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Making breast health a global priority

TREATMENT

Locoregional Therapy: Radiation Therapy for Breast Cancer

Knowledge Summary



Locoregional Therapy: Radiation Therapy for Breast Cancer

INTRODUCTION

Radiotherapy is an essential component of the multimodality treatment of breast cancer. Estimates suggest that 60% of all breast cancer patients in the United States would benefit from at least one course of radiotherapy for either curative, definitive treatment or palliation. In LMICs, where most women present with locally advanced breast cancer, the percentage of women who would benefit from radiotherapy is even greater, yet the gap between the demand and available supply continues to grow, with an estimated deficit of 7,000 radiotherapy machines globally. According to The Global Taskforce on Radiotherapy for Cancer Control, 29 of Africa's 52 countries have no radiotherapy facilities, and those 29 countries account for nearly 200 million people. This deficit results in additional barriers, long wait times, treatment delays and poor outcomes.

Delivering safe and effective radiotherapy requires accessible facilities, staff and equipment, as well as the coordination of treatment plans, including timely referrals that incorporate timely radiotherapy into treatment planning. Access to safe and reliable radiotherapy should be a public health priority.

Concerns about the cost and complexity of radiotherapy have limited its availability in countries with competing health priorities and underdeveloped infrastructures. Even in limited resource settings, radiotherapy services can be delivered in a cost-effective manner. There are logistical issues that must be addressed to safely implement radiotherapy, including support systems that allow the delivery of therapy, geographic accessibility for patients, trained personnel and appropriately designed facilities for radiotherapy and related equipment (e.g., simulator, planning computer system, tools for dosimetry).

The large upfront capital costs can be minimized with novel financing approaches and collaborative efforts with institutions such as the IAEA, partnerships with NGOs, public-private sector partnerships or a combination of these options. Fiscal constraints and the pressure to treat as many patients as possible in low-resource settings may lead to cost-cutting efforts, resulting in compromised staffing levels, limited facilities and less attention to quality. The framework for quality radiation therapy must include appropriate infrastructure and facilities, equipment (hardware and software) and trained personnel with credentialing, when available.

For a radiotherapy program to be accessible, it must take into account the geographic distribution of the population, sociocultural barriers, direct and indirect financial costs to the patient, as well as beliefs about the purpose or effectiveness of treatment. Even in LMICs, where government-owned facilities and government-subsidies or insurance may be available, a fee—which can be prohibitive—is often charged to the patient. Treatment fees are compounded by other indirect costs to the patient and her family. The location and distribution of radiotherapy services significantly impacts the utilization of services and outcomes. Communities with the greatest distance to radiotherapy services have been associated with an up to 20% increased mortality rate compared with communities lacking geographic barriers. Individuals from rural communities outside a major urban center incur transportation costs and temporary relocation costs if radiotherapy is to be delivered over multiple fractions/visits. This burden is significant, particularly in regions where the majority of the population lives outside urban centers or in countries without radiation services.



KEY SUMMARY

Radiation therapy for breast cancer

- Radiotherapy is an essential component of optimal breast cancer care: it is necessary for breast conserving therapy; it reduces locoregional recurrence and mortality from breast cancer; and it can be used to palliate symptoms of advanced breast cancer.
- Health system capacity for radiation therapy is necessary for a breast cancer program and requires sustainable investments in equipment and infrastructure, training specialized personnel and ensuring an adequate workforce, and a quality assurance program.
- Investments in radiotherapy equipment, supplies, and radiotherapy specialists can facilitate the introduction and incremental advancement of radiotherapy in low- and middle-income (LMICs).

Health systems and coordination of care

- Introducing radiotherapy services requires health system strengthening to ensure adequate and appropriate human resources, infrastructure, equipment, and quality assurance protocols.
- Regional partnerships, clinical guidelines, radiotherapy training, expertise and quality assurance programs are required to provide safe and effective radiotherapy.
- Health systems need to address referral mechanisms and patient barriers to accessing radiotherapy facilities, including transportation, particularly for low-income and rural communities.

- Radiotherapy programs must include security measures for source transfers, disposal and the vault that houses the cobalt unit.
- Evaluate sustainable resources, infrastructure and personnel requirements to determine the most appropriate investment with respect unit type[s] and numbers and locations of radiation equipment.

