trial: PARSORT, a UK multicentre Phase III trial comparing conventional radiotherapy and parotid sparing IMRT for locally advanced head and neck cancer. *Br J Radiol.* 2009; 82: 585-594.
82. Chan K, Gomez DR, Gomez J, et al.. Intensity-Modulated Radiotherapy in Postoperative Treatment of Oral Cavity Cancers. *Int J Radiat Oncol Biol Phys.* 2009; 73(4): 1096-1103.
83. Chao KS, Ozyigit G, Blanco AI, et al. Intensity-modulated radiation therapy for oropharyngeal carcinoma: impact of tumor volume. *Int J Radiat Oncol Biol Phys.* 2004; 59(1): 43-50.
84. Chen AM, Farwell DG, Luu Q, et al. Intensity-modulated radiotherapy is associated with improved global quality of life among long-term survivors of head-and-neck cancer. *Int J Radiat Oncol Biol Phys.* 2012; 84(1): 170-175.
85. Chua DT, Sham JS, Leung LH, et al. Re-irradiation of nasopharyngeal carcinoma with intensity-modulated radiotherapy. *Radiother Oncol.* 2005; 77(3): 290-294.
86. Clavel S, Nguyen DHA, Fortin B, et al. Simultaneous integrated boost using intensity-modulated radiotherapy compared with conventional radiotherapy in patients treated with concurrent carboplatin and 5-fluorouracil for locally advanced oropharyngeal carcinoma. *Int J Radiat Oncol Biol Phys.* 2012; 82(2): 582-589.
87. Doornaert P, Langendijk JA, Leemans RC, et al. Intensity-Modulated Radiotherapy Reduces Radiation-Induced Morbidity and Improves Health-Related Quality of Life: Results of a Nonrandomized Prospective Study Using a Standardized Follow-Up Program. *Int J Radiat Oncol Biol Phys.* 2009; 74(1): 1-8.
88. Duprez F, Madani I, Morbée L, et al. IMRT for sinonasal tumors minimizes severe late ocular toxicity and preserves disease control and survival. *Int J Radiat Oncol Biol Phys.* 2012; 83(1): 252-259.
89. Eisbruch A, Harris J, Garden A, et al. Multi-institutional trial of accelerated hypofractionated intensity-modulated radiation therapy for early-stage oropharyngeal cancer (RTOG 00-22). *Int J Radiat Oncol Biol Phys.* 2010; 76(5): 1333-1338.
90. Eisbruch A, Kim HM, Feng FY, et al. Chemo-IMRT of oropharyngeal cancer aiming to reduce dysphagia: swallowing organs late complication probabilities and dosimetric correlates. *Int J Radiat Oncol Biol Phys.* 2011; 81(3): e93-e99.
91. Feng FY, Kim HM, Lyden TH, et al. Intensity-Modulated radiotherapy of head and neck cancer aiming to reduce dysphagia: early dose-effect relationships for the swallowing structures. *Int J Radiat Oncol Biol Phys.* 2007; 68(5): 1289-1298.
92. Graff P, Lapeyre M, Desandes E, et al. Impact of intensity-modulated radiotherapy on health-related quality of life for head and neck cancer patients: matched-pair comparison with conventional radiotherapy. *Int J Radiat Oncol Biol Phys.* 2007; 67(5): 1309-1317.
93. Habl G, Jensen AD, Potthoff K, et al. Treatment of locally advanced carcinomas of head and neck with intensity-modulated radiation therapy (IMRT) in combination with cetuximab and chemotherapy: the REACH protocol. *BMC Cancer.* 2010; 10: 651.
94. Jabbari S, Kim HM, Feng M, et al. Matched case-control study of quality of life and xerostomia after intensity-modulated radiotherapy or standard radiotherapy for head-and-neck cancer: Initial report. *Int J Radiat Oncol Biol Phys.* 2005; 63(3): 725-731.
95. Kam MK, Leung SF, Zee B, et al. Prospective randomized study of intensity-modulated radiotherapy on salivary gland function in early-stage nasopharyngeal carcinoma patients. *J Clin Oncol.* 2007; 25(31): 4873-4879.
96. Klem ML, Mechalakos JG, Wolden SL, et al. Intensity-modulated radiotherapy for head and neck cancer of unknown primary: toxicity and preliminary efficacy. *Int J Radiat Oncol Biol Phys.* 2008; 70(4): 1100-1107.
97. Kwong DL, Pow EH, Sham JS, et al. Intensity-modulated radiotherapy for early-stage nasopharyngeal carcinoma: a prospective study on disease control and preservation of salivary function. *Cancer.* 2004; 101(7): 1584-1593.
98. Kwong DL, Sham JS, Leung LH, et al. Preliminary results of radiation dose escalation for locally advanced nasopharyngeal carcinoma. *Int J Radiat Onc Biol Phys.* 2006; 64(2): 374-381.
99. Lauve A, Morris M, Schmidt-Ullrich R, et al. Simultaneous integrated boost intensity-modulated radiotherapy for locally advanced head-and-neck squamous cell carcinomas: II—clinical results. *Int J Radiat Oncol Biol Phys.* 2004; 60(2): 374-387.

