ASTRO Model Policies

INTENSITY MODULATED RADIATION THERAPY (IMRT)

This Model Policy[1] 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 specified targets with radiation beams whose intensity varies throughout the individual treatment fields. IMRT is particularly useful for delivering highly conformal radiation dose to targets positioned near sensitive normal tissues. Several methods can be used to perform IMRT, including step-and-shoot, sliding window, and volumetric modulated arc therapy (VMAT) approaches .

TREATMENT

IMRT Treatment Planning

IMRT treatment plans are tailored to target volumes and are geometrically more accurate than conventional, two-dimensional, or three-dimensional conformal radiation therapy plans. IMRT planning determines the gantry angles, fluences, and other beam parameters necessary to achieve desired radiation dose distributions.

IMRT treatment planning is a multi-step process:

1. **Imaging:** Three-dimensional image acquisition of the target and adjacent regions during simulation with immobilization devices employing CT, MR, PET scanners or similar 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 during radiotherapy delivery, the radiation oncologist may elect to order breath hold or multi-phasic treatment planning image sets to help account for motion when specifying targets.

2. **Contouring:** Defining the target and avoidance structures is a multi-step process:
   a. The radiation oncologist reviews the three-dimensional images and outlines the anatomic target(s) of treatment on each slice of the image set. These contours can consist of Gross Tumor Volumes (GTVs), Clinical Target Volumes (CTVs) and/or Internal Target Volumes (ITVs). GTVs represent macroscopic tumor apparent on exam or imaging and CTVs represent areas at risk of harboring microscopic disease. Some patients who have had previous treatment with surgery or chemotherapy may not have GTVs.

   b. If medically necessary, to assess and compensate for respiratory and other sources of motion, multiple image sets may be acquired, and appropriate targets made. The radiation oncologist may outline multiple GTVs at different phases of the respiratory cycle to help account for the effect of respiration on target location and shape. Likewise, the radiation oncologist may outline multiple CTVs to account for bladder filling or other causes of motion. Volumes created to account for respiratory or other motion are known as Internal Target Volumes (ITVs).

   c. To account for variation in daily patient set-up given a particular anatomic area and immobilization technique, the radiation oncologist adds an appropriate margin to create a Planning Target Volume (PTV).

   d. Many combinations of the GTV, CTV, ITV and/or PTV may be contoured depending on the clinical situation and intent of treatment.

   e. Normal structures that could potentially be harmed by radiation (i.e., "organs at risk", or OARs) are also contoured.

[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.

3. **Planning Direction:** The radiation oncologist provides a list of objectives and parameters to guide the treatment planning team. Examples may include metrics that evaluate coverage of targets at specific isodose lines, proportion of target volume covered at a prescription dose, conformity metrics, measures of gradients, and heterogeneity. Additionally, differential dosing may be prescribed to different targets within the same treatment plan based on estimated probability of risk of tumor within a specific volume, or proximity of organs at risk. This can include the nominal quantity of dose to be delivered to various targets over a certain amount of treatments as well as accompanying descriptive metrics. In other cases, a highly heterogeneous dose profile with sharp fall off may be desired. Details regarding motion management and image guidance, limits that should not be exceeded, or constraints for OAR's, and the relative prioritization of objectives that may conflict are also provided. Given a patient's specific anatomy, a treatment plan that balances clinical and dosimetric objectives should maximize the potential for disease control and minimize the risk of injury to normal tissue.

4. **Dosimetric Planning and Calculations:** The medical physicist or dosimetrist utilizes specialized treatment planning software to iterate combinations of radiation beams or arcs to meet the radiation oncologist's specified objectives. Cross-sectional imaging overlaid with isodose lines and dose-volume histograms are prepared for the radiation oncologist's evaluation. The essential feature of an IMRT plan is that it describes the means to deliver treatment utilizing non-uniform beam intensities. Each radiation beam and/or arc is, in effect, a collection of numerous "beamlets," each with a different level of radiation intensity; the summation of these "beamlets" delivers characteristic conformal IMRT dose distributions. The physicist and dosimetrist perform basic dose calculations for each of the modulated beams and/or arcs and verify monitor unit computations through an independent secondary dose calculation method.

5. **Radiation Dose Prescription:** The radiation oncologist approves the treatment plan and formally prescribes radiation to the target volumes, specifying the anatomic treatment site, type and method of radiation treatment delivery, total dose, dose per fraction, number of fractions, frequency of treatment, and image guidance to be used during the course of treatment.

6. **Patient Specific Dose Verification:** The calculated beams or arcs are delivered to a phantom or other dose measuring device to confirm that the dose distribution intended for the patient is physically verified as technically deliverable. Additional detail can be found in the ASTRO IMRT Quality and Safety 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 treatment delivery 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 in the immobilized patient. IMRT treatment delivery may be accomplished via various combinations of gantry motion, table motion, slice-by-slice treatment (e.g., TomoTherapy), multi-leaf collimators (MLC) and/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 organs at risk; thus reproducible patient immobilization is essential for IMRT. Imaging techniques such as stereoscopic kilovoltage or megavoltage X-ray, ultrasound, cone beam or megavoltage cone beam CT, MRI, and optical surface monitoring systems (collectively referred to as Image Guided Radiation Therapy or IGRT) may be utilized to mitigate inter and intra-fractional motion and ensure accurate delivery of the radiation.