Resource-stratified pathway across the continuum of care

- Follow a defined resource-stratified pathway to allow for coordinated incremental program improvement across the continuum of care.
- Program design and improvements should be based on outcome goals, identified barriers and needs and available resources.
- Radiotherapy should be available at all levels of resources, beginning with minimum standards for radiotherapy services. Increasing complexity of radiotherapy equipment can be introduced as resources become available.
- Implementing radiotherapy is a long-term investment that will result in short-term and long-term health gains. Findings of the Lancet Oncology commission provide evidence that investing in radiotherapy not only enables the treatment of large numbers of cancer patients to save lives but also brings positive economic benefits.

POINTS FOR POLICYMAKERS:

OVERVIEW

Preplanning

- Identify data sources to estimate disease burden and radiotherapy needs.
- Identify stakeholders, key decision-makers and champions.
- Identify who will lead the process.

Planning Step 1: Where are we now?

Investigate and assess

- Map the burden of disease in each community to inform health system planning and assist with geographic placement of radiotherapy services.
- Assess workforce capacity and needs and treatment protocols.
- Identify barriers to delivery of treatment (structural, socio-cultural, personal, financial).

Planning Step 2: Where do we want to be?

Set objectives and priorities

- Address deficits in the availability, safety and accessibility of radiotherapy.
- Address the financial and health resource investments required to establish, develop and sustain radiotherapy services both in terms of equipment and people.
- Government commitment and support is necessary to build and sustain radiotherapy capacity.
- Multisector partnerships, such as with the International Atomic Energy Agency (IAEA) or collaborative cancer centers, can strengthen existing services and bridge gaps in the delivery of radiotherapy.

Planning Step 3: How do we get there?

Implement and evaluate

- Program development should be done in a step-wise manner beginning with education and training, acquiring core equipment, promoting imaging services, establishing guidelines and protocols, developing a research and quality assurance program and forming partnerships.

WHAT WE KNOW

Radiation Therapy

Regardless of the stage of breast cancer at the time of diagnosis, radiotherapy can be utilized as a treatment modality to reduce the risk of local recurrence, improve survival or provide palliation of symptoms.

Radiotherapy has a key role in the treatment of breast cancer because breast cancer cells are sensitive to the cytotoxic effects of ionizing radiation. In addition to directly damaging DNA, ionizing radiation splits water molecules to produce charged particles (ions) that can also damage DNA. If the cumulative damage is large enough, a loss of DNA integrity will occur, followed by cell death in the targeted area.

Both normal cells and malignant cells are subject to the toxic effects of ionizing radiation. In radiation treatment, the “therapeutic ratio” captures the balance between minimizing the toxicity to normal cells while maximizing the dose to cancer cells. Splitting the delivery of radiotherapy into a number of smaller daily doses (fractionation) allows the same total amount of radiation to be administered while reducing the amount of toxicity to normal tissues. Radiation dosing and scheduling (how often it is given) have been studied to assess the safety and the efficacy of using lower total doses and shorter schedules.

In breast cancer radiotherapy, both electrons and photons can be used. Electrons are often used for superficial targets, whereas photons penetrate tissue more effectively and must be targeted to avoid damage to critical structures.

Technique and planning for stage I-III breast cancer: Treatment planning includes determining the radiation field with definition of the target area (preferably by imaging), delineating the target volume and organs at risks, immobilizing the patient to assure multiple doses are delivered precisely to the same region and determining the dose and schedule of treatment.

Timing, duration and combined therapy: Radiotherapy should be initiated without delay after breast conserving therapy (BCT); a prolonged postoperative interval may compromise local control. The timing of adjuvant radiotherapy and chemotherapy may depend on clinical factors, including tumor margins, chemotherapy agents used, patient preferred radiotherapy schedule and access to treatment. In patients with a high risk of distant recurrence, administering chemotherapy before radiation therapy may decrease the risk of distant metastasis. Therefore, when chemotherapy is indicated, it is common that the chemotherapy be administered first. Concomitant chemotherapy can reduce overall treatment time, but synchronous administration of some chemotherapies should be avoided due to increased toxicities. However, the targeted agent, trastuzumab, has been administered during irradiation on the condition that the cardiac volume irradiated is as limited as possible. Treatment should be completed without delay in overall treatment time. Interruptions of more than one week during postoperative irradiation of breast cancer adversely affect treatment outcomes.

