Modern Advancements in Radiation Oncology: What Every Oncologist Should Know

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ABSTRACT

Radiation oncology has undergone a profound transformation over the past 50 years, evolving from broad techniques to highly conformal, precision-guided treatments. This review synthesizes key advancements in the field, first from technological innovations allowing the provision of precisely aligned and uniquely tailored radiation, customized to patient anatomy (such as intensity modulated radiation therapy, stereotactic body radiation therapy, and MR Linac) to emerging applications of particle beams, radiopharmaceuticals, and adaptive planning platforms. These advances have facilitated more accurate treatments and decreased side effect burden. The role of radiation therapy has also expanded in the management of metastatic disease beyond simply palliation, with ablative techniques leading to improved progression-free survival in oligometastatic settings. The combination of radiation with immunotherapy can introduce synergistic effects and is reshaping treatment paradigms across disease sites. However, widespread adoption of radiation innovation faces challenges, including rising financial toxicity, geographic disparities in access, and administrative burdens of previous authorization. As radiation oncology enters a new era, oncologists across specialties must remain informed about the evolving factors that affect timely radiation delivery.

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INTRODUCTION

Over the past 50 years, the field of radiation oncology has markedly transformed. From the discovery of X-ray–based treatment, advancements have allowed improvements from large-field radiation to millimeter precision in tumor targeting.[1] Today, radiation therapy is not only guided by anatomic considerations but increasingly tailored toward tumor biology. The evolving treatment paradigm of radiation oncology holds personalized medicine at its center, while also integrating the importance of de-escalation and shared decision making (SDM).

This review will highlight key advancements including cutting-edge treatment, the evolving paradigm of metastatic disease, and the integration of immunotherapy with radiation. In addition, it will explore the critical concerns surrounding access to care and the growing burden of previous authorization, which collectively influences how radiation therapy is delivered in the modern day.

CUTTING-EDGE TREATMENT MODALITIES

Radiation treatment advances have allowed more precise treatment with highly conformal doses, tailored to patient anatomy in four dimensions. Table 1 summarizes modalities discussed in this section.

Customized and Conformal Techniques

Three-dimensional conformal radiation therapy (3D-CRT) was the first major advance beyond 2D planning, using three-dimensional, cross-sectional imaging to plan conformal radiation with custom blocking based on patient and tumor anatomy, maximizing dose to tumor and minimizing exposure to organs at risk.

Intensity-modulated radiation therapy (IMRT) builds upon the personalized treatment principles of 3D-CRT by integrating advanced beam-shaping technology and inverse treatment planning software; it has become the standard of care for specific cancer disease sites, such as head and neck, anal, prostate, and gynecologic cancers. IMRT represents a major advance over 3D-CRT by using inverse planning, an algorithm-driven process in which clinicians design target and organ-at-risk constraints, and then, computer optimization software generates beam arrangements that best meet these goals. Dynamic multileaf collimators allow IMRT techniques to deliver highly conformal dose distributions, shaping the radiation as it is being delivered.[2,3] In anal cancer, reduction in acute GI and genitourinary toxicities, such as rectal bleeding and bowel dysfunction, is among some clearly demonstrated benefits of dose-painted IMRT with chemoradiation.[4] IMRT was among the first oncology technologies to showcase the power of computer-driven

TABLE 1. Overview of Contemporary Radiation Oncology Modalities

Modality	Key Features
IMRT	Inverse planning, dynamic multileaf collimators which allow radiation to be sculpted away from organs at risk, homogenous dose distribution
SBRT/SABR	Hypofractionation, high dose, steep dose falloff
Proton therapy	Bragg peak, greatly reduced exit dose, good for pediatrics/CNS
Carbon ion therapy	Sharper falloff than protons, radioresistant tumors, CNS
3D image-guided brachytherapy	CT-/MRI-guided adaptive treatment delivery, replaces X-ray anatomy-based planning
MR-linac	Superior soft tissue contrast, can be paired with adaptive planning
ETHOS adaptive planning	AI-driven, adaptive planning based on high-quality on-treatment imaging
FLASH radiotherapy	Ultrahigh-dose rate, reduced toxicity
Radiopharmaceuticals	Targeted radiotherapy with radionuclides, able to go to multiple lesions, minimal dose risk to nontarget tissue