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. Planning direction which defines the goals and requirements of the treatment plan, including specific dose objectives for the target and nearby critical structures.

3. A note of medical necessity for IMRT by the treating physician.

4. Signed IMRT plan that corresponds with the approved prescription.

5. The medical record must include the following:
   a. Documentation of clinically appropriate GTV/CTV/ITV/PTV
   b. Documentation of dose volume histograms for targets and OAR's.
   c. 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-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-10 codes to incorporate additional considerations of clinical scenario and medical necessity with appropriate documentation. For some anatomical sites such as head and neck malignancies prostate, anus, central nervous system and thoracic malignancies, IMRT is commonly performed. In all cases, documentation of the medical necessity is required.

INTENSITY MODULATED RADIATION THERAPY (IMRT)

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. 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.

IMRT is considered reasonable and medically necessary in instances where sparing the surrounding normal tissue is of added clinical benefit to the patient. This may include instances in which clinically relevant tolerances of normal tissues are exceeded for a single plan or in the re-irradiation setting. IMRT is also indicated if the patient's general medical condition (namely, the performance status) justifies aggressive local therapy to one or more deposits of metastatic cancer in an effort either to achieve total disease clearance in the setting of oligometastatic disease. Based on this principle, several common indications for IMRT are included below. This is not an exhaustive list but represents situations in which IMRT is usually of clinical benefit based on normal anatomy and typical prescribed doses.

General
Medically inoperable patients with a diagnosis of cancer typically treated with surgery where dose escalation is required due to the inability to receive surgery
Re-irradiation cases (where cumulative critical structure dose would exceed tolerance dose)
Primary malignant or benign bone tumors
Central Nervous System
Ocular tumors, including intraocular melanomas
Tumors that approach or are located at the base of skull
Primary CNS tumors, primary spine,or metastatic tumors to the spine or spinal cord where organ at risk tolerance may be exceeded with 3-D conformal treatments
Primary and metastatic tumors requiring craniospinal irradiation
Brain metastases requiring hippocampal-sparing whole brain radiotherapy
Head and Neck
Definitive, adjuvant, or palliative treatment of primary/secondary head and neck cancers or draining lymphatics of the neck including (but not limited to) cancers of the nasopharynx, nasal cavity, paranasal sinuses, oropharynx, oral cavity, hypopharynx, larynx , thyroid, or salivary glands
Cutaneous tumors with cranial nerve invasion to the base of skull, cavernous sinus, and/or brainstem
Mucosal Melanoma
Occult (or unknown) primary malignancies of the head and neck
Breast
Bilateral breast cancers requiring nodal treatment on at least one side
Breast cancer patients being treated with definitive intent and who have unfavorable anatomy (e.g. pectus excavatum) that would deliver unacceptably high doses to organs-at-risk
Early-stage breast cancer in which dose to the heart is unacceptably high with conventional photon or photon/electron using cardiac sparing techniques.
Accelerated partial breast irradiation (APBI), regardless of laterality.
Patients in whom internal mammary lymph nodes are targeted.
Breast cancer patients who have limited ipsilateral arm range of motion and require treatment in the arms down position

Thoracic
Primary or secondary tumors of the mediastinum, including thymic tumors, mediastinal tumors, mediastinal lymphomas and thoracic sarcomas
Early-stage lung cancer for which SBRT is not feasible secondary to anatomic considerations.
Locally advanced lung cancer in which IMRT significantly reduces dose to normal tissues. (ex: bilateral mediastinal disease, paraspinal tumors, N3 disease, reducing esophageal dose).
Malignant pleural mesothelioma
Gastrointestinal
Hepatocellular cancer, bile duct, gallbladder and cholangiocarcinoma cancers
Primary cancers of the esophagus and GE junction
Abdominal malignancies, including primary pancreatic, gastric, and adrenal cancers
Primary and Secondary liver cancers
Anal & colorectal cancers
Sarcomas
Retroperitoneal sarcomas
Desmoid tumors
Extremity sarcomas
Pelvic/Gynecological
Cervical cancer
Vulvar and Vaginal cancers
Genitourinary
Prostate Cancer
Renal cancer
Bladder cancer
Penile cancer
Ureteral cancer

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.