Whole breast radiation: Early stage (stage I or II) breast cancer is managed surgically with BCT (i.e., lumpectomy) or mastectomy, depending on resource availability and an individual woman’s preference [see *Locoregional Therapy: Surgery for Breast Cancer*]. The availability of radiotherapy, reliable pathology, surgical expertise and high-quality breast imaging are considered prerequisites for BCT [see Table 1]. Women who undergo BCT followed by whole breast radiotherapy have equivalent disease-free and overall survival to those treated with mastectomy alone. A meta-analysis of women who underwent BCT without radiotherapy compared to BCT with radiotherapy showed a greater likelihood of recurrence without radiotherapy (35% versus 19%) and a higher 15-year risk of death due to breast cancer (25% versus 21%). The most common schedule for irradiation after BCT is daily administration, five times per week for 5–5.5 weeks. Hypofractionation schedules which use a higher dose and shorter overall treatment time have shown similar efficacy and toxicity when compared with conventional schedules, representing an important way of increasing patient access to radiotherapy and allowing for more efficient use of resources.

Accelerated partial breast irradiation: Accelerated partial breast irradiation (APBI) refers to the use of focused radiotherapy to a limited portion of the breast and includes brachytherapy, intraoperative radiotherapy or external-beam radiotherapy (e.g., conformal external-beam radiation, intensity modulated radiation). Partial breast irradiation aims to reduce recurrence in the vicinity of the tumor bed, where most local relapses occur. The target volume is smaller, allowing for accelerated completion of therapy in only one week. There are insufficient data to support the role of APBI as a standard alternative to whole breast radiation at this time.

Postmastectomy chest wall irradiation: In women with axillary lymph node-positive breast cancer, radiotherapy after mastectomy improves local control and overall disease-free survival. Local recurrence after mastectomy usually occurs within the first 24 months. The major predictor of recurrence is positive axillary lymph nodes. Women with axillary lymph node involvement who receive postoperative radiotherapy to the chest wall have improved disease-free and overall survival.

Postmastectomy irradiation schedule: The generally accepted postmastectomy treatment schedule lasts five weeks. High-risk patients should be treated with an additional boost dose to the mastectomy scar. Radiation therapy should precede the placement of autologous tissue in breast reconstruction. When implant reconstruction is planned in a woman requiring radiotherapy, immediate tissue expander placement followed by implant placement in second step is recommended.

Regional lymph node irradiation: In the absence of axillary lymph node involvement, direct irradiation of the regional lymphatics is not recommended, since this is an uncommon site of isolated recurrence and carries a risk of morbidity without validated benefit. Several radiotherapy techniques incorporate the axillary bed to varying degrees.



Internal mammary lymph nodes: Patients with clinical or pathologically positive internal mammary lymph nodes often receive radiation to the internal mammary chain, in addition to the supraclavicular lymph nodes, because studies have shown an associated improvement in disease-free and overall survival. Internal mammary chain irradiation should be considered according to risk factors and the systemic treatment that the patient received. It requires technical expertise to minimize dose delivery to the lung and heart and the concomitant long-term toxicities.

Preoperative radiotherapy: Breast cancer patients in low-resource settings often present with locally-advanced breast cancer for which initial surgical management is not feasible. Systemic therapy should be started because the majority of inoperable tumors will regress sufficiently to become operable. If surgery is performed, then postoperative radiotherapy is indicated, including to the breast (or chest wall) and the regional lymph nodes. If a patient with locally advanced breast cancer is not a candidate for surgery after chemotherapy, preoperative radiotherapy can be applied and an operative evaluation performed after that treatment. If the patient is still inoperable, then additional radiotherapy is administered. Whole-breast and regional lymph node irradiation should be given in tumoricidal doses to the areas of bulk disease.

Palliative irradiation: The goal of palliative radiotherapy is to prevent or relieve symptoms or loss of function. Single-fraction radiotherapy is as effective as multifraction radiotherapy in relieving metastatic bone pain. Palliative radiation may prevent a loss of neurologic function in patients with spinal metastases that are close to or impinging on the spinal cord. Palliative whole-brain irradiation with steroids can also be considered at appropriate resource levels.

Role of radiation in recurrence: Locally recurrent breast cancer after mastectomy can also be treated with radiation, assuming the chest wall has not been previously irradiated. If the recurrence is operable, radiation therapy follows surgical excision.

Brachytherapy: Brachytherapy is a form of radiotherapy in which a radiation source is placed inside or next to the area requiring treatment, emitting radiation over a short distance. In breast cancer, it can be delivered with interstitial, intracavitary or intraoperative delivery systems. Generally, brachytherapy is only used in specialty centers. Intraoperative radiation therapy is associated with a higher risk of in-breast recurrences.

