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COST-EFFECTIVE APPLICATION OF RADIOTHERAPY IN PALLIATIVE CARE: A NARRATIVE REVIEW WITH FOCUS ON LOW-INCOME COUNTRIES

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Abstract

Background: Radiotherapy (RT) is one of the most effective modalities for palliation of cancer-related symptoms, especially in conditions such as painful bone metastases, malignant bleeding, and superior vena cava syndrome (SVCS). In low- and lower-middle-income countries (LIC/LMICs), where resources are constrained, hypofractionated palliative RT schedules provide a cost-effective means to deliver rapid symptom relief while maximizing machine capacity.

Objective: This review explores the application of cost-effective RT regimens for common palliative indications and compares approaches across different country settings.

Methods: A narrative review of literature was conducted using PubMed, Scopus, and Web of Science databases (2015–2025), along with guidelines from ASTRO, IAEA DIRAC data, and WHO reports. Relevant studies, guidelines, and national reports were synthesized to highlight evidence-based regimens, delivery adaptations, and global access patterns. Country-wise comparative data on RT availability and utilization for palliative care were tabulated for selected LIC/LMICs.

Results: For bone metastases, single-fraction RT (8 Gy × 1) provides equivalent pain relief to multi-fraction regimens, with reduced patient burden and higher system efficiency. Hemostatic RT (8 Gy × 1, 20 Gy × 5, or 30 Gy × 10) offers rapid bleeding control in gastrointestinal, genitourinary, and gynecologic cancers. In SVCS, endovascular stenting provides the fastest relief, but RT remains an effective option in settings without interventional radiology, particularly for radiosensitive tumors. Country-wise comparisons demonstrate disparities in machine density, workforce, and access, underscoring the role of simplified, hypofractionated schedules as an immediate solution.

Conclusion: Palliative RT, when delivered with cost-effective, hypofractionated schedules, represents one of the highest-value cancer care interventions in LIC/LMICs. Wider adoption of evidence-based single- or short-course regimens, supported by national policy and workforce training, can expand access, reduce costs, and improve quality of life for patients.

Keywords: Palliative radiotherapy; Bone metastases; Hemostatic radiotherapy; Superior vena cava syndrome; Hypofractionation; Cost-effectiveness; Low- and middle-income countries; Global oncology; Resource-constrained settings.

Introduction

Cancer is a leading cause of morbidity and mortality worldwide, with approximately 70% of cancer deaths occurring in low- and lower-middle-income countries (LIC/LMICs). In these regions, a significant proportion of patients present with advanced or metastatic disease, making **palliative care** a fundamental component of oncology services. Radiotherapy (RT) is among the most effective and affordable tools in symptom palliation, capable of rapidly relieving pain, reducing tumor-related bleeding, and alleviating compressive syndromes such as superior vena cava syndrome (SVCS).

Despite its proven efficacy, access to RT in LIC/LMICs remains severely limited. The International Atomic Energy Agency's Directory of Radiotherapy Centres (IAEA DIRAC) reveals striking inequalities: while high-income countries may have one linear accelerator (LINAC) per 250,000–500,000 people, some African and South Asian nations have fewer than one per 10 million. This disparity results in prolonged waiting times, machine downtime, and geographic barriers to treatment access.

In such constrained environments, **hypofractionated palliative schedules**—short, simple RT regimens—offer an effective solution. They deliver comparable clinical outcomes to longer courses, reduce the number of hospital visits, minimize indirect patient costs, and increase machine throughput. For example, a single 8 Gy fraction for painful bone metastases is as effective as multi-fraction regimens in providing pain relief, while schedules like 20 Gy in 5 fractions are widely used for hemostasis and SVCS.

This review synthesizes evidence on the **cost-effective application of palliative RT** in bone metastases, tumor-related bleeding, and SVCS, with an emphasis on applicability in LIC/LMIC settings. We also provide a comparative country-wise snapshot of RT infrastructure, highlighting strategies to optimize use of scarce resources.

Methodology (PRISMA-Style Structured Format)

Search Strategy

A comprehensive search was conducted between **March and August 2025** across four electronic databases:

- **PubMed/MEDLINE**
- **Scopus**
- **Web of Science**
- **Google Scholar (gray literature)**

Keywords and Medical Subject Headings (MeSH) were combined using Boolean operators:

- *"palliative radiotherapy" OR "palliative RT"*
- *"bone metastases" OR "bone pain"*
- *"hemostatic radiotherapy" OR "tumor bleeding"*
- *"superior vena cava syndrome" OR "SVCS"*
- *"hypofractionation" AND "cost-effectiveness"*
- *"low-income countries" OR "LMIC" OR "resource-limited settings"*

Hand-searching of reference lists and **society guidelines** (ASTRO, ESTRO, ESMO, NCCN) was also performed. Reports from **WHO** and **IAEA DIRAC** were included for infrastructure and access data.