Site	ICD-10	Description
Central Nervous System		
Ocular tumors, including intraocular melanomas	C69.00 - C69.82	Malignant neoplasm of ocular structures
Tumors that approach or are located at the base of skull	C41.0 - C41.2 C75.1, C75.2, C75.4, C75.5 D16.4, D16.6 D35.3	Malignant neoplasm of bones of skull and face, mandible, vertebral column; Malignant neoplasm of other endocrine glands and related structures; Benign neoplasm of bone; Benign neoplasm of craniopharyngeal duct
Primary CNS tumors, primary spine, or metastatic tumors to the spine or spinal cord where organ at risk tolerance may be exceeded with 3-D conformal treatments	C41.2, C41.4 C70.1 C72.0, C72.1 D16.6, D16.8, D32.1, D33.4 D33.0-D33.2 D43.0-D43.2	Malignant neoplasm of bones of vertebral column, sacrum, and coccyx; Malignant neoplasm of spinal meninges; Malignant neoplasm of spinal cord and cauda equina; Benign neoplasm of vertebral column, sacrum, coccyx, spinal meninges, spinal cord Benign neoplasm of brain Neoplasm of uncertain behavior of brain
Primary and metastatic tumors requiring craniospinal irradiation	C70.0 - C72.59, C75.3	Malignant neoplasm of meninges, brain, cranial nerves, spinal cord, pineal gland
Brain metastases requiring hippocampal-sparing whole brain radiotherapy	C79.31-C79.32, C79.49	Secondary malignant neoplasm of brain, Secondary malignant neoplasm of cerebral meninges, Secondary malignant neoplasm of other parts of nervous system
Head and Neck		
Primary/Secondary head and neck cancers or draining lymphatics of the neck	C11.0 - C11.8 C30.0, C30.1 C31.0 - C31.8 C00.0 - C14.8 C32.0-C32.8 C73 C75.0 C76.0 C77.0	Malignant neoplasm of nasopharynx; Malignant neoplasm of nasal cavity and middle ear; Malignant neoplasm of accessory sinuses; Malignant neoplasm of head and neck sites Malignant neoplasm of glottis, larynx Malignant neoplasm of thyroid gland Malignant neoplasm of parathyroid gland Malignant neoplasm of head, face and neck Secondary and unspecified malignant neoplasm of lymph nodes of head, face and neck
Mucosal Melanoma	C06.0	Malignant neoplasm of cheek mucosa
Breast		
Breast cancer	C50-C50.822	Malignant neoplasm of female, male breast

Thoracic		
Primary or secondary tumors of the mediastinum, including thymic tumors, mediastinal tumors, mediastinal lymphomas, and thoracic sarcomas	C33 C37 C38.0 - C38.8 C81.00-C81.79 C82.01-C82.99 C83.01-C83.89 C84.01-C84.79 C76.1 C77.1	Malignant neoplasm of trachea; Malignant neoplasm of thymus Malignant neoplasm of heart, mediastinum, and pleura; Nodular lymphocyte predominant Hodgkin lymphoma, intrathoracic lymph nodes; Nodular sclerosis Hodgkin lymphoma, intrathoracic lymph nodes; Mixed cellularity Hodgkin lymphoma, intrathoracic lymph nodes; Lymphocyte depleted Hodgkin lymphoma, intrathoracic lymph nodes; Lymphocyte-rich Hodgkin lymphoma, intrathoracic lymph nodes; Other Hodgkin lymphoma, intrathoracic lymph nodes; Follicular lymphoma grade IIIa, intrathoracic lymph nodes; Follicular lymphoma grade IIIb, intrathoracic lymph nodes; Small cell B-cell lymphoma, intrathoracic lymph nodes; Mantle cell lymphoma, intrathoracic lymph nodes; Diffuse large B-cell lymphoma, intrathoracic lymph nodes; Lymphoblastic (diffuse) lymphoma, intrathoracic lymph nodes; Burkitt lymphoma, intrathoracic lymph nodes; Other non-follicular lymphoma, intrathoracic lymph nodes Malignant neoplasm of thorax Secondary and unspecified malignant neoplasm of intrathoracic lymph nodes
Malignant pleural mesothelioma	C45.0-C45.7	Mesothelioma of pleura, other sites
Lung cancer	C34.00-C34.92 C78.01-C78.02 C78.2, C78.39	Malignant neoplasm of bronchus, lung Secondary malignant neoplasm of lung Secondary malignant neoplasm of pleura, other respiratory organs
Gastrointestinal		
Hepatocellular cancer, bile duct, gallbladder and cholangiocarcinoma cancers	C22.0 - C22.7 C23.0 C24-C24.9	Liver cell carcinoma, liver sarcomas, intrahepatic bile duct carcinoma Malignant neoplasm of gallbladder Malignant neoplasm of bile duct, biliary tract
Primary cancers of the esophagus and GE Junction	C15.3 - C15.8	Malignant neoplasm of esophagus