NOTE. A comprehensive summary of advanced radiation therapy techniques highlighting their key technical features and therapeutic advantages. Modalities include conformal therapies (IMRT, SBRT), particle therapy (proton and carbon ion), brachytherapy, adaptive radiation platforms (MR-Linac, ETHOS), FLASH radiotherapy, and radiopharmaceuticals.
Abbreviations: AI, artificial intelligence; CT, computed tomography; IMRT, intensity modulated radiation therapy; MR, magnetic resonance ; MRI, magnetic resonance imaging; SABR, stereotactic ablative radiotherapy ; SBRT, stereotactic body radiation therapy.

planning, a concept widely appreciated both within and outside of medicine. Volumetric-modulated arc therapy is an extension of IMRT that delivers radiation continuously as the gantry rotates around the patient, allowing for anatomically conformal dynamic adjustments of the radiation beam.

Historically, external beam radiation therapy was delivered using a uniform dose of 180-200 cGy per treatment over a course of 6-8 weeks. Increasing understanding of radiobiology has led to the adoption of site- and stage-specific regimens. For example, hypofractionation (fewer treatments with higher daily doses) is now a standard option in prostate, breast, and lung cancers. Stereotactic body radiation therapy (SBRT, also known as stereotactic ablative radiotherapy) administers precise, high-dose radiation in typically five treatments or fewer.[5] Advanced treatment planning concentrates high radiation doses with a steep dose falloff around the target, minimizing exposure to normal tissue; daily target localization also allows margins to be reduced, and thus, treatment volumes have shrunk.[6]

Among the notable advances in radiation oncology is respiratory gating using a 4-D framework which allows cancers in the thorax and abdomen to be treated during specific respiratory phases, tailored to the patient's anatomic changes over time. Respiratory motion management is particularly important for SBRT, where breath-hold and gating strategies can reduce dose to the heart and lungs. Translational and rotation variation correction in the treatment setup also improves radiation treatment precision. For example, the six-degree-of-freedom robotic couch accounts for corrections in rotation for patients receiving treatment for intracranial metastases.[7] Minute shifts can substantially improve tumor target coverage in radiosurgery.

Stereotactic Radiosurgery

Stereotactic radiation refers to the delivery of highly focused, ablative doses of radiation that encompasses both stereotactic radiosurgery (SRS) for intracranial targets and SBRT for extracranial sites, including lungs, spine, liver, and pancreas.

Historically, whole-brain radiation therapy has been the standard approach for managing intracranial metastasis. Recently, SRS has become a preferred treatment option because of its ability to minimize radiation to normal brain parenchyma and preserve quality of life.[8] SRS can be further categorized into two primary approaches: frame-based systems such as Gamma Knife and frameless techniques on a linear accelerator (linac; Table 2).

Gamma Knife typically uses a rigid metal halo frame that requires invasive fixation to the skull with pins. The simulation, planning, and delivery are usually conducted on the same day, which can impose significant time constraints and psychological stress on the patient because of lengthy immobilization.[8] To combat this concern, some centers will do planning using magnetic resonance imaging (MRI) from the previous day. SRS is delivered based on the geometry of gamma radiation from an array of cobalt sources. Frameless SRS options have proliferated as linac technology, and precision has increased; this treatment typically involves a rigid plastic face mask (which can itself be anxiety-inducing) and requires separate simulation. Stress can depend on the type of immobilization used, but ability to conduct treatment in 1 day can reduce financial and logistical burden associated with multiple visits.

Particle Radiotherapy

Linear accelerator–based external beam radiation therapy is conducted with photons. Photons are generated by the linac, which produces high-energy X-rays by directing accelerated electrons onto a tungsten target. Both proton and carbon ion therapies represent continuous advancements in particle therapy.

Proton therapy uses positively charged particles which exhibit a higher depth-dose distribution, also known as Bragg peak, delivering the majority of doses at depth and essentially eliminating the exit dose. This improves sparing of normal tissue in the area behind the treated tumor compared

TABLE 2. Comparison of Gamma Knife and Linac-Based Frameless SRS Techniques

Feature	Gamma Knife	Linac-Based Frameless SRS
Immobilization	Invasive head frame (less commonly used mask)	Noninvasive thermoplastic mask
Treatment time	Single, full-day session (less commonly given over multiple fractions)	Reduced session time, 1-5 treatments
Applications	Complex targets near critical structures with sharp dose falloff, heterogenous dose	Larger treatment volumes, homogenous dose