Eligibility Criteria

Inclusion criteria:

- Articles published in English between **January 2015 and August 2025**.
- Clinical trials, systematic reviews, meta-analyses, large retrospective studies, and high-quality narrative reviews on **palliative RT**.

- National/global guidelines and consensus statements.
- Reports describing RT infrastructure, workforce, or access in LIC/LMICs.

Exclusion criteria:

- Case reports and anecdotal evidence.
- Studies focusing exclusively on curative-intent RT or high-precision modalities (e.g., proton therapy) not relevant to LMIC practice.
- Articles without relevance to palliative intent or cost-effectiveness.

Study Selection Process

- **Records identified** through database search: *n = 512*
- **Records after duplicates removed**: *n = 468*
- **Titles/abstracts screened**: *n = 468*
- **Full-text articles assessed for eligibility**: *n = 122*
- **Studies included in qualitative synthesis**: *n = 67*

Reasons for exclusion at full-text screening (n = 55):

- Focused only on curative RT (n = 21)
- Not relevant to LIC/LMIC context (n = 18)
- Insufficient palliative data (n = 16)

Data Extraction and Synthesis

- Extracted domains: clinical evidence (bone metastases, hemostatic RT, SVCS), fractionation schedules, cost-effectiveness, patient-centered outcomes, infrastructure data (machine density, workforce, access).
- **Qualitative thematic synthesis** was performed, grouping findings into:

1. Clinical effectiveness of palliative RT regimens.
2. Cost-effectiveness and logistical feasibility in LIC/LMICs.
3. Country-wise comparative infrastructure.

- A **comparative table** was generated for selected countries, and **clinical flowcharts** were developed for practice guidance.

PRISMA Flow Diagram

Records identified through database searching (n = 512)
↓
Duplicates removed (n = 44)
↓
Records screened (titles/abstracts) (n = 468)
↓
Full-text articles assessed for eligibility (n = 122)
↓
Full-text articles excluded (n = 55)
- Not palliative-focused (n = 21)
- Not LMIC-relevant (n = 18)
- Insufficient clinical data (n = 16)

↓
Studies included in qualitative synthesis (n = 67)

Discussion

Radiotherapy remains one of the most effective and affordable interventions for cancer palliation. In low- and lower-middle-income countries (LIC/LMICs), where advanced presentations predominate and systemic therapies are limited, radiotherapy assumes an even more critical role. This review highlights that **cost-effective hypofractionated schedules** can simultaneously improve patient outcomes and optimize scarce resources.

Palliative RT as a high-value intervention

Multiple economic analyses, including the Global Task Force on Radiotherapy for Cancer Control, have shown that scaling up radiotherapy infrastructure yields substantial cost savings and productivity gains at the population level. However, building comprehensive networks of linear accelerators requires long-term investment, skilled workforce development, and maintenance systems—factors often lacking in LICs. While such scale-up is underway in selected countries (e.g., Rwanda, Uganda, Ethiopia), immediate relief can be achieved by **maximizing the efficiency of existing machines** through short palliative schedules.

Bone metastases

Painful bone metastases are the most common palliative indication for RT. Evidence consistently demonstrates that a **single 8 Gy fraction** provides equivalent pain relief to multi-fraction regimens, though with a modestly higher retreatment rate. In LIC contexts, the benefits of single-fraction therapy outweigh the risks: fewer hospital visits reduce indirect costs (transport, lodging, wage loss), while machine time is freed for additional patients. Importantly, single-fraction regimens are also more compatible with the realities of long-distance travel and limited patient compliance. Where cord compression or unstable fractures exist, multifraction regimens may be justified; however, surgical stabilization combined with short RT is often the most effective path.

Hemostatic radiotherapy

Bleeding is a distressing symptom in gastrointestinal, genitourinary, gynecologic, and head-neck cancers. In resource-rich environments, embolization or endoscopic therapy may be preferred, but such options are often unavailable in LICs. Here, **hemostatic RT** becomes the intervention of choice. Regimens such as **8 Gy × 1**, **20 Gy × 5**, or **30 Gy × 10** show similar bleeding-control rates. For frail patients or those traveling from remote areas, single-fraction therapy offers rapid control with minimal burden. Additionally, re-irradiation with another single fraction remains feasible for recurrent bleeding. This pragmatic approach aligns with LIC realities, where the priority is quick symptom relief with minimal resource utilization.