100. Lee N, Xia P, Fischbein NJ, et al. Intensity-modulated radiation therapy for head-and-neck cancer: the UCSF experience focusing on target volume delineation. *Int J Radiat Oncol Biol Phys.* 2003; 57(1): 49-60.
101. Lee NY, de Arruda FF, Puri DR, et al. A comparison of intensity-modulated radiation therapy and concomitant boost radiotherapy in the setting of concurrent chemotherapy for locally advanced oropharyngeal carcinoma. *Int J Radiat Oncol Biol Phys.* 2006; 66(4): 966-974.
102. Lin A, Kim HM, Terrell JE, et al. Quality of life after parotid-sparing IMRT for head-and-neck cancer: a prospective longitudinal study. *Int J Radiat Oncol Biol Phys.* 2003; 57(1): 61-70.
103. Lu TX, Mai WY, Teh BS, et al. Initial experience using intensity-modulated radiotherapy for recurrent nasopharyngeal carcinoma. *Int J Radiat Oncol Biol Phys.* 2004; 58(3): 682-687.
104. Madani I, Bonte K, Vakael L, et al. Intensity-Modulated Radiotherapy for Sinonasal Tumors: Ghent University Hospital Update. *Int J Radiat Oncol Biol Phys.* 2009; 73(2): 424-432.
105. McMillan AS, Pow EH, Kwong DL, et al. Preservation of quality of life after intensity-modulated radiotherapy for early-stage nasopharyngeal carcinoma: results of a prospective longitudinal study. *Head Neck.* 2006; 28(8): 712-722.
106. Miah AB, Bhide SA, Guerrero-Urbano MT, et al. Dose-escalated intensity-modulated radiotherapy is feasible and may improve locoregional control and laryngeal preservation in laryngo-hypopharyngeal cancers. *Int J Radiat Oncol Biol Phys.* 2012; 82(2): 539-547.
107. Milano MT, Vokes EE, Kao J, et al. Intensity-modulated radiation therapy in advanced head and neck patients treated with intensive chemoradiotherapy: preliminary experience and future directions. *Int J Oncol.* 2006; 28(5): 1141-1151.
108. Montejo ME, Shrieve DC, Bentz BG, et al. IMRT with simultaneous integrated boost and concurrent chemotherapy for locoregionally advanced squamous cell carcinoma of the head and neck. *Int J Radiat Oncol Biol Phys.* 2011; 81(5): e845-e852.
109. Nutting CM, Morden JP, Harrington KJ, et al. Parotid-sparing intensity modulated versus conventional radiotherapy in head and neck cancer (PARSPORT): a phase 3 multicentre randomised controlled trial. *Lancet Oncol.* 2011; 12(2): 127-136.
110. Nutting CM, Rowbottom CG, Cosgrove VP, et al. Optimization of radiotherapy for carcinoma of the parotid gland: a comparison of conventional, three-dimensional conformal, and intensity-modulated techniques. *Radiation Oncol.* 2001; 60(2): 163-172.
111. Ozyigit G, Yang T, Chao KS. Intensity-modulated radiation therapy for head and neck cancer. *Curr Treat Options Oncol.* 2004; 5(1): 3-9.
112. P.M. Braam, C.H. Terhaard, J.M. Roesink et al. Intensity-modulated radiotherapy significantly reduces xerostomia compared with conventional radiotherapy. *Int J Radiat Oncol Biol Phys.* 2006; 66: 975-980.
113. Pacholke HD, Amdur RJ, Morris CG, et al. Late xerostomia after intensity-modulated radiation therapy versus conventional radiotherapy. *Am J Clin Oncol.* 2005; 28(4): 351-358.
114. Parliament MB, Scrimger RA, Anderson SG, et al. Preservation of oral health-related quality of life and salivary flow rates after inverse-planned intensity-modulated radiotherapy (IMRT) for head-and-neck cancer. *Int J Radiat Oncol Biol Phys.* 2004; 58(3): 663-673.
115. Pow EH, Kwong DL, McMillan AS, et al. Xerostomia and quality of life after intensity-modulated radiotherapy vs. conventional radiotherapy for early-stage nasopharyngeal carcinoma: initial report on a randomized controlled clinical trial. *Int J Radiat Oncol Biol Phys.* 2006; 66(4): 981-991.
116. Puri DR, Chou W, Lee N. Intensity-modulated radiation therapy in head-and-neck cancers: dosimetric advantages and update of clinical results. *Am J Clin Oncol.* 2005; 28(4): 415-423.
117. Qiu S, Lin S, Tham IWK, et al. Intensity-modulated radiation therapy in the salvage of locally recurrent nasopharyngeal carcinoma. *Int J Radiat Oncol Biol Phys.* 2012; 83(2): 676-683.
118. Saarialhti K, Kouri M, Collan J, et al. Intensity modulated radiotherapy for head and neck cancer: evidence for preserved salivary gland function. *Radiation Oncol.* 2005; 74(3): 251-258.
119. Saarialhti K, Kouri M, Collan J, et al. Sparing of the submandibular glands by intensity modulated radiotherapy in the treatment of head and neck cancer. *Radiation Oncol.* 2006; 78(3): 270-275.
120. Schoenfeld JD, Sher DJ, Norris CM, et al. Salivary gland tumors treated with adjuvant intensity-modulated radiotherapy with or without concurrent chemotherapy. *Int J Radiat Oncol Biol Phys.* 2012; 82(1): 308-314.
121. Setton J, Caria N, Romanyshyn J, et al. Intensity-modulated radiotherapy in the treatment of oropharyngeal cancer: An update of the Memorial Sloan-Kettering Cancer Center experience. *Int J Radiat Oncol Biol Phys.* 2012; 82(1): 291-298.
122. Shoushtari A, Saylor D, Kerr K, et al. Outcomes of patients with head-and-neck cancer of unknown primary origin treated with intensity-modulated radiotherapy. *Int J Radiat Oncol Biol Phys.* 2011; 81(3): e83-e91.
123. Sulman E, Schwartz D, Le T, et al. IMRT Reirradiation of head and neck cancer: Disease control and morbidity outcomes. *Int J Radiat Oncol Biol Phys.* 2009; 73(2): 399-409.
124. Villeneuve H, Després P, Fortin B, et al. Cervical lymph node metastases from unknown primary cancer: A single-institution experience with intensity-modulated radiotherapy. *Int J Radiat Oncol Biol Phys.* 2012; 82(5): 1866-1871.
125. Wiegner E, Daly M, Murphy J, et al. Intensity-modulated radiotherapy for tumors of the nasal cavity and paranasal sinuses: clinical outcomes and patterns of failure. *Int J Radiat Oncol Biol Phys.* 2012; 83(1): 243-251.
126. Yao M, Dornfeld KJ, Buatti JM, et al. Intensity-modulated radiation treatment for head-and-neck squamous cell carcinoma—the University of Iowa experience. *Int J Radiat Oncol Biol Phys.* 2005; 63(2): 410-421.
127. Zwicker F, Roeder F, Thieke C, et al. IMRT reirradiation with concurrent cetuximab immunotherapy in recurrent head and neck cancer. *Strahlenther Onkol.* 2011; 187(1): 32-38.