NOTE. This table highlights key differences in immobilization, treatment delivery, clinical applications, and considerations.
Abbreviation: SRS, stereotactic radiosurgery.

with photons which pass through a patient.[9] Proton therapy is most commonly recommended for the treatment of pediatric cancers because of the importance of reducing long-term toxicities. For example, proton craniospinal irradiation has been shown to reduce cognitive decline (intelligence quotient preservation), endocrine dysfunction, and hematologic toxicities for pediatric patients.[10-12] In adults, protons have been shown to reduce toxicity in esophageal cancer[13] and extend survival in patients with leptomeningeal metastasis.[14] Despite increasing availability, the evidence supporting proton therapy, particularly for breast and prostate cancers, remains limited. The RADCOMP pragmatic randomized trial[15] found no differences in overall acute toxicity between protons and photons with primary end points (major cardiovascular events and local recurrence) still be reported in long-term follow-up.[16]

Carbon ions offer unique advantages specifically in the treatment of radioresistant and rare tumors. They produce an even sharper dose falloff at depth when compared with protons.[17] Carbon ions are also more effective at transferring radiation dose because of higher linear energy transfer, meaning that they deposit more energy per unit track length within tissue, conferring a higher relative biological effectiveness. This is thought to be more effective in treating hypoxic tumors. Preliminary studies suggest that carbon ion therapy offers benefits over proton therapy in the treatment of chondrosarcomas and chordomas.[18] The first clinical carbon ion center in the Unites States is under construction in Florida with estimated treatment start in 2028.

Advancements in Brachytherapy

Brachytherapy is a radiation treatment defined by inserting radioactive sources directly in or near tumors; this can be done permanently (via seed brachytherapy for prostate cancer) or by dwelling sources temporarily within or immediately adjacent to the tumor (as with interoperative radiation or in the treatment of gynecologic cancers). Two main approaches are used: high dose rate (HDR) which delivers dose at a rate higher than 12 Gy/h and low dose rate (LDR) which delivers dose at a rate between 0.4 Gy/h and 2 Gy/h. The transition from LDR to HDR has improved both convenience and outcomes for patients. In prostate cancer, randomized data have shown HDR brachytherapy to be associated with lower toxicity compared with seed-based LDR.[19]

The largest brachytherapy gains have been achieved in the modern era in the treatment of cervical cancer. Historically, radiation doses were based on fixed anatomic landmarks on X-ray, rather than the actual size, shape, and location of a tumor.[20] This often fails to align with the variations in pelvic structures, leading to dose discrepancies (underdosing tumor or overdosing bladder and/or rectum). Image-guided adaptive brachytherapy with computed tomography (CT) and MRI (supported by the landmark EMBRACE-I registry) is the new standard of care.[21] The EMBRACE-I set modern dose benchmarks for cervical cancer using HDR or pulsed rate brachytherapy, showing that a cumulative dose of 85 Gy (in 2Gy equivalents) had better local control and lower toxicity than historical priors. This informed current GEC-ESTRO guidelines and spurred EMBRACE II to further refine dosing.[21]

MR-Linac

MRI-based localization in radiation is valuable because of high soft tissue contrast and lack of ionizing radiation.[22,23] The MR-Linac integrates MRI with a linear accelerator to enable precise delivery while tracking motion (either tumor or nearby tissues) during treatment.[22] An advantage is the facilitation of adaptive treatment accounting for anatomic changes between (interfractional) or during treatment sessions (intrafractional).[24] Adaptive planning allows real-time optimization to reflect anatomic changes, such as shifts in tumor size or position, organ motion, and tissue variations. This is especially important in the treatment of GI or genitourinary cancers, where daily changes in bowel or bladder filling can alter the tumor position and, in turn, affect the dose delivered to both the tumor and the surrounding healthy tissue. Previous advances do not fully address the challenge of motion given that they rely on a radiation plan based on imaging from 1 to 2 weeks before treatment delivery. Adaptive planning, whether MRI- or CT-based, holds great promise in addressing this challenge and improving the therapeutic ratio.