Treatment-related toxicities: Whole-breast radiation is associated with acute toxicities in up one third of women and is related to the region treated (e.g., skin, muscle). Late complications are infrequent but could include damage to skeletal muscle, connective tissue or bone [13%]; fat necrosis [6%]; nerve [2%] and lung injury [2%]; and cardiac toxicities [<1%]. Rarely, secondary malignancies, such as sarcoma, may develop decades posttreatment [see *Palliative Care During Treatment for Breast Cancer*].

Symptomatic radiation pneumonitis (inflammation of the lungs), presenting with a dry cough or dyspnea (labored breathing), is rare, particularly with more advanced radiotherapy techniques that include less lung volume in the radiation field. Breast radiotherapy also carries a low but increased risk of cardiac events, although these events have been substantially reduced with modern radiotherapy techniques. Older data suggest a small increased risk of non-breast-cancer deaths after radiation therapy, but a more recent meta-analysis demonstrated a 3% improvement in overall survival for patients undergoing breast radiotherapy, underscoring that the risk-benefit ratio remains in favor of radiation therapy.

Contraindications: Absolute contraindications to breast radiotherapy include pregnancy and a history of prior therapeutic radiation that included a portion of the affected breast and would result in an excessively high total radiation dose to that tissue. Radiotherapy is a relative contraindication for women with connective tissue diseases (e.g. scleroderma) and the decision to proceed with care should occur only after detailed counseling and consideration of alternative treatment plans.

WHAT WORKS

Health system investments: Providing radiotherapy services requires an investment in equipment and staff [see Table 4]. Improving access to radiotherapy includes addressing equipment availability, location and service/maintenance, as well as health system infrastructure needs related to human resources limitations, training and expertise.

Machine selection and financial considerations: Although radiotherapy requires a large initial investment, the long-term gains for the patient and the system are significant. Capital investments include a radiotherapy room, radiation machine and equipment and treatment planning equipment. The cost of radiotherapy services varies by region and resource availability, equipment variables, measures of productivity and utilization of services. The long-term health benefit costs are favorable because the equipment has a long life with high throughput and most patients are managed in the outpatient setting. The high initial costs are generally recovered because of the long lifetime of the capital purchase, although the recovery time may be longer in low-resource settings.

Radiation equipment: The main equipment required for radiotherapy is a megavoltage teletherapy [external beam] unit, either a cobalt-60 unit or a LINAC unit [see Tables 3]. LINACs can range in design from simple, single-photon energy machines to sophisticated dual-energy machines with electrons and other features that provide more functionality than cobalt machines. Cobalt machines are more simple to maintain —mechanically and electronically— and cost less than LINACs, but they are less versatile, have a less favorable beam profile and are less able to deliver complex treatments. The longevity of both machine types is approximately 17 years. The required maintenance for LINACs is estimated to be 1.5-times greater than that for cobalt machines. Without regular maintenance, there may be more frequent interruptions in treatment with a negative effect on patient outcomes. Strengthening the purchasing power between institutions may help reduce costs.

Cost effectiveness: Radiotherapy has been generally assessed as being cost effective. The Lancet Oncology Commission reported in 2015 that a scale-up of radiotherapy capacity in 2015–35 from current levels could lead to 26.9 million life-years saved in LMICs over the lifetime of the patients who received treatment. In addition, the economic benefits of investment in radiotherapy are substantial.

Optimal utilization and access to treatment: For a radiotherapy program to be accessible, it must take into account the geographic distribution of the population, sociocultural barriers, direct and indirect financial costs to the patient and beliefs about the purpose or effectiveness of treatment. The optimal utilization of radiotherapy requires an efficient referral process. Offering travel assistance and accommodation during treatment can reduce patient transportation barriers. Partnering with community support and advocacy groups can help address sociocultural barriers.

Multidisciplinary care: Multidisciplinary breast programs can improve patient care through a coordinated approach, ensuring integrated and effective care. In low-resource settings, the team may include only 2–4 members [e.g., radiation oncologist, surgeon, nurse, pathologist, or medical oncologist].