Liver

128. Kalapurakal JA, Pokhrel D, Gopalakrishnan M, et al. Advantages of Whole-liver Intensity Modulated Radiation Therapy in Children With Wilms Tumor and Liver Metastasis. *Int J Radiat Oncol Biol Phys.* 2012 Jul 4 [epub ahead of print].
129. Kuo YC, Chiu YM, Shih WP, et al. Volumetric intensity-modulated Arc (RapidArc) therapy for primary hepatocellular carcinoma: comparison with intensity-modulated radiotherapy and 3-D conformal radiotherapy. *Radiation Oncol.* 2011; 6: 76.

Lung

130. Choi Y, Kim JK, Lee HS, et al. Impact of intensity-modulated radiation therapy as a boost treatment on the lung-dose distributions for non-small-cell lung cancer. *Int J Radiat Oncol Biol Phys.* 2005; 63(3): 683-689.
131. Jiang ZQ, Yang K, Komaki R, et al. Long-term clinical outcome of intensity-modulated radiotherapy for inoperable non-small-cell lung cancer: The MD Anderson experience. *Int J Radiat Oncol Biol Phys.* 2012; 83(1): 332-339.
132. Loo SW, Smith S, Promnitz DA, et al. Synchronous bilateral squamous cell carcinoma of the lung successfully treated using intensity-modulated radiotherapy. *Br J Radiol.* 2012; 85(1009): 77-80.
133. Murshed H, Liu HH, Liao Z, et al. Dose and volume reduction for normal lung using intensity-modulated radiotherapy for advanced-stage non-small-cell lung cancer. *Int J Radiat Oncol Biol Phys.* 2004; 58(4): 1258-1267.
134. Rosenzweig KE, Zauderer MG, Laser B, et al. Pleural intensity-modulated radiotherapy for malignant pleural mesothelioma. *Int J Radiat Oncol Biol Phys.* 2012; 83(4): 1278-1283.
135. Sura S, Gupta V, Yorke E, et al. Intensity-modulated radiation therapy (IMRT) for inoperable non-small cell lung cancer: the Memorial Sloan-Kettering Cancer Center (MSKCC) experience. *Radiother Oncol.* 2008; 87(1): 17-23.
136. Yom SS, Liao Z, Liu HH, et al. Initial evaluation of treatment-related pneumonitis in advanced-stage non-small-cell lung cancer patients treated with concurrent chemotherapy and intensity-modulated radiotherapy. *Int J Radiat Onc Biol Phys.* 2007; 68(1): 94-102.

Lymphoma

137. Allan DS, Fox GW, Gerig LH, et al. Total scalp radiation using image-guided IMRT for progressive cutaneous T cell lymphoma. *Br J Radiol.* 2009; 82: e122-e125.
138. Goodman KA, Toner S, Hunt M, et al. Intensity-modulated radiotherapy for lymphoma involving the mediastinum. *Int J Radiat Oncol Biol Phys.* 2005; 62(1): 198-206.
139. Koeck J, bo-Madyan Y, Lohr F, et al. Radiotherapy for early mediastinal Hodgkin lymphoma according to the German Hodgkin Study Group (GHSG): The roles of intensity modulated radiotherapy and involved-node radiotherapy. *Int J Radiat Oncol Biol Phys.* 2012; 83(1): 268-276.
140. Lu NN, Li YX, Wu RY, et al. Dosimetric and clinical outcomes of involved-field intensity-modulated radiotherapy after chemotherapy for early-stage Hodgkin's lymphoma with mediastinal involvement. *Int J Radiat Oncol Biol Phys.* 2012; 84(1): 210-216.
141. Wang H, Li YX, Wang WH, et al. Mild toxicity and favorable prognosis of high-dose and extended involved-field intensity-modulated radiotherapy for patients with early-stage nasal NK/T-cell lymphoma. *Int J Radiat Oncol Biol Phys.* 2012; 82(3): 1115-1121.

Ovary

142. Rochet N, Kieser M, Sterzing F, et al. Phase II study evaluating consolidation whole abdominal intensity-modulated radiotherapy (IMRT) in patients with advanced ovarian cancer stage FIGO III—the OVAR-IMRT-02 Study. *BMC Cancer.* 2011; 11: 41.