Abdominal malignancies, including primary pancreatic, gastric, and adrenal cancers	C16.0-C16.8 C17.0-C17.8 C25.0-C25.8 C74.01-C74.92 C76.2 C77.2 C78.4 C78.5	Malignant neoplasm of stomach Malignant neoplasm of intestines Malignant neoplasm of pancreas Malignant neoplasm of adrenal gland(s) Malignant neoplasm of abdomen Secondary and unspecified malignant neoplasm of intra-abdominal lymph nodes
Primary and Secondary liver cancers	C22.8, C22.9 C78.7	Malignant neoplasm of liver, primary & secondary
Anal & colorectal cancers	C18.0-C18.8 C19, C20 C21.0-C21.8	Malignant neoplasm of colon Malignant neoplasm of rectum Malignant neoplasm of anus, anal canal
Sarcomas		
Retroperitoneal sarcomas	C48.0 - C48.8 C78.6	Malignant neoplasm of retroperitoneum and peritoneum
Desmoid tumors	D48.110-D48.119	Various regions
Extremity sarcomas	C76.40-C76.52	Malignant neoplasm of upper, lower limbs
Pelvic/Gynecological		
Endometrial cancer	C54.1, C54.2	Malignant neoplasm of endometrium, myometrium
Cervical cancer	C53.0-C53.8	Malignant neoplasm of cervix
Vulvar and vaginal cancers	C51.0-C51.8 C52	Malignant neoplasm of vulva Malignant neoplasm of vagina
Genitourinary		
Prostate cancer	C61	Malignant neoplasm of prostate
Renal cancer	C65.1-C65.2 C64.1, C64.2	Malignant neoplasm of renal pelvis Malignant neoplasm of kidney(s)
Bladder cancer	C67.0-C67.8 C68.0-C68.8 C79.11	Malignant neoplasm of bladder Malignant neoplasm of urethra
Penile cancer	C60-C60.8 C63.00-C63.9	Malignant neoplasm of penis
Ureteral cancer	C54.0, C54.3, C54.8 C55 C56.1-C56.3 C57.01-C57.02 C57.11-C57.22 C57.3 C57.7-C57.8 C66.1-C66.2	Malignant neoplasm of uteri Malignant neoplasm of uterus Malignant neoplasm of ovaries Malignant neoplasm of fallopian tubes Malignant neoplasm of broad, round ligament(s) Malignant neoplasm of parametrium Malignant neoplasm of other, overlapping specified female genital organs Malignant neoplasm of ureter
Skeletal		
Primary malignant or benign bone tumors	C40.0 - C40.8; C41.0 - C41.9 D16.0 - D16.8	Malignant neoplasm of bone and articular cartilage; Benign neoplasm of bone and articular cartilage

Reirradiation		
Various regions	Z92.3 T66.XXXA*	Personal history of irradiation

*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.

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. *This code is typically reported only once per course of IMRT.*
+77293	Respiratory motion management simulation (List separately in addition to code for primary procedure). *This is an add-on code and cannot be billed on its own. It should be billed with either CPT code 77295 or 77301.*

CPT Codes for IMRT Treatment Delivery

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

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 *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.*

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

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 in-trafraction tracking, when performed
G6001	Ultrasonic guidance for placement of radiation therapy fields *Report under the Medicare Physician Fee Schedule to payers that do not accept CPT code 77387.*
G6002	Stereoscopic X-ray guidance for localization of target volume for the delivery of radiation therapy *Report under the Medicare Physician Fee Schedule to payers that do not accept CPT code 77387.*
77014	Computed tomography guidance for placement of radiation therapy fields *Report under the Medicare Physician Fee Schedule to payers that do not accept CPT code 77387.*

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 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.*
77285	Therapeutic radiology simulation-aided field setting; intermediate *Criteria for level: Two separate treatment areas.*
77290	Therapeutic radiology simulation-aided field setting; complex *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.*
77295	3-dimensional radiotherapy plan, including dose-volume histograms *May be reported once per treatment course per treatment volume.*
77321	Special teletherapy port plan, particles, hemibody, total body *Use for particle beam isodose planning. Use for electrons, protons and neutron therapy; half body or total body therapy.*
77331	Special dosimetry (e.g., TLD, microdosimetry) (specify), only when prescribed by the treating physician *Explanation of medical necessity may be required.*
77370	Special medical radiation physics consultation *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.*

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 15 years reporting clinical outcomes in patients treated with IMRT, organized by disease site.

General

0. Bortfeld T, Schmidt-Ulrich R, De Neve W, Wazer DE. *Image-Guided IMRT*. Berlin, Germany: Springer; 2006.

1. Chao KSC, Apisarnthanarax S, Ozyigit G. Practical Essentials of Intensity Modulated Radiation Therapy. 2nd edition. Philadelphia, PA: Lippincott Williams & Wilkins; 2005.

2. DeVita VT, Hellman S, Rosenberg SA. Radiation Oncology. Cancer, Principles & Practice of Oncology. 9th edition. Philadelphia, PA: Lippincott William & Wilkins; 2011: 297-306.

3. Guerrero Urbano MT, Nutting CM. Clinical use of intensity-modulated radiotherapy: part I. Br) Radiol. 2004; 77(914): 88-96.

4. Guerrero Urbano MT, Nutting CM. Clinical use of intensity-modulated radiotherapy: part II. Br) Radiol. 2004; 77(915): 177-182.

5. 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.

6. 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.

7. 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) Clin Oncol. 2012; 35(6): 612-617.

8. 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.

9. McCormick B, Hunt M. Intensity-modulated radiation therapy for breast: is it for everyone? Semin Radiat Oncol. 2011; 21: 51-54.