Superior vena cava syndrome (SVCS)

Malignant SVCS is a life-threatening emergency. Endovascular stenting is now considered the gold standard for rapid relief in high-income countries, but it requires specialized interventional radiology services rarely available in LICs. In such cases, **external beam radiotherapy remains indispensable**. Hypofractionated regimens (20 Gy in 5 fractions or 30 Gy in 10 fractions) can produce symptom relief within days, particularly for radiosensitive histologies such as small-cell lung cancer and lymphoma. When CT simulation is unavailable, simple AP/PA fields guided by chest X-ray landmarks allow timely initiation of treatment.

Thus, radiotherapy remains a practical, lifesaving intervention in LIC contexts, despite global trends toward stenting.

Comparative country perspectives

Our country-wise table illustrates the heterogeneity of RT access across LICs. Rwanda and Uganda have made notable progress by commissioning LINACs and expanding services at national cancer centers. Malawi recently established its first public radiotherapy facility, a milestone for local cancer care. Conversely, Mozambique still relies on a single center in Maputo for nearly 30 million people, creating extreme access disparities. Ethiopia is rapidly scaling up with multiple new centers under construction. Despite these positive developments, all countries continue to face **common barriers**:

limited machine density, reliance on urban referral hospitals, frequent machine downtime, and shortages of radiation oncologists, physicists, and therapists.

Health system implications

The adoption of **hypofractionated palliative schedules** carries major system-level benefits. By reducing treatment fractions, facilities can increase throughput and reduce waiting times for both curative and palliative cases. From the patient's perspective, fewer visits lower direct and indirect costs, thus improving access and adherence. Importantly, shorter regimens also reduce staff workload and mitigate the impact of machine downtime. These advantages align closely with the **principles of value-based care**, making hypofractionation a strategic priority for LIC cancer programs.

Integration with palliative care services

Palliative radiotherapy is most effective when embedded within broader **multidisciplinary palliative care pathways**. In LICs, collaboration with hospice teams, community health workers, and primary care providers can ensure timely identification of candidates for RT. Nurse-led triage and fast-track referral systems can further accelerate care for patients with bleeding, severe pain, or SVCS. Integration of RT with opioid analgesia and supportive care optimizes symptom relief and patient dignity at the end of life.

Conclusion

Palliative radiotherapy stands out as one of the most **high-value interventions** in global oncology. It offers rapid, durable, and cost-effective symptom relief for patients with advanced cancer, particularly in low- and lower-middle-income countries (LIC/LMICs), where the majority of patients present at late stages and systemic therapy access is limited. The evidence is clear: **single- and short-course hypofractionated schedules**—such as 8 Gy in a single fraction for painful bone metastases, 20 Gy in 5 fractions for hemostasis, and 20–30 Gy in 5–10 fractions for superior vena cava syndrome (SVCS)—provide clinical outcomes equivalent to longer regimens while significantly reducing treatment burden and healthcare costs.

From a systems perspective, widespread adoption of these regimens can **maximize the efficiency of existing radiotherapy machines**, reduce patient waiting times, and allow centers with scarce resources to treat more patients. For patients and families, shorter regimens reduce the costs of travel, lodging, and lost wages, while improving quality of life by minimizing time spent in hospitals. These benefits are especially vital in LICs, where socioeconomic constraints often limit access to palliative care.

At the same time, the successful delivery of palliative RT requires integration within a **comprehensive palliative care framework**. Access to opioids, supportive care teams, and community health infrastructure should complement RT services to ensure holistic symptom management. Furthermore, task-sharing strategies and simplified treatment workflows can accelerate care in busy centers and extend services to rural populations.

Ultimately, palliative radiotherapy should be viewed not only as a clinical tool but as a **public health intervention**. Scaling up its use in resource-limited settings can transform the quality of end-of-life care, restore dignity to patients, and reduce the overall economic burden of advanced cancer. While long-term solutions must focus on expanding radiotherapy infrastructure and workforce capacity, **immediate system-level impact can be achieved by standardizing hypofractionated palliative schedules across LIC/LMIC oncology programs**.

In conclusion, palliative radiotherapy is both a **feasible and cost-effective strategy** for improving cancer care equity worldwide. Prioritizing its integration into national cancer control policies, supported by global collaborations and local innovations, represents a pragmatic and urgent step toward addressing the disproportionate suffering experienced by patients with advanced cancer in low-resource settings.