Pancreas

143. Abelson J, Murphy J, Minn A, et al. Intensity-modulated radiotherapy for pancreatic adenocarcinoma. *Int J Radiat Oncol Biol Phys.* 2012; 82(4):e595-601. Ben-Josef E, Shields AF, Vaishampayan U, et al. Intensity-modulated radiotherapy (IMRT) and concurrent capecitabine for pancreatic cancer. *Int J Radiat Oncol Biol Phys.* 2004; 59(2): 454-459.
144. Milano MT, Chmura SJ, Garofalo MC, et al. Intensity-modulated radiotherapy in treatment of pancreatic and bile duct malignancies: toxicity and clinical outcome. *Int J Radiat Oncol Biol Phys.* 2004; 59(2):445-453.
145. Nakamura A, Shibuya K, Matsuo Y, et al. Analysis of dosimetric parameters associated with acute gastrointestinal toxicity and upper gastrointestinal bleeding in locally advanced pancreatic cancer patients treated with gemcitabine-based concurrent chemoradiotherapy. *Int J Radiat Oncol Biol Phys.* 2012; 84(2): 369-375.
146. Yovino S, Maidment B, Herman J, et al. Analysis of local control in patients receiving IMRT for resected pancreatic cancer. *Int J Radiat Oncol Biol Phys.* 2012; 83(3): 916-920.

Prostate

147. Afonso SL, Stefano ES, Viani GA. Higher-Than-Conventional Radiation Doses in Localized Prostate Cancer Treatment: A Meta-analysis of Randomized, Controlled Trials. *Int J Radiat Oncol Biol Phys.* 2009; 74(5): 1405-1418.
148. Alicikus ZA, Yamada Y, Zhang Z, et al. Ten-year outcomes of high-dose, intensity-modulated radiotherapy for localized prostate cancer. *Cancer.* 2011; 117(7): 1429-1437.
149. Al-Mamgani A, Heemsbergen W, Peeters S, et al. Role of Intensity-Modulated Radiotherapy in Reducing Toxicity in Dose Escalation for Localized Prostate Cancer. *Int J Radiat Oncol Biol Phys.* 2009; 73(3): 685-691.
150. Alongi F, Fiorino C, Cozzarini C, et al. IMRT significantly reduces acute toxicity of whole-pelvis irradiation in patients treated with post-operative adjuvant or salvage radiotherapy after radical prostatectomy. *Radiother Oncol.* 2009; 93(2): 207-212.
151. Brabbins D, Martinez A, Yan D, et al. A dose escalation trial with the adaptive radiotherapy process as a delivery system in localized prostate cancer: analysis of chronic toxicity. *Int J Radiat Oncol Biol Phys.* 2005; 61(2): 400-408.
152. Cahlon O, Hunt M, Zelefsky MJ. Intensity-modulated radiation therapy: supportive data for prostate cancer. *Semin Rad Oncol.* 2008; 18(1): 48-57.
153. Chung H, Xia P, Chan L, et al. Does image-guided radiotherapy improve toxicity profile in whole pelvic-treated high-risk prostate cancer? Comparison between IG-IMRT and IMRT. *Int J Radiat Onc Biol Phys.* 2009; 73(1): 53-60.
154. Eade TN, Horwitz EM, Ruth K, et al. A Comparison of acute and chronic toxicity for men with low-risk prostate cancer treated with intensity-modulated radiation therapy or 125I permanent implant. *Int J Radiat Onc Biol Phys.* 2008; 71(2): 338-345.