In anatomically complex areas, such as the pelvis and abdomen, the use of MR-Linac may be advantageous.[25] When treating prostate cancer, the MR-Linac can adapt to the structural changes over the course of treatment to minimize motion-related variations based on bowel and bladder filling.[26] MOMENTUM is a 2019 international registry to examine

the utility of MRI-guided radiation therapy to evaluate feasibility and long-term outcomes; data published for 425 patients with prostate cancer are promising with only a single Grade 3 toxicity and no Grade 4/5 toxicity.[27]

Adaptive Planning

ETHOS is a branded advanced planning system that leverages artificial intelligence (AI) and high-quality on-treatment imaging to modify treatment plans in real time. The clinical impact of adaptive planning is practical in cancers where organ movement significantly influences treatment precision or when a tumor volume is expected to change during a course radiotherapy. The use of ETHOS in prostate cancer has shown to consistently meet safe and effective radiation doses, with the adaptive plan being preferable in 95% of fractions.[28] Offline adaptive radiotherapy involves replanning between fractions, whereas online adaptive radiotherapy reoptimizes the plan in real time using on-table MRI or CT imaging.[29] The addition of AI into treatment planning holds much promise at improving efficiency in the creation of complex plans.[30]

FLASH Radiotherapy

FLASH is an emerging approach that delivers radiation at an ultrahigh dose rate of >40 Gy per second, a cumulative dose that would typically be delivered over 4 weeks. Preclinical studies suggest reduced normal tissue toxicity compared with conventional radiotherapy, while maintaining efficacy even in hypoxic environments which is particularly advantageous for radioresistant tumors.[31] FLASH reduces treatment duration by delivering a single high dose in milliseconds, a phenomenon coined as the FLASH effect.[32]

The first use of FLASH in a human was documented in a 75-year-old patient with multiresistant $CD30^+$ T-cell cutaneous lymphoma who received 15 Gy delivered in 90 ms.[33] The patient experienced complete tumor regression at 5 months post-treatment with toxicity limited to grade 1 effects.[33] FLASH-01 is the first in-human trial investigating the feasibility and efficacy of FLASH proton radiotherapy in treating bone metastasis.[34] The LANCE phase II trial documented reduced toxicity relative to conventional radiation and enhanced recovery for localized nonmelanomatous skin cancer.[35]

In addition to the limited clinical data, a barrier to the widespread practicality of FLASH is limited dosimetry tools available to effectively measure dose delivery, urging the need to establish standardized quality assurance protocols tailored to this modality.[36,37]

Radiopharmaceuticals

Radioactive pharmaceuticals (radiobiological therapy) are agents composed of a radionuclide that delivers ionizing radiation and selectively directs the isotope to a specific site in the body.[38] Radium-223 is an alpha-emitter; it serves as a calcium mimetic and is preferentially taken up in areas of osteoblastic activity. Radium is effective in the treatment of bone metastasis because of the high energy transfer and short tissue penetration of alpha particles.[39] Lutetium-177-prostate-specific membrane antigen (PSMA)-617 is a beta-emitter with short tissue penetration range allowing for precise radiation targeting cells expressing PSMA while sparing normal tissue.[40]

Improving the optimal radiopharmaceutical dose will likely depend on moving beyond a one-size-fits-all approach. Currently, most agents are prescribed on a fixed dose or are weight-based. Many emerging agents require companion imaging diagnostics, for example, Lutetium-177-PSMA-617 must be matched with a PSMA positron emission tomography scan to guide treatment.[41] Movement into dosimetry-based radiopharmaceutical therapy would tailor dose delivery to a patient's unique biodistribution using advanced imaging to improve how dose is quantified. Next steps include developing predictive markers including radiomics to define optimal treatment delivery and to identify which patients benefit the most.[42]

PARADIGM SHIFTS IN THE USE OF RADIOTHERAPY FOR METASTATIC DISEASE

As systemic treatment improves, there is a growing role for local therapy in patients with limited metastatic disease. This reflects a broader paradigm shift across oncology. While metastatic disease was once viewed as uniformly requiring lifelong systemic therapy alone, it is now recognized that patients with metastatic disease exist on a spectrum. Metastasis-directed therapy is an approach to treating oligometastatic (typically defined as ≤5 disease sites) or oligoprogressive (limited progression) disease. It often involves the utilization of ablative techniques like SBRT, intended to eradicate disease in a limited area.[43]