10. Mell LK, Mehrotra AK, Mundt AJ. Intensity-modulated radiation therapy use in the U.S., 2004. Cancer. 2005; 104(6): 1296-1303.

11. Moran JM, Dempsey M, Eishbruch A, et al. Safety consideration for IMRT: Executive Summary. Pract Radiat Oncol. 2011; 1: 190-195.

12. Mundt AJ, Roeske JC. Intensity Modulated Radiation Therapy. Hamilton, Ontario: BC Decker; 2005.

13. Laskar S, Kakoti S, Khanna N, et al. Outcomes of osteosarcoma, chondrosarcoma and chordoma treated with image guided-intensity modulated radiation therapy. Radiother Oncol. 2021;164:216-222.

Anus

14. 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.

15. 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.

0. 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.

1. 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.

2. 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) Radiat Oncol Biol Phys. 2009; 75(3): 791-794.

3. Kachnic LA, Tsai HK, Coen JJ, et al. Dose-painted intensity-modulated radiation therapy for anal cancer: a multi-institutional report of acutetoxicity and response to therapy. Int) Radiat Oncol Biol Phys. 2012; 82(1): 153-158.

4. Milano MT, Jani AB, Farrey KJ, et al. Intensity-modulated radiation therapy (IMRT) in the treatment of anal cancer: toxicity and clinical outcome. Int) Radiat Oncol Biol Phys. 2005; 63(2): 354-361.

5. Pepek JM, Willett CG, Wu QJ, et al. Intensity-modulated radiation therapy for anal malignancies: a preliminary toxicity and disease outcomes analysis. Int) Radiat Oncol Biol Phys. 2010; 78(5): 1413-1419.

6. 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.

7. Salama JK, Mell LK, Schomas DA, et al. Concurrent chemotherapy and intensity-modulated radiation therapy for anal canal cancer patients: a multicenter experience.) Clin Oncol. 2007; 25(29): 4581-4586.

8. 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.

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. Wegner RE, Abel S, Hasan S, et al. Trends in Radiation Dose and Technique For Anal Canal Squamous Cell Carcinoma. Am J Clin Oncol. 2019;42(6):519-526.

20. 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) Radiat Oncol Biol Phys. 2009; 75(3): 791-794.

21. Kachnic LA, Tsai HK, Coen JJ, et al. Dose-painted intensity-modulated radiation therapy for anal cancer: a multi-institutional report of acutetoxicity and response to therapy. Int) Radiat Oncol Biol Phys. 2012; 82(1): 153-158.

22. 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.

23. Milano MT, Jani AB, Farrey KJ, et al. Intensity-modulated radiation therapy (IMRT) in the treatment of anal cancer: toxicity and clinical outcome. Int) Radiat Oncol Biol Phys. 2005; 63(2): 354-361.

24. Pepek JM, Willett CG, Wu QJ, et al. Intensity-modulated radiation therapy for anal malignancies: a preliminary toxicity and disease outcomes analysis. Int) Radiat Oncol Biol Phys. 2010; 78(5): 1413-1419.

25. 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.

26. Salama JK, Mell LK, Schomas DA, et al. Concurrent chemotherapy and intensity-modulated radiation therapy for anal canal cancer patients: a multicenter experience.) Clin Oncol. 2007; 25(29): 4581-4586.

27. 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

28. 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) Radiat Oncol Biol Phys. 2012; 82(2): 715-723.

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.

9. 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.

10. 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.

11. 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.) Clin Oncol. 2007; 25(21): 3031-3037.

12. De Neve W, De Gersem W, Madani I. Rational Use of Intensity-Modulated Radiation Therapy: The Importance of Clinical Outcome. Sem Radiat Oncol. 2012; 22(1): 40–49.

13. 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.

14. 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) Radiat Oncol Biol Phys. 2012; 84(4): 888-893.

15. 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) Clin Oncol. 2006; 29(1): 66-70.

16. 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) Radiat Oncol Biol Phys. 2009; 74: 689–694.

17. 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) Radiat Oncol Biol Phys. 2007; 68(5): 1375-1380.

18. Ho AY, Ballangrud A, Li G, et al. Long-term pulmonary outcomes of a feasibility study of inverse-planned, multibeam intensity modulated radiation therapy in node-positive breast cancer patients receiving regional nodal irradiation. Int J Radiat Oncol Biol Phys 2019;103:1100–1108.

19. Jagsi R, Griffith KA, Moran JM, et al. A randomized comparison of radiation therapy techniques in the management of node-positive breast cancer: Primary outcomes analysis. Int J Radiat Oncol Biol Phys 2018;101:1149–1158.

20. Jagsi R, Moran J, Marsh R, et al. Evaluation of four techniques using intensity-modulated radiation therapy for comprehensive locoregional irradiation of breast cancer. Int J Radiat Oncol Biol Phys 2010;78:1594–1603.

21. Jagsi R, Griffith KA, Moran JM, et al. Michigan Radiation Oncology Quality Consortium. Comparative Effectiveness Analysis of 3D-Conformal Radiation Therapy Versus Intensity Modulated Radiation Therapy (IMRT) in a Prospective Multicenter Cohort of Patients with Breast Cancer. Int J Radiat Oncol Biol Phys. 2022 Mar 1;112(3):643-653.