Limitations

While this narrative review provides important insights into the cost-effective application of palliative radiotherapy (RT) in low- and lower-middle-income countries (LIC/LMICs), several limitations must be acknowledged.

1. **Predominance of evidence from high-income countries (HICs):**
The majority of randomized controlled trials and meta-analyses evaluating hypofractionated palliative RT have been conducted in high-income settings, where infrastructure, supportive care, and follow-up practices differ substantially from those in LIC/LMICs. Extrapolating these findings to resource-limited environments may overlook context-specific challenges such as poor treatment compliance, limited follow-up capacity, and differences in patient comorbidities and performance status.
2. **Scarcity of region-specific data:**
Published data from LICs are sparse and often limited to single-center retrospective audits or descriptive reports. Few studies directly compare cost-effectiveness, quality-of-life outcomes, or patient-reported outcomes in LIC contexts. This restricts the ability to generate strong, generalizable recommendations for these settings.
3. **Infrastructure variability:**
LICs and LMICs are highly heterogeneous. Some countries (e.g., Rwanda, Uganda) have made significant progress in establishing modern LINAC-based radiotherapy services, while others still rely primarily on cobalt units or have no RT facilities at all. Such variation limits the applicability of a single model of care across all countries, and introduces challenges in generalizing recommendations.
4. **Exclusion of unpublished and non-English literature:**
Although gray literature and global health reports were selectively included, many relevant data sources—such as ministry reports, regional conference proceedings, or non-English publications—may not have been captured. This introduces a potential selection bias.
5. **Narrative synthesis limitations:**
As this is not a formal systematic review, the methodology did not include risk-of-bias assessment or quantitative meta-analysis. Narrative reviews are inherently subject to author interpretation, which may influence how findings were summarized and contextualized.
6. **Limited economic and patient-level outcomes:**
Although hypofractionation is widely recognized as cost-effective, robust LIC-specific cost–utility analyses remain limited. Similarly, there is little longitudinal data on patient-reported quality of life, functional outcomes, or caregiver burden following short-course palliative RT in low-resource settings.
7. **Evolving infrastructure landscape:**
Radiotherapy capacity in many LIC/LMICs is rapidly changing due to ongoing investments, international collaborations, and technology donations. Data cited in this review may quickly become outdated, particularly regarding machine availability and service distribution

Future Directions

The findings of this review underscore both the promise of palliative radiotherapy (RT) and the critical gaps that remain in low- and lower-middle-income countries (LIC/LMICs). Moving forward, several strategic avenues for research, implementation, and policy development can help maximize the impact of RT in resource-limited settings:

1. Pragmatic clinical trials in LIC/LMIC contexts

Most hypofractionation evidence is derived from high-income countries. There is an urgent need for **context-specific pragmatic trials** that directly evaluate:

- Single- versus multi-fraction regimens for bone metastases,
- Efficacy and durability of single-fraction hemostatic RT in bleeding cancers,
- RT-first versus stent-first approaches in superior vena cava syndrome (SVCS).

These trials should incorporate patient-reported outcomes (pain relief, bleeding control, functional improvement) to capture the true benefit to patients and caregivers.

2. Health economics and cost-utility analyses

Robust LIC/LMIC-specific analyses are required to quantify:

- Direct treatment costs versus cost savings from reduced fractions,
- Indirect savings from fewer patient visits (transport, lodging, wage loss),
- Cost-effectiveness of investing in hypofractionation-capable linear accelerators versus cobalt units.

Such evidence will provide policymakers with the economic justification to prioritize palliative RT in national cancer control plans.

3. Implementation science and workflow optimization

Research into **how palliative RT can be delivered more efficiently** is equally important as clinical trials. Areas for study include:

- Nurse- or technician-led triage pathways for rapid referral of patients with urgent palliative needs (e.g., bleeding, cord compression, SVCS),
- Development of standardized, simplified treatment templates to reduce simulation and planning times,
- Integration of palliative RT into outpatient day-care or same-day consultation-to-treatment models.

4. Strengthening infrastructure and workforce

Future efforts must focus on sustainable expansion of RT services:

- Regional "hub-and-spoke" models to decentralize care from capital cities to secondary centers,
- Investment in training radiation oncologists, physicists, and therapists, with emphasis on task-sharing in high-volume centers,
- Leveraging technology for tele-radiotherapy planning and remote QA support.