Safety: The safe and effective use of radiotherapy requires trained radiation oncologists, physicists and technicians. The education of radiation oncologists, radiation technicians and medical physicists should be coordinated with the introduction or expansion of radiotherapy services. Distance-learning courses and professional associations can assist in-country training of radiation oncologists. Additionally, experts from other partner organizations or countries can be used as valuable resources.

Training and personnel: Human resource limitations present a significant challenge in establishing and maintaining radiotherapy programs. The IAEA recommends staffing of about 20 trained personnel [e.g., 4–5 radiation oncologists, 3–4 medical physicists, 7 radiation therapy technologists, 3 radiotherapy nurses and a maintenance engineer] at each radiotherapy center, a target that is difficult to achieve in regions without trained personnel. Collaborative programs and novel training models are needed to bridge this shortfall.

Collaborations: Partnerships between radiotherapy centers can facilitate the bilateral transfer of expertise, safety and quality processes and protocols. An integrated multitiered network involving primary, secondary and tertiary radiotherapy centers in LMICs and high-income countries, coordinated through a teletherapy network, is a cost effective model that can help to bridge service gaps and improve access to state-of-the-art technology in radiotherapy. Links between institutions with different resource levels can coordinate and facilitate clinical reviews, provide training and provide quality assurance and support research projects.

Quality assurance: To facilitate utilization of radiotherapy, implementation plans and quality assurance measures should be introduced. International quality assurance protocols have been developed, such as the IAEA/WHO TLD [Thermoluminescent Dosimetry] postal program and intercenter dosimetry project. Quality checks can identify dosing problems [e.g., doses higher than the recommended range are associated with severe or even lethal toxicities]. Radiotherapy programs should monitor the outcomes of therapies and use collective data to develop evidence-based protocols to standardize treatments. Quality checks should ensure that clinical practice guidelines are followed. Quality assurance measures should be introduced with every new radiation treatment technique.



POINTS FOR POLICYMAKERS:

PLANNING STEP 1: WHERE ARE WE NOW?

Investigate and assess

Assess the burden of breast cancer and radiotherapy needs

- Identify the burden of breast cancer and disease stage at presentation to help inform health system planning.
- Curative radiotherapy and palliative radiotherapy require different treatment regimens. Establishing how many women will benefit from each type of radiotherapy and their anticipated treatment plan is required to calculate radiotherapy needs.
- Map the burden of disease in each community to assist with geographic placement of radiotherapy services.

Assess patient access and barriers to delivery of radiotherapy

- Identify structural, sociocultural, personal and financial barriers to implementing radiotherapy.
- The geographic location of the radiotherapy unit should be based on maximizing access and should be coordinated with regional leaders and health professionals.
- Evaluate the coordination of care and referral system. Radiotherapy must be part of a coordinated treatment plan that requires multidisciplinary care and timely referrals. Time from breast surgery to the initiation of radiotherapy and the per-

centage of women whose radiotherapy extends longer than the anticipated duration can be used as a quality metrics.

- Reduce financial barriers for patients to ensure treatment access for all breast cancer patients.

Assess health system capacity

- Identify all existing radiotherapy equipment and associated supplies [e.g., imaging devices or simulators, shielding devices, tools for dosimetry], as well as treatment planning systems and available expertise.
- Assess health workforce needs as well as training and additional support needs.
- Document the number of patients served and the hours of service for each radiotherapy facility. Note that extending the hours of service can improve the cost profile but may compromise the quality of services.
- Secure long-term technical support from manufacturers, including the training of local engineers.
- A long-term financial sustainability model is needed to optimize the utilization of available services and the return on health investment.

Assess monitoring, quality assurance and safety

- Secure resources for a quality assurance program of radiotherapy resources, including regular monitoring, safety checks and maintenance.
- See IAEA tools: Setting Up a Radiotherapy Program: http://www-pub.iaea.org/MTCD/publications/PDF/pub1296_web.pdf and Planning National Radiotherapy Services: A Practical Tool: http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1462_web.pdf

PLANNING STEP 2: WHERE DO WE WANT TO BE?

Set objectives and priorities

Identify community and health system partnerships

- Engage survivor and advocacy groups to understand barriers to access as well as existing beliefs and misconceptions about radiotherapy.
- Seek partnerships to support patients in need of transportation or housing during treatment.

Identify gaps and in radiotherapy services

- In LMICs, there are significant gaps in available radiotherapy services and human resource expertise that require a coordinated program improvement plan.
- Initial and continuing training programs must be provided for health professionals in the radiotherapy program.
- Perform a needs assessment and econometric analysis; initiate multisectoral planning with assistance from the IAEA, the World Health Organization (WHO), professional associations and/or partners; implement training modules for involved personnel.