155. Fonteyne V, Lumen N, Villeirs G, et al. Clinical results after high-dose intensity-modulated radiotherapy for high-risk prostate cancer. *Adv Urol*. 2012; 2012: 368528.
156. Forsythe K, Blacksbury S, Stone N, et al. Intensity-modulated radiotherapy causes fewer side effects than three-dimensional conformal radiotherapy when used in combination with brachytherapy for the treatment of prostate cancer. *Int J Radiat Oncol Biol Phys*. 2012; 83(2): 630-635.
157. Jani A, Su A, Milano MT. Intensity-modulated versus conventional pelvic radiotherapy for prostate cancer: analysis of acute toxicity. *Urology*. 2006; 67: 147-151.
158. Lim TS, Cheung PC, Loblaw DA, et al. Hypofractionated Accelerated radiotherapy using concomitant intensity-modulated radiotherapy boost technique for localized high-risk prostate cancer: acute toxicity results. *Int J Rad Onc Bio Phys*. 2008; 72(1): 85-92.
159. Myrehaug S, Chan G, Craig T, et al. A Treatment Planning and Acute Toxicity Comparison of Two Pelvic Nodal Volume Delineation Techniques and Delivery Comparison of Intensity-Modulated Radiotherapy Versus Volumetric Modulated Arc Therapy for Hypofractionated High-Risk Prostate Cancer Radiotherapy. *Int J Radiat Oncol Biol Phys*. 2012; 82(4): e657-e662.
160. Pederson AW, Fricano J, Correa D, et al. Late toxicity after intensity-modulated radiation therapy for localized prostate cancer: an exploration of dose-volume histogram parameters to limit genitourinary and gastrointestinal toxicity. *Int J Radiat Oncol Biol Phys*. 2012; 82(1): 235-241.
161. Pollack A, Hanlon AL, Horwitz EM, et al. Dosimetry and preliminary acute toxicity in the first 100 men treated for prostate cancer on a randomized hypofractionation dose escalation trial. *Int J Radiat Oncol Biol Phys*. 2006; 64(2): 518-526.
162. Quon H, Cheung PCF, Loblaw DA, et al. Quality of life after hypofractionated concomitant intensity-modulated radiotherapy boost for high-risk prostate cancer. *Int J Radiat Oncol Biol Phys*. 2012; 83(2): 617-623.
163. Sharma NK, Li T, Chen DY, et al. Intensity-modulated radiotherapy reduces gastrointestinal toxicity in patients treated with androgen deprivation therapy for prostate cancer. *Int J Radiat Oncol Biol Phys*. 2011; 80(2): 437-444.
164. Zelefsky MJ, Chan H, Hunt M, et al. Long-term outcome of high dose intensity modulated radiation therapy for patients with clinically localized prostate cancer. *J Urol*. 2006; 176(4 Pt 1): 1415-1419.
165. Zelefsky MJ, Kollmeier M, Cox B, et al. Improved Clinical Outcomes with High-Dose Image Guided Radiotherapy Compared with Non-IGRT for the Treatment of Clinically Localized Prostate Cancer. *Int J Radiat Oncol Biol Phys*. 2012; 84(1): 125-129.
166. Zelefsky MJ, Yamada Y, Kollmeier M, et al. Long-term outcome following three-dimensional conformal/intensity-modulated external-beam radiotherapy for clinical stage T3 prostate cancer. *Eur Urol*. 2008; 53(6): 1172-1179.
167. Zietman AL, DeSilvio ML, Slater JD, et al. Comparison of conventional dose vs high-dose conformal radiation therapy in clinically localized adenocarcinoma of the prostate: a randomized controlled trial. *JAMA*. 2005; 294(10): 1233-1229.
