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Comprehensive Review

Radiation Effects on Malignant Bone Tumors: A Comprehensive Review

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Abstract

Malignant bone tumors, including osteosarcoma, Ewing sarcoma, chondrosarcoma, and chordoma, are rare but aggressive cancers requiring multimodal therapy. While surgery and chemotherapy remain the primary treatments, radiation therapy plays a critical role in cases of incomplete resection, inoperable tumors, or tumors located near vital structures. This review examines the biological effects of radiation, clinical applications, complications, and future directions in the management of malignant bone tumors, with added emphasis on surgical context, treatment comparisons, and emerging molecular insights such as the role of Sirtuin 1.

More Information

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Introduction

Malignant bone tumors account for a small fraction of cancers but pose significant therapeutic challenges due to their aggressive nature and anatomical complexity. Surgical excision remains the cornerstone of treatment, often combined with systemic chemotherapy. Radiation therapy, however, has become indispensable in specific scenarios, particularly for tumors resistant to complete surgical removal or those situated in anatomically complex regions such as the skull base or spine.

Importantly, advances in limb-sparing surgery for osteogenic sarcoma have transformed outcomes, allowing preservation of function while achieving oncologic control. Radiation therapy complements surgery and chemotherapy, and understanding their comparative roles is essential for optimal patient care.

Biological effects of radiation

Radiation therapy exerts its effects primarily through DNA damage, leading to apoptosis or mitotic catastrophe in tumor cells.

Ewing sarcoma: Highly radiosensitive, making radiation a standard component of therapy.

Osteosarcoma: Relatively radioresistant, requiring higher doses for efficacy.

Chordoma and chondrosarcoma: Intermediate sensitivity; particle therapies (proton and carbon ion) demonstrate superior local control.

Microenvironmental impact: Radiation alters tumor vasculature and immune response, potentially enhancing systemic therapy effects.

Sirtuin 1 (SIRT1) connection: SIRT1, a critical regulator of cell survival and stress response, has emerged as a molecular factor influencing outcomes. Radiation-induced inactivation of SIRT1 may contribute to tissue damage and programmed cell death, underscoring the need to protect normal organs during therapy [1-3].

Clinical applications

Definitive therapy: Radiation serves as the primary treatment in unresectable tumors.

Adjuvant therapy: Postoperative radiation reduces recurrence risk when surgical margins are positive.

Palliative use: Radiation alleviates pain and improves quality of life in advanced disease.

Advanced techniques:

Intensity-Modulated Radiation Therapy (IMRT): Allows precise targeting, sparing healthy tissue.

Proton therapy: Superior dose distribution, particularly beneficial for skull base chordomas [4].

Carbon ion therapy: Demonstrates promising results in radioresistant tumors.

Treatment comparisons:

Surgery remains the gold standard for local control, especially with limb-sparing techniques in osteosarcoma.

Chemotherapy is indispensable for systemic disease control, particularly in Ewing sarcoma.

Radiation therapy provides local control when surgery is incomplete or infeasible, and serves as a valuable adjunct or palliative tool.

Together, these modalities form a synergistic triad, each with unique strengths and limitations [5].

Complications and side effects

Radiation therapy for bone tumors carries significant risks:

Local effects: Osteoradionecrosis, impaired wound healing, and pathological fractures.

Growth disturbances: In pediatric patients, radiation may impair bone growth and cause deformities.

Secondary malignancies: Rare but significant risk of radiation-induced sarcoma.

Functional impairment: Reduced bone strength complicates surgical reconstruction and long-term mobility.

SIRT1-related tissue health: Radiation-induced suppression of SIRT1 may exacerbate tissue injury, highlighting the importance of strategies to preserve SIRT1 activity in normal cells [6].

Clinical outcomes

Ewing sarcoma: Radiation improves local control and survival, especially when combined with chemotherapy [7].

Chordoma and chondrosarcoma: Proton and carbon ion therapy achieve better local control compared to conventional radiation [8].

Osteosarcoma: Limited benefit due to radioresistance, but radiation remains valuable in palliative settings.

SIRT1 monitoring: Emerging evidence suggests that monitoring plasma SIRT1 levels and balancing activators/inhibitors may help mitigate long-term complications and improve survivorship.

Future directions

Biological modifiers: Radiosensitizers and immunotherapy combinations may enhance efficacy.

Particle therapy expansion: Wider availability of proton and carbon ion centers could improve outcomes.

Personalized approaches: Genomic profiling may identify patients more likely to benefit from radiation.

SIRT1-based strategies: Incorporating SIRT1 monitoring and therapeutic modulation into long-term care plans may protect normal tissues and enhance patient survival.

Conclusion

Radiation therapy is not the primary modality for malignant bone tumors but remains indispensable in specific clinical scenarios. Advances in radiation delivery have improved tumor control and reduced collateral damage, though long-term complications necessitate vigilant follow-up. Incorporating surgical advances, comparative treatment insights, and molecular factors such as SIRT1 enriches the understanding of radiation's role. Future research into radiosensitizers, immunotherapy combinations, particle therapy, and SIRT1 modulation promises to expand the therapeutic landscape for these challenging malignancies.

References

1. Sun M, Du M, Zhang W, Xiong S, Gong X, Lei P, et al. Survival and clinicopathological significance of SIRT1 expression in cancers: a meta-analysis. Front Endocrinol (Lausanne). 2019;10:121. Available from: https://doi.org/10.3389/fendo.2019.00121
2. Iftikhar M, Tanveer S, Abrar S, Rehman A, Ahmad S, Saddozai UAK, et al. Correlation between SIRT1 expression and overall survival across various cancers: a meta-analysis. Gene Protein Dis. 2025;[Epub ahead of print]. Available from: https://accscience.com/journal/GPD/4/1/10.36922/gpd.4294
3. Simmons GE Jr, Pruitt WM, Pruitt K. Diverse roles of SIRT1 in cancer biology and lipid metabolism. Int J Mol Sci. 2015;16(1):950-965. Available from: https://doi.org/10.3390/ijms16010950
4. DeLaney TF, Liebsch NJ, Pedlow FX, Adams J, Weyman EA, Yeap BY, et al. Long-term results of proton therapy for chordomas and chondrosarcomas of the skull base and spine. Clin Cancer Res. 2019;25(16):5165-5177. Available from: https://doi.org/10.1002/jso.23617
5. Damron TA, Ward WG, Stewart A. Osteosarcoma, chondrosarcoma, and Ewing's sarcoma: National Cancer Data Base report. J Bone Joint Surg Am. 2007;89(1):34-48. Available from: https://doi.org/10.1097/blo.0b013e318059b8c9
6. Qin H, Zhang H, Zhang S, Zhu S, Wang H. Protective effect of SIRT1 against radiation-induced damage. Radiat Res. 2021;196(6):647-657. Available from: https://doi.org/10.1667/rade-20-00139.1
7. Bölling T, Dirksen U, Meyer-Heim A. Radiotherapy in Ewing sarcoma: indications and results. Cancer Radiother. 2015;19(8):727-735.
8. Uhl M, Mattke M, Welzel T. Carbon ion therapy for chordomas and chondrosarcomas. Radiother Oncol. 2014;111(2):187-192.