Set achievable objectives

- Identify the type of radiotherapy machine—linear accelerator (LINAC) and/or cobalt—that is feasible. This determination depends on local radiotherapy experience and case-mix [usage], as well as on financial, technical and human resources available.
- Develop national or regional evidence-based guidelines for breast cancer radiotherapy.
- Develop guidelines for the safe use of radiotherapy and expected standards of care.
- Accreditation standards can be used to ensure each radiation oncology facility offers quality assurance programs that follow international guidelines.
- Establish fair payment structures and fees and develop radiation protection, safety and security infrastructure.

Set priorities and determine feasibility of interventions

- Radiotherapy is an essential part of multidisciplinary breast cancer care. Effective, timely and safe radiotherapy should be available to all breast cancer patients.
- Follow a resource-stratified pathway for incremental program improvement that includes evaluation of available resources across the continuum of care [see Table 1].

PLANNING STEP 3: HOW DO WE GET THERE?

Implement and evaluate

Establish financial support and partnerships

- Multisectoral partnerships, such as with IAEA or other institutions, nongovernmental organizations (NGOs) or cancer centers, can strengthen existing services and bridge gaps in the availability and delivery of radiotherapy.
- An integrated multitiered network between primary, secondary and tertiary radiotherapy centers in LMICs and high-income countries, coordinated through a teletherapy network, is a cost-effective model that can help to bridge service gaps and give all patients access to the state-of-the-art technology in radiotherapy.
- Links between institutions with difference resource levels can help coordinate and facilitate clinical, teaching, quality assurance and research projects. These activities can include an exchange of personnel, technical assistance, implementation models and the expansion of safe radiotherapy services.

Implement and disseminate

- Organize services within the health system to maximize the utilization of existing radiotherapy services.
- Educate health care professionals about the availability of and indications for radiotherapy.
- Strengthen referral networks to avoid delays in care and improve adherence to treatment regimens.
- As resources allow, develop programs [e.g., transportation and accommodation subsidies] to reduce barriers for patients who must travel for therapy.

Monitor and evaluate

- Establish quality assurance protocols; consider adopting international protocols, such as the IAEA/WHO TLD postal program and intercenter dosimetry project [<http://www-naweb.iaea.org/nahu/DMRP/tld.html>].
- Quality assurance should include machine calibrations, dosimetry and accurate simulations to minimize potential harm to the patient.
- Ensure a quality assurance measure is introduced with every new radiation treatment technique.
- Review accreditation procedures.

CONCLUSION

There is a tremendous need for radiotherapy in LMICs, where 85% of the world's population lives but less than 35% of the world's radiotherapy facilities are located. Significant barriers to implementing radiotherapy services exist: resource limitations and competing health priorities, scarcity of trained professionals, technical support and proper equipment (and their appropriate geographical distribution) and financial barriers for patients. Investment in radiotherapy is a long-term investment that can result in short-term and long-term health gains as well as economic benefits. The misconception that radiotherapy is prohibitively expensive or it has low clinical utility should be dispelled. Radiotherapy should be included as part of breast cancer treatment planning and be based on clinical best-practice guidelines and ongoing research. As radiotherapy becomes available, health professionals should direct their efforts toward collaborating and improving the availability, quality and surveillance of this critical treatment modality.

Table 1. Radiotherapy recommendations by disease stage and resource level allocation

Disease stage	Basic	Limited	Enhanced	Maximal
Stage I	See footnote*		Breast conserving whole breast irradiation, as part of breast conserving therapy	
Stage II	See footnote*	Postmastectomy irradiation of chest wall and regional nodes for high-risk cases**	Breast conserving whole breast irradiation, as part of breast conserving therapy	
Locally advanced		Postmastectomy irradiation of chest wall and regional lymph nodes**	Breast conserving whole breast irradiation, as part of breast conserving therapy	
Metastatic disease and recurrent breast cancer		Palliative radiation therapy		

*Chest wall and regional lymph node irradiation substantially decreases the risk of postmastectomy local recurrence. If available, it should be used as a basic-level resource.

** Breast conserving surgery can be provided as a limited-level resource but requires breast conserving radiation therapy. If breast conserving radiation is unavailable, then patients should be transferred to a higher level facility for postlumpectomy radiation.