Several trials show the benefit of metastasis-directed therapy in relation to systemic and hormone therapy. The SABR-COMET (a randomized phase II trial) demonstrated a durable overall survival benefit for SBRT in oligometastatic disease.[44] The EXTEND trial (a randomized phase II trial) combined ablative radiation with chemotherapy for multiple tumor types; results in pancreatic cancer showed that metastasis-directed treatment improved progression-free survival (PFS) over systemic treatment alone.[45] The STOMP trial found that metastasis-directed therapy in prostate cancer delayed the start of androgen-deprivation therapy and improved PFS.[46] Similarly, the EXTEND prostate cancer cohort showed PFS benefit for radiation with intermittent hormone therapy.[45] The SABR-5 trial found that SBRT was well-tolerated with Grade 3 toxicities <5%.[47] The NRG-B002 trial in oligometastatic breast cancer found no benefit in survival and higher toxicity for metastasis-directed therapy.[48]

While consolidation and metastasis-directed therapy are conceptually related for those patients with limited metastatic

disease, they differ slightly in terms of the target and intent. Consolidation involves the treatment of all detectable diseases, including both the primary tumor and metastatic lesions.[49] Metastasis-directed therapy targets only metastatic sites (or at times, only progressive metastatic sites). Trial data for patients with oligometastatic non–small cell lung cancer have shown that adding consolidation to maintenance systemic therapy has potentially mixed success at improving PFS.[43,50] While results for oligometastatic disease have been positive across multiple tumor types, breast cancer remains an exception. The randomized NRG-BR002 trial showed no improvement in progression-free or overall survival with metastasis-directed therapy.[48]

INTEGRATING RADIATION AND IMMUNOTHERAPY

Immune checkpoint inhibitors (ICIs) have markedly advanced the treatment of metastatic cancers and complement radiation therapy by inducing cell death which further triggers T-cell priming, providing a synergistic benefit.[51] Combining radiation therapy with ICIs has been hypothesized to drive an abscopal effect, the reduction of tumor at sites distant from the initial treatment field mediated by immune activation.[51] Radiation also induces the upregulation of PD-L1 on tumor cells, a main target for ICIs, thereby preventing T-cell exhaustion.[51]

Combining radiation and immunotherapy is heavily influenced by the timing and sequencing of treatment.[52,53] For example, preclinical data suggest that CTLA-4 inhibitors were more effective when given before radiation, suggesting an immunomodulatory priming effect.[54] Radiation has immunomodulatory effects, enhancing local tumor death and antigen release,[55] and has the potential to convert immune-excluded or cold tumors to immune-rich hot tumors by enhancing antigen presentation.[56] A randomized trial adding neoadjuvant pembrolizumab to radiation before surgery in high-risk soft tissue sarcoma reduced relapse risk, suggesting a paradigm shift in managing aggressive sarcomas.[57]

Concurrent administration of immunotherapy with radiation has garnered interest; however, results have been lackluster. The randomized CALLA trial for locally advanced cervical cancer found that durvalumab in addition to standard-of-care chemoradiation did not improve progression-free-survival.[58]

There is a parallel need beyond immunotherapy to define how radiation can be optimally integrated with targeted agents and cellular therapies, including as a bridge to chimeric antigen receptor-T-cell therapy. Sequencing radiation with targeted therapies that have CNS penetration in brain metastases is under investigation[46] as timing of radiotherapy and immunotherapy can affect both safety and efficacy.[59]

PERSONALIZED MEDICINE

Personalized medicine in the context of radiation therapy refers to radiation customization in dose or delivery based on patient clinical, genetic, or phenotypic information. Genomic data may predict tumor sensitivity to radiation, and models including tissue of origin, ras status, and/or p53 status might have future use to escalate or deescalate treatment.[31,60,61] Genomic-adjusted radiation[62] was explored retrospectively in the PORTEC-1 and PORTEC-2 trials for early-stage endometrioid endometrial cancer. Patients with *POLE*-mutated and mismatch repair-deficient cancers had improved regional control, suggesting benefit from reduced radiotherapy; those with abnormal p53 benefited from traditional external radiation over vaginal brachytherapy.[63] The ongoing randomized PORTEC-4a explores optimized radiation including the potential of omission based on molecular profiling.[64] Decipher is an example of a validated genomic assay that might play a role in improving patient selection for treatment; it may be helpful to determine optimal prostate cancer treatment from active surveillance to treatment escalation.[65]

Tumor hypoxia contributes to radiation resistance; hypoxic tumor cells require higher radiation doses to induce the same level of damage as normoxic cells.[66] Response-directed treatment (using imaging to detect and quantify hypoxia) may allow for tailored radiation strategies. Hypoxia-directed chemoradiation for human papillomavirus (HPV)+ oropharyngeal carcinoma was explored recently. Nonhypoxic tumors received de-escalated chemoradiation (30 Gy over 3 weeks with two chemotherapy cycles), and hypoxic tumors received standard chemoradiation (70 Gy over 7 weeks with three chemotherapy cycles).[67] Acute side effects were lower in the de-escalated group, and progression-free and overall survival was excellent, demonstrating that hypoxia-directed de-escalation may preserve quality of life and right size radiation treatment.[67]

DE-ESCALATION

De-escalation refers to the intentional reduction in treatment intensity including lowering radiation dose, minimizing field size, using more conformal techniques, or limiting elective volumes while maintaining disease control.