22. 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 Cencer Center experience. Int) Radiat Oncol Biol Phys. 2012; 84(4): 881-887.

23. Leonard C, Carter D, Kerscher J, et.al. Prospective trial of accelerated partial breast intensity-modulated radiotherapy. Int) Radiat Oncol Biol Phys. 2007; 67(5): 1291-1298.

24. 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) Radiat Oncol Biol Phys. 2012; 82(5): 2104-2110.

25. Mukesh M, Barnett G, Wilkinson J, et al. Randomized controlled trial of intensity-modulated radiotherapy for early breast cancer: 5-year results confirm superior overall cosmesis. J Clin Oncol 2013;31:4488–4495.

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

Central Nervous System

47. 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) Radiat Oncol Biol Phys. 2007; 68(3): 858-863.

48. 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.

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

50. 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.) Neurooncol. 2011; 104(1): 339-349.

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

52. 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.

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

54. 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.

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

56. Doi H, Tamari K, Masai N, et al. Intensity-modulated radiation therapy administered to a previously irradiated spine is effective and well-tolerated. Clin Transl Oncol. 2021;23(2):229-239.

57. Brown PD, Gondi V, Pugh S, et al. Hippocampal Avoidance During Whole-Brain Radiotherapy Plus Memantine for Patients With Brain Metastases: Phase III Trial NRG Oncology CC001. J Clin Oncol. 2020;38(10):1019-1029.

Cervix

58. 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) Radiat Oncol Biol Phys. 2004; 60(2): 505-512.

59. 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) Radiat Oncol Biol Phys. 2011; 79(4): 1043-1047.

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

27. 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.

28. 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) Radiat Oncol Biol Phys. 2007; 67(5): 1438-1444.

29. 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.

30. 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) Radiat Oncol Biol Phys. 2008; 72(4): 1134-1139.

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

32. 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) Radiat Oncol Biol Phys. 2010; 77: 1085–1091.

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

34. 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) Radiat Oncol Biol Phys. 2012; 83(1): e81-e86.

35. 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) Radiat Oncol Biol Phys. 2006; 64(1): 189-196.

Esophagus

36. 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) Radiat Oncol Biol Phys. 2012; 83(5): 1580-1586.

37. 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.

38. 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) 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) 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) 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. ....

77. Salama JK, Mundt AJ, Roeske J, et al: Preliminary outcome and toxicity report of extended-field, intensity-modulated radiation therapy for gynecologic malignancies. Int) Radiat Oncol Biol Phys. 2006; 65: 1170-1176.

78. Vandecasteele K, Tummers P, Makar A, et al. Postoperative intensity-modulated arc therapy for cervical and endometrial cancer: A prospective reportr on toxicity. Int) Radiat Oncol Biol Phys. 2012; 84 (2): 408-414.

79. Small Jr W, Bosch WR, Harkenrider MM, et al. NRG Oncology/RTOG Consensus Guidelines for Delineation of Clinical Target Volume for Intensity Modulated Pelvic Radiation Therapy in Postoperative Treatment of Endometrial and Cervical Cancer: An Update. Int J Radiat Oncol Biol Phys. 2021; 109(2): 413-424

80. Yeung AR, Pugh SL, Klopp AH, et al. Improvement in Patient-Reported Outcomes With Intensity-Modulated Radiotherapy (RT) Compared With Standard RT: A Report From the NRG Oncology RTOG 1203 Study. J Clin Oncol. 2020; 38:1685-1692

81. Lin AJ, Kidd E, Dehdashti F, et al. Intensity Modulate Radiation Therapy and Image-Guided Adapted Brachytherapy for Cervix Cancer. Int J Radiat Oncol Biol Phys. 2019; 103(5): 1088-1097

82. Klopp AH, Yeung AR, Deshmukh S, et al. Patient-reported toxicity during pelvic intensity-modulated radiation therapy: NRG Oncology-RTOG 1203. J Clin Oncol. 2018; 36:2538-2544

83. Shih KK, Hajj C, Kollmeier M, et al. Impact of postoperative intensity-modulated radiation therapy (IMRT) on the rate of bowel obstruction in gynecologic malignancy. Gynecol Oncol. 2016;143(1): 18-21

84. Hymel R, Jones GC, Simone II CB, Whole Pelvic Intensity-modulated Radiotherapy for Gynecological Malignancies: A Review of the literature. Crit Rev Oncol Hematol. 2015; 94(3): 371-379

85. Viswanathan AN, Moughan J, Miller BE, et al. NRG Oncology/RTOG 0921: a phase 2 study of postoperative intensity-modulated radiotherapy with concurrent cisplatin and bevacizumab followed by carboplatin and paclitaxel for patients with endometrial cancer. Cancer. 2015; 121: 2156-2163