Source: Bese NS, Munshi A, Budrukkar A, Elzawawy A, Perez CA; Breast Health Global Initiative Radiation Therapy Focus Group. Breast radiation therapy guideline implementation in low- and middle-income countries. *Cancer*. 2008 Oct 15;113(8 Suppl):2305-14.

Table 2. Radiotherapy services by resource level allocation

	Basic	Limited	Enhanced	Maximal
Simulator	Not available [NA]	Conventional	3D Computed tomography simulation	4D simulation
Dosimetry	NA	2Dimensional [D]	3D	4D
Teletherapy equipment and beam energy	NA	3D	Electrons	Compensators
Accessories	NA	4D	6-18 MV x-rays, particles	NA
Accelerated partial breast irradiation	NA	No	No	Experimental
Brachytherapy	NA	No	Yes	Yes
Quality assurance	NA	Simple or intermediate	Intermediate	Complex

Source: Bese NS, Munshi A, Budrukkar A, Elzawawy A, Perez CA; Breast Health Global Initiative Radiation Therapy Focus Group. Breast radiation therapy guideline implementation in low- and middle-income countries. *Cancer*. 2008 Oct 15;113(8 Suppl):2305-14.

Table 3. Advantages and disadvantages of Cobalt-60 machine versus linear accelerator (LINAC)

Cobalt-60		Linear Accelerator	
Advantages	Disadvantages	Advantages	Disadvantages
<ul style="list-style-type: none"> Less costly More simple mechanical, electrical components and operations Easy to maintain Relative constancy of beam output, predictability of decay Quality assurance (QA) program is simple 	<ul style="list-style-type: none"> Poor field flatness Lower % depth dose Greater penumbra Lower dose rate Less favorable beam output Need to change source every 5 years Inability to deliver complex treatment 	<ul style="list-style-type: none"> Ability of delivering complex treatments Better dose distribution, especially after breast conserving surgery (BCS) Decreased skin dose, especially after BCS Decreased dose to the contralateral breast 	<ul style="list-style-type: none"> Preventive maintenance is essential, expensive and requires a maintenance technician More detailed QA program is needed

Source: Bese NS, Munshi A, Budrukkar A, Elzawawy A, Perez CA; Breast Health Global Initiative Radiation Therapy Focus Group. Breast radiation therapy guideline implementation in low- and middle-income countries. *Cancer*. 2008 Oct 15;113(8 Suppl):2305-14.

Table 4. Roles of staff and equipment requirements in safe and effective radiotherapy for breast cancer

	Requirement	Role
Staff	Radiation oncologist	Clinical evaluation, therapeutic decision, target volume localization, treatment planning, simulation/verification of treatment plan, treatment evaluation during treatment and follow up examinations
	Medical physicist	Quality control, computerized treatment planning, complex calculations and quality checks
	Radiotherapy technologist/radiographer	Simulation/verification of treatment plan, routine calculations and quality checks and treatment
	Maintenance technician ^a	Maintenance of equipment
Equipment	Megavoltage teletherapy unit ^b	Radiation source
	Dosimetry equipment	Physical quality assurance
	Clinical quality assurance equipment ^c	Clinical quality assurance
	Immobilization devices	Accuracy of therapy
	Shielding devices	Protection of healthy tissues, such as heart, lungs and spinal cord
	Treatment planning computer system	Calculation of radiation distribution

^a Required if a linear accelerator (LINAC) is being used.

^b A cobalt-60 or LINAC unit; choice will depend on the factors discussed in the text. Breast brachytherapy is investigational at this time.

^c Includes a simulator (fluoroscopic or computed tomography).

Source: Bese NS, Kiel K, El-Gueddari Bel-K, Campbell OB, Awuah B, Vikram B; International Atomic Energy Agency. Radiotherapy for breast cancer in countries with limited resources: program implementation and evidence-based recommendations. *Breast J*. 2006 Jan-Feb;12 Suppl 1:S96-102.

ACKNOWLEDGEMENTS

This series is a collaborative effort by the following organizations and individuals in support of the goals of BCI2.5. Authors: Benjamin O. Anderson [BHGI], Allison Dvaladze [University of Washington], Andre Ilbawi [UICC Fellow], Silvana Luciani [PAHO], Julie Torode, [UICC] and Jo Anne Zujewski [NCI]. Cover photographs generously contributed by Carolyn Taylor. Updated: 3/2017.

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