Breast cancer is an example of an organ site which lends itself to de-escalation. The phase III IMPORT LOW trial compared partial breast irradiation and reduced dose radiation with standard whole breast radiation in early-stage breast cancer. It showed comparable 10-year control with equivalent or reduced toxicity for both de-escalation options.[68] PRIME-II and CALGB 9343 also explored de-escalation in older women (older than 65 or 70 years, respectively) with early-stage, hormone receptor+, HER2-negative breast cancer planned for antiestrogen treatment,[69,70] finding that radiation can be safely omitted without decreasing survival (albeit with higher local recurrence rates) for this well-selected population. By contrast, radiation monotherapy and omission of antiestrogen treatment was found to have improved quality of life in a similarly selected population.[71]

De-escalation is also used in HPV-related head and neck cancer given radiosensitivity of p16+ cancers[72]; this can be done by hypoxia-directed de-escalation as already discussed or other dose reductions for favorable-risk disease.[73]

SHARED DECISION MAKING

The concept of de-escalation in radiation oncology reflects a broader shift toward a balance between disease control and lowering toxicities and treatment burden. SDM is a process that encourages the collaboration of both patients and providers when developing a treatment plan.[74] SDM can play a pivotal role in patient-centered care, ensuring that selected treatments are aligned with a patient's goals and preferences.

Prostate cancer is an excellent model to evaluate SDM given multiple primary treatment modalities leading to high rates of cure including radical proctectomy, external radiation, and brachytherapy. Active surveillance is also an option for patients with low-risk disease and/or limited life expectancy.[75] The ProtecT trial found that prostate cancer–specific mortality was low regardless of randomized treatment assignment (surgery, radiation, or active surveillance) although patient-reported outcomes (urinary, bowel, and sexual function) differed substantially.[76] This is important as nearly one in five men treated for early-staged prostate cancer may regret their treatment choice.[77]

SDM is also important in breast cancer as multiple prospective randomized trials and meta-analysis find that mastectomy is comparable with breast-conserving therapy (lumpectomy with radiation) for early-stage breast cancer.[71,78] As previously mentioned, radiation omission is possible for favorable-risk older patients planned for antiestrogen treatments. The randomized B-21 trial showed that radiation monotherapy reduced recurrence risk more than tamoxifen monotherapy.[79] EUROPA builds on this by comparing monotherapy (antiestrogen vs radiation) in a modern cohort of older women (70 years and older) with early-stage breast cancer after lumpectomy, with early results showing superior health-related quality of life with radiation.[71]

Early-stage lung cancer presents with unique considerations toward adopting SDM, where discussions surrounding radiation, surgery, and patient comorbidities are critical. Retrospective review has found better survival in patients receiving surgery over SBRT but similar local control; confounders remain given disparate patient populations.[80] The phase III VALOR trial aims to compare SBRT and surgery while incorporating SDM and other multidisciplinary considerations (ClinicalTrials.gov identifier: NCT02984761).[81,82]

ROLE OF RADIATION ONCOLOGY WITHIN MULTIDISCIPLINARY TEAMS

Robust discussion within collaborative teams is critical for oncologists to review all reasonable treatment options and have evidence-based discussion. Multidisciplinary tumor boards are a cornerstone of interdisciplinary care, bringing together various specialties to guide treatment recommendations. An international survey demonstrated that almost all respondents (96%) believed that tumor boards provided benefit to patients with cancer.[83]

As systemic therapies improve and decrease the risk of widespread metastatic progression, local therapies like radiation have taken on a new role. Management within a multidisciplinary team is strongly linked to increased use of local therapies like radiation for recurrent, metastatic rectal cancer[84] and may improve survival for those with esophageal cancer, particularly for those who receive radiation.[85] A pre- versus post–head and neck cancer tumor board review found improvements in both overall and disease-specific survival for patients discussed.[86]