- Rectum**
168. Arbea L, Martinez-Monge R, Diaz-Gonzalez JA, et al. Four-week neoadjuvant intensity-modulated radiation therapy with concurrent capecitabine and oxaliplatin in locally advanced rectal cancer patients: A validation phase II trial. *Int J Radiat Oncol Biol Phys*. 2012; 83(2): 587-593.
169. Aristu J, Arbea L, Rodriguez J, et al. Phase I-II trial of concurrent capecitabine and oxaliplatin with preoperative intensity-modulated radiotherapy in patients with locally advanced rectal cancer. *In. J Radiation Oncology Biol Phys*. 2008; 71(3): 748-755.
170. Freedman G, Meropol N, Sigurdson E, et al. Phase I trial of preoperative hypofractionated intensity-modulated radiotherapy with incorporated boost and oral capecitabine in locally advanced rectal cancer. *Int J Radiat Oncol Biol Phys*. 2007; 67(5): 1389-1393.
171. Gasent Blesa JM, Garde Noguera J, Laforga Canales JB. Phase II Trial of Concomitant Neoadjuvant Chemotherapy with Oxaliplatin and Capecitabine and Intensity-Modulated Radiotherapy (IMRT) in Rectal Cancer. *J Gastrointest Cancer*. 2012; 43(4): 553-561.
172. Gunnlaugsson A, Kjellen E, Nilsson P, et al. Dose-volume relationships between enteritis and irradiated bowel volumes during 5-fluorouracil and oxaliplatin based chemoradiotherapy in locally advanced rectal cancer. *Acta Oncol*. 2007; 46: 937-944.
173. Samuelian JM, Callister MD, Ashman JB, et al. Reduced acute bowel toxicity in patients treated with intensity-modulated radiotherapy for rectal cancer. *Int J Radiat Oncol Biol Phys*. 2012; 82(5): 1981-1987.
174. Tho L, Glegg M, Patterson J, et al. Acute small bowel toxicity and preoperative chemoradiotherapy for rectal cancer: investigating dose-volume relationships and role for inverse planning. *Int J Radiat Oncol Biol Phys*. 2006; 66(2): 505-513.
- Stomach**
175. Chakravarty T, Crane C, Ajani J, et al. Intensity-modulated radiation therapy with concurrent chemotherapy as preoperative treatment for localized gastric adenocarcinoma. *Int J Radiat Oncol Biol Phys*. 2012; 83(2): 581-586.
176. Minn AY, Hsu A, La T, et al. Comparison of intensity-modulated radiotherapy and 3-dimensional conformal radiotherapy as adjuvant therapy for gastric cancer. *Cancer*. 2010; 116(16): 3943-3952.
- Testis**
177. Zilli T, Boudreau C, Doucet R, et al. Bone marrow-sparing intensity-modulated radiation therapy for Stage 1 seminoma. *Acta Oncol*. 2011; 50(4): 555-562.
- Uterus**
178. Beriwal S, Jain SK, Heron DE, et al. Dosimetric and toxicity comparison between prone and supine position IMRT for endometrial cancer. *Int J Radiat Oncol Biol Phys*. 2007; 67(2): 485-489.
179. Beriwal S, Jain SK, Heron DE, et al. Clinical outcome with adjuvant treatment of endometrial carcinoma using intensity-modulated radiation therapy. *Gynecol Oncol*. 2006; 102(2): 195-199.
180. Bouchard M, Nadeau S, Gingras L, et al. Clinical Outcome of Adjuvant Treatment of Endometrial Cancer Using Aperture-Based Intensity Modulated Radiation Therapy. *Int J Radiat Oncol Biol Phys*. 2008; 71(5): 1343-1350. (doi:10.1016/j.ijrobp.2007.12.004)