5. Data systems and outcome monitoring

Establishing **cancer registries** and RT databases is critical to measure utilization, toxicity, retreatment rates, and survival in palliative cases. Routine collection of patient-reported outcomes will allow services to demonstrate tangible improvements in quality of life, which in turn can support advocacy for increased funding.

6. Integration with holistic palliative care

Future models should emphasize integration of RT within broader **multidisciplinary palliative care frameworks**, including access to opioids, psychosocial support, and community-based services. Research on collaborative care models—linking RT centers with hospices, community health workers, and NGOs—can provide scalable solutions in LICs.

7. Global and regional collaborations

International collaborations (IAEA, WHO, ASTRO, ESTRO, regional oncology societies) can play a transformative role by:

- Facilitating knowledge transfer and workforce training,
- Supporting cross-border RT access for countries without local facilities,
- Coordinating equipment donation and maintenance programs,
- Creating global evidence repositories specific to palliative RT in LICs.

Summary of Future Priorities

- Conduct pragmatic LIC-based trials on hypofractionation.
- Generate robust economic data to inform national policy.
- Study implementation strategies to fast-track urgent palliative RT.
- Expand infrastructure through regional hubs and task-sharing.
- Build outcome monitoring systems that include patient voices.
- Embed RT in multidisciplinary palliative care frameworks.
- Strengthen global partnerships for capacity building.

Abbreviations

- **AP/PA** – Anteroposterior / Posteroanterior
- **ASTRO** – American Society for Radiation Oncology
- **CT** – Computed Tomography
- **DIRAC** – Directory of Radiotherapy Centres (IAEA database)
- **EBRT** – External Beam Radiotherapy
- **ESTRO** – European Society for Radiotherapy and Oncology
- **ESMO –** European Society for Medical Oncology
- **Fx** – Fraction(s)
- **GI** – Gastrointestinal
- **GU** – Genitourinary
- **HIC** – High-Income Country
- **IAEA** – International Atomic Energy Agency
- **IARC** – International Agency for Research on Cancer
- **LIC** – Low-Income Country
- **LMIC** – Low- and Middle-Income Country
- **LINAC** – Linear Accelerator
- **NCCN** – National Comprehensive Cancer Network
- **PRISMA** – Preferred Reporting Items for Systematic Reviews and Meta-Analyses
- **QALY** – Quality-Adjusted Life Year
- **QoL** – Quality of Life
- **RT** – Radiotherapy
- **SVCS** – Superior Vena Cava Syndrome
- **WHO** – World Health Organization