86. Barillot I, Tavernier E, Peignaux K, et al. Impact of post operative intensity modulated radiotherapy on acute gastro-intestinal toxicity for patients with endometrial cancer: Results of the phase II RTCMIENDOMETRE French multicentre trial. Radiother Oncol. 2014;111:138-143

87. Desai NB, Stein NF, LaQuaglia MP, et al. Reduced Toxicity with Intensity Modulated Radiation therapy (IMRT) for Desmoplastic Small Round Cell Tumor (DSRCT): An Update on the Whole Abdominopleivc Radiation Therapy (WAP-RT) Experience. Int J Radiat Oncol Biol Phys. 2013 January 1;85(1): e67-e72

88. Klopp AH, Moughan J, Portelance L, et al. Hematologic Toxicity on RTOG 0418: A Phase II Study of Postoperative IMRT for Gynecologic Cancer. Int J Radiat Oncol Biol Phys. 2013; 86(1): 83-90

Head and Neck

89. Arcangeli G, Benassi M, Giovinazzo 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) Radiat Oncol Biol Phys. 2009; 73(4): 1252-1259.

90. Chan K, Gomez DR, Gomez J, et al.. Intensity-Modulated Radiotherapy in Postoperative Treatment of Oral Cavity Cancers. Int) Radiat Oncol Biol Phys. 2009; 73(4): 1096-1103.

91. Maddalo M, Bonomo P, Belgioia L, et al. Re-irradiation with curative intent in patients with squamous cell carcinoma of the head and neck: a national survey of usual practice on behalf of the Italian Association of Radiation Oncology (AIRO). Eur Arch Otorhinolaryngol. 2018;275(2):561-567.

92. 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) Radiat Oncol Biol Phys. 2012; 84(1): 170-175.

93. Chua DT, Sham JS, Leung LH, et al. Re-irradiation of nasopharyngeal carcinoma with intensity-modulated radiotherapy. Radiother Oncol. 2005; 77(3): 290-294.

94. 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) Radiat Oncol Biol Phys. 2012; 82(2): 582-589.

95. 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) Radiat Oncol Biol Phys. 2009; 74(1): 1-8.

96. Duprez F, Madani I, Morbée L, et al. IMRT for sinonasal tumors minimizes severe late ocular toxicity and preserves disease control and survival. Int) Radiat Oncol Biol Phys. 2012; 83(1): 252-259.

97. 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) Radiat Oncol Biol Phys. 2011; 81(3): e93-e99.

98. 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) Radiat Oncol Biol Phys. 2007; 68(5): 1289-1298.

99. 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) Radiat Oncol Biol Phys. 2007; 67(5): 1309-1317.

100. 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.

101. 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) Radiat Oncol Biol Phys. 2005; 63(3): 725-731.

102. 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.) Clin Oncol. 2007; 25(31): 4873-4879.

103. Klem ML, Mechalakos JG, Wolden SL, et al. Intensity-modulated radiotherapy for head and neck cancer of unknown primary: toxicity and preliminary efficacy. Int) Radiat Oncol Biol Phys. 2008; 70(4): 1100-1107.

104.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.

105. 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) RadiatOncol Biol Phys. 2004; 60(2): 374-387

100. 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) Radiat Oncol Biol Phys. 2006; 66(4): 966-974.

101. 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)Radiat Oncol Biol Phys. 2003; 57(1): 61-70.

102. Madani I, Bonte K, Vakael L, et al. Intensity-Modulated Radiotherapy for Sinonasal Tumors: Ghent University Hospital Update. Int) Radiat Oncol Biol Phys. 2009; 73(2): 424-432.

103. 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.

104. 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-hypopharyn geal cancers. Int) Radiat Oncol Biol Phys. 2012; 82(2): 539-547.

105. 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) Radiat Oncol Biol Phys. 2011; 81(5): e845-e852.

106. 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.

107. P.M. Braam, C.H. Terhaard, J.M. Roesink et al. Intensity-modulated radiotherapy significantly reduces xerostomia compared with conventional radiotherapy. Int) Radiat Oncol Biol Phys. 2006; 66: 975-980.

108. Pacholke HD, Amdur RJ, Morris CG, et al. Late xerostomia after intensity-modulated radiation therapy versus conventional radiotherapy. Am) Clin Oncol. 2005; 28(4): 351-358.

109.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) Radiat Oncol Biol Phys. 2004; 58(3): 663-673.

60. 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) RadiatOnc Biol Phys. 2006; 66(4): 981-991.

61. Qiu S, Lin S, Tham IWK, et al. Intensity-modulated radiation therapy in the salvage of locally recurrent nasopharyngeal carcinoma. Int) Radiat Oncol Biol Phys. 2012; 83(2): 676-683.

62. Saarilahti K, Kouri M, Collan J, et al. Intensity modulated radiotherapy for head and neck cancer: evidence for preserved salivary gland function. Radiother Oncol. 2005; 74(3): 251-258.

63. Saarilahti K, Kouri M, Collan J, et al. Sparing of the submandibular glands by intensity modulated radiotherapy in the treatment of head and neck cancer. Radiother Oncol. 2006; 78(3): 270-275.