- 
181. Jhingran A, Winter K, Portelance L, et al. A Phase II Study of Intensity Modulated Radiation Therapy to the Pelvis for Postoperative Patients With Endometrial Carcinoma: Radiation Therapy Oncology Group Trial 0418. *Int J Radiat Oncol Biol Phys*. 2012; 84(1): e23-28.
182. Lian J, Mackenzie M, Joseph K, et al. Assessment of extended-field radiotherapy for stage IIIc endometrial cancer using three-dimensional conformal radiotherapy, and helical tomography. *Int J Radiat Oncol Biol Phys*. 2008; 70(3): 935-943.
183. Veldeman L, Madani I, Hulstaert F, et al. Evidence behind use of intensity-modulated radiotherapy: a systematic review of comparative clinical studies. *Lancet Oncol*. 2008; 9(4): 367-375.
184. Wong E, D'Souza D, Chen J, et al. Intensity-modulated arc therapy for treatment of high-risk endometrial malignancies. *Int J Radiat Oncol Biol Phys*. 2005; 61(3): 830-841.
185. Zwahlen DR, Ruben JD, Jones P, et al. Effect of intensity modulated pelvic radiotherapy on second cancer risk in the postoperative treatment of endometrial and cervical cancer. *Int J Radiat Oncol Biol Phys*. 2009; 74(2): 539-545.
- Vulva**
186. Beriwal S, Coon D, Heron D, et al. Peroperative intensity-modulated radiotherapy and chemotherapy for locally advanced vulvar carcinoma. *Gynecol Oncol*. 2008; 109(2): 291-295.
187. Beriwal S, Heron DE, Kim H, et al. Intensity modulated radiotherapy for the treatment of vulvar carcinoma: a comparative dosimetric study with early clinical outcome. *Int J Radiat Oncol Biol Phys*. 2006; 64(5): 1395-1400.