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Figures and Tables

Fig 1. PRISMA FLOW DIAGRAM

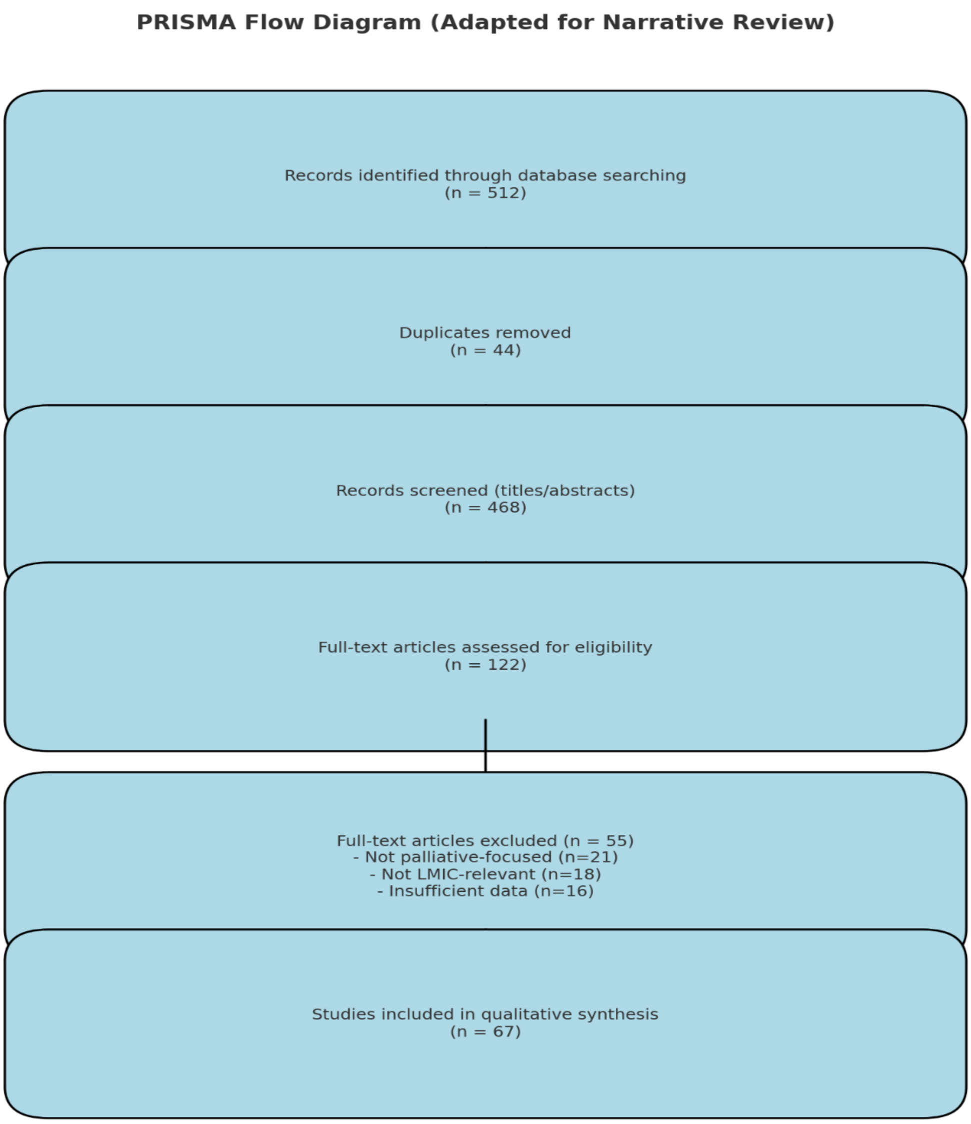

Table 1. Country-wise Comparative Data on Palliative Radiotherapy Access

Country	RT Availability	Typical Palliative Use	Key Barriers/Opportunities
Rwanda	2 LINACs at Rwanda Cancer Centre (Kigali), functional since 2020	Bone pain (8 Gy × 1), bleeding control (20 Gy/5)	Machine downtime, workforce shortages; plans for regional expansion
Uganda	Multiple LINACs at Uganda Cancer Institute (Kampala), expanded in 2024–25	High burden of bone metastases, bleeding palliation with 1–5 fx regimens	Staffing outside capital limited; demand exceeds capacity
Malawi	First RT centre commissioned in Lilongwe (1 cobalt, 2 LINACs, HDR, 2024)	Centralized urgent palliative RT for bone pain, bleeding, SVCS	Need for commissioning, training, and maintenance contracts
Mozambique	One functional RT centre in Maputo, serving ~29M population	Short hypofractionation for bone and thoracic palliation	Single-site bottleneck; extreme travel barriers for rural patients
Ethiopia	TASH (Addis Ababa) + 5 new RT centres under construction (2024)	Hypofractionated RT in tertiary centre; regional centres emerging	Rapid scale-up requires workforce training and quality assurance

Figures 2–4. Clinical Algorithms for Palliative Radiotherapy

2.Algorithm: Palliative RT for Bone Metastases

Step	Description
1	Patient with painful bone metastasis → Assess fracture risk and neurological deficit
2	If unstable/pathologic fracture risk → Orthopedic consult + stabilization
3	If uncomplicated → 8 Gy × 1 fraction EBRT (default)
4	If cord compression/nerve root involvement → Consider 20 Gy/5 or 30 Gy/10
5	Reassess at 4–6 weeks → Retreatment if pain persists or recurs

3. Algorithm: Hemostatic Radiotherapy

Step	Description
1	Patient with tumor-related bleeding (GI/GU, gynecologic, head-neck, breast)
2	Stabilize patient (fluids, transfusion, local measures)
3	If persistent/contraindicated to endoscopy or embolization → Radiotherapy
4	EBRT options: 8 Gy × 1 OR 20 Gy/5 (default LIC choice) OR 30 Gy/10
5	Reassess in 7–10 days → Repeat 8 Gy if re-bleed occurs

4. Algorithm: Radiotherapy in Superior Vena Cava Syndrome (SVCS)

Step	Description
1	Patient presents with malignant Superior Vena Cava Syndrome (SVCS)
2	If severe compromise (airway obstruction, coma) → Attempt endovascular stent (if available)
3	If stent unavailable/delayed → Start urgent RT
4	Radiotherapy options: 20 Gy/5 OR 30 Gy/10; add steroids if airway edema
5	Simple AP/PA fields if CT sim unavailable → Add systemic therapy per histology