64. Schoenfeld JD, Sher DJ, Norris CM, et al. Salivary gland tumors treated with adjuvant intensity-modulated radiotherapy with or without concurrent chemotherapy. Int) Radiat Oncol Biol Phys. 2012; 82(1): 308-314.

65. Setton J, Caria N, Romanyshyn J, et al. Intensity-modulated radio therapy in the treatment of oropharyngeal cancer: An update of the Memorial Sloan-Kettering Cancer Center experience. Int) Radiat Oncol Biol Phys. 2012; 82(1): 291-298.

66. 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) Radiat Oncol Biol Phys. 2011; 81(3): e83-e91.

67. Sulman E, Schwartz D, Le T, et al. IMRT Reirradiation of head and neck cancer: Disease control and morbidity outcomes. Int) Radiat Onc Biol Phys. 2009; 73(2): 399-409.

68. Villenueve H, Després P, Fortin B, et al. Cervical lymph node metastases from unknown primary cancer: A single-institution experience with intensity-modulated radiotherapy. Int) Radiat Oncol Biol Phys. 2012; 82(5): 1866-1871.

69. 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) Radiat Oncol Biol Phys. 2012; 83(1): 243-251.

70. 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.

71. Velez MA, Veruttipong D, Wang PC, et al. Re-irradiation for recurrent and second primary cancers of the head and neck. Oral Oncol. 2017;67:46-51.

72. Leong YH, Soon YY, Lee KM, Wong LC, Tham IWK, Ho FCH. Long-term outcomes after reirradiation in nasopharyngeal carcinoma with intensity-modulated radiotherapy: A meta-analysis. Head Neck. 2018;40(3):622-631.

73. Mohamed ASR, Smith BD, Smith JB, et al. Outcomes of carotid-sparing IMRT for T1 glottic cancer: Comparison with conventional radiation. Laryngoscope. 2020;130(1):146-153.

74. Razavian NB, D'Agostino RB Jr, Shenker RF, Hughes RT. Intensity-Modulated Radiation Therapy for Early-Stage Squamous Cell Carcinoma of the Glottic Larynx: A Systematic Review and Meta-Analysis. Int J Radiat Oncol Biol Phys. 2023;117(3):652-663.

Liver

75. 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) Radiat Oncol Biol Phys. 2012 Jul 4 [epub ahead of print].

76. 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. Radiat 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) 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) 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) 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) 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) 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) 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) 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) 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) 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 radio therapy for patients with early-stage nasal NK/T-cell lymphoma. Int) 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) Radiat Oncol Biol Phys. 2004; 59(2): 454-459.

144. Milano MT, Chmura SJ, Garofalo MC, et al. Intensity-modulated radio therapy in treatment of pancreatic and bile duct malignancies: toxicity and clinical outcome. Int) 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 chemoradio therapy. Int) 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) Radiat Oncol Biol Phys. 2012; 83(3): 916-920.

147. Prasad S, Cambridge L, Huguet F, et al. Intensity modulated radiation therapy reduces gastrointestinal toxicity in locally advanced pancreas cancer. Pract Radiat Oncol.

Prostate

148. Afonso SL, Stefano ES, Viani GA. Higher-Than-Conventional Radiation Doses in Localized Prostate Cancer Treatment: A Meta-analysis of Randomized, Controlled Trials. Int) Radiat Oncol Biol Phys. 2009; 74(5): 1405-1418.

149. 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.

150. 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) Radiat Oncol Biol Phys. 2009; 73(3): 685-691.

151. 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.

152. 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) Radiat Oncol Biol Phys. 2005; 61(2): 400-408.

153. Cahlon O, Hunt M, Zelefsky MJ. Intensity-modulated radiation therapy: supportive data for prostate cancer. Semin Rad Oncol. 2008; 18(1): 48-57.

154. 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) Radiat Onc Biol Phys. 2009; 73(1): 53-60.

155. 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) 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, Blacksburg S, Stone N, et al.. Intensity-modulated radiotherapy causes fewer side effects than three-dimensional con formal 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. IntJ 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

110. 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.

111. 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.

112. 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.

113. 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.

114. 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.

115. 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.

116. 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.

117. Dapper H, Rodríguez I, Münch S, et al. Impact of VMAT-IMRT compared to 3D conformal radiotherapy on anal sphincter dose distribution in neoadjuvant chemoradiation of rectal cancer. Radiat Oncol. 2018;13(1):237.

Stomach

118. 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.

119. Minn AY, Hsu A, La T, el al. Comparison of intensity-modulated radiotherapy and 3-dimensional conformal radiotherapy as adjuvant therapy for gastric cancer. Cancer. 2010; 116(16): 3943-3952.

120. Trip AK, Nijkamp J, van Tinteren H, et al. IMRT limits nephrotoxicity after chemoradiotherapy for gastric cancer. Radiother Oncol. 2014;112(2):289-294.

Testis

121. 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

122. 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.

123. 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.

124. Bouchard M, Nadeau S, Gingras L, et al.Clinical Outcome of Adjuvant Treatment of Endometrial Cancer Using Apeture-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.