While medical and surgical oncologists may traditionally take the lead in early patient management and survivorship care, the primary provider role is highly disease-specific. For example, in prostate cancer treated definitively with radiation, radiation oncologists deliver the radiation but may also prescribe androgen deprivation therapy and coordinate long-term survivorship care. In addition, growing evidence highlights the importance of radiation oncology involvement to support patient-centered care, including in end-of-life care. Radiation has known benefits to reduce pain and bleeding from metastatic disease.[87] The role of the radiation oncologist in discussing complex care decisions including end-of-life discussions remains limited however.[88] Even for diseases managed collaboratively, shared models of post-treatment follow-up are often variable based on the treatment center.

PAYMENT REFORM AND PREVIOUS AUTHORIZATION

Over the past two decades, radiation oncology has seen substantial cuts in reimbursement despite rapid technological advancements allowing for more precise treatment.[89] Proposed bundled episode-based payment systems[90] shift away from fee-for-service in hopes of reducing costs and maintaining quality. This has raised concerns that payments for innovative treatments, including protons and SBRT, could drop substantially (as much as 71%-31%, respectively).[91] Additional concerns include added financial strain for centers treating vulnerable populations that may be more medically complex.[90] The current proposed episode-based payment system, Radiation Oncology Case Rate (ROCR), attempts to address this specifically with provisions for wraparound services, such as transportation, for those from underserved communities. ROCR could achieve Medicare savings[92]; however, concerns regarding the disproportionately negative impact on freestanding centers in rural areas remain. Notably, proton therapy is currently excluded ROCR; in addition, Prospective Payment System–exempt cancer centers remain shielded from reimbursement reforms, perpetuating payment disparities for these select centers.[93]

More than any other specialty, radiation oncology faces the greatest previous authorization burden.[94] This may stem from treatment technical complexity driving higher costs for delayed benefits; the reduced long-term toxicities or improved survival gains from advanced technologies may take years to decades to be realized. Over 90% of radiation oncologists in the United States report delays in treatment start because of previous authorization.[95] An analysis of initially denied cases found that almost all (98%) received authorization eventually, but some were only approved after plan modification to less targeted treatment or lower dose.[96] Previous authorization is estimated to cost approximately $40 million in US dollars in extra labor for academic radiation oncology practices in the United States[97] with patient-facing burdens (in time or anxiety) also high.[98]

Policy initiatives have been proposed to streamline previous authorization procedures. The Centers for Medicare & Medicaid Services Interoperability and Prior Authorization Final Rule mandates that insurance plans must respond to urgent requests within 72 hours and to nonurgent plans within 7 days, effective 2026.[99] Gold card programs are state-led initiatives that are designed to exempt health care providers from previous authorization for commonly approved services; sadly, to date, cancer-related services have not been included.

ACCESS TO RADIATION

Consolidation of health systems in radiation oncology has affected the structure and delivery of care. The number of large radiation practices has increased by 50%, whereas the number of solo practices decreased by 11%.[100] Areas previously served by small practices providing service to vulnerable populations may now be faced with reduced access as they are absorbed into larger conglomerates. While the majority of the US population (78%) resides within 12.5 miles of a radiation facility, a small portion (1%) lives over 50 miles away, emphasizing geographic disparities in access to care.[101]

One significant challenge faced by patients with cancer is treatment-related financial burden. One study of >38K patients found that 15% reported transportation insecurity and 17% reported that they borrowed money to pay for cancer treatment; patients receiving radiation reported higher transportation insecurity and financial toxicity.[102]

Maintaining high-quality radiation therapy in medically underserved areas remains an ongoing challenge. Key strategies include securing financial support through state sponsored grants, community engagement, transportation solutions via free parking initiatives and ride-share programs, and reducing financial toxicity by using hypofractionated radiotherapy, and telemedicine.[103] Continuous efforts to bridge access to care are underway, but greater systemic support is needed.

In conclusion, modern innovations have changed the landscape of radiation oncology. While the field continues on a transformative trajectory with care innovation and delivery, patients—especially those of underserved areas—are still not receiving high-quality multidisciplinary cancer care. As radiation oncology enters a new era, oncologists across specialties should strive to remain informed about the evolving factors that affect timely radiation delivery.

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AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

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AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

Modern Advancements in Radiation Oncology: What Every Oncologist Should Know

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