Fundamentals of radiotherapy for cancer

Key concepts

- Factors influencing the selection of radiotherapy for cancer.
- Applied radiation physics and radiation biology.
- Role of radiotherapy in the treatment and palliation of cancer.
- Methods for delivering radiotherapy.
- Future directions in radiotherapy in the management of cancer.
- Experience and impact of radiotherapy on various health domains.
- Prevention, detection, and management of common health alterations experienced by people undergoing radiotherapy for cancer.

Objectives

On completion of this supporting resource, you should be able to:

1. Explain the role of radiotherapy in the treatment and palliation of cancer.
2. Outline the key concepts of radiobiology.
3. Describe various methods for delivering radiotherapy.
4. Discuss principles of radiation safety.
5. Discuss the experience and impact of radiotherapy on the various domains of health.
6. Implement interventions to prevent, detect and manage common health alterations experienced by people undergoing radiotherapy for cancer.

Learning activities

At times, you will have learning activities to complete. Click on the learning activities button and a list of questions will pop up. The questions will relate to the content you've just read or the video you've just watched.

Resource links

Resource links are included throughout the resource. These links lead to interesting articles or websites, and are designed to encourage you to explore other available resources.

PDF of EdCaN module: Fundamentals of radiotherapy for cancer
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The role of radiotherapy in cancer control

Radiotherapy can be used alone, or as an effective neoadjuvant and adjuvant treatment in combination with other treatment modalities such as surgery, chemotherapy and hormonal therapy.[1-5]

The aim of radiotherapy may be cure, control, and palliation, offering benefits in terms of:[6, 7]

- organ preservation
- quality of life
- survival outcomes
- effective palliation of symptoms.

The treating team considers a range of factors when deciding on a course of radiotherapy. Tumour related factors include:[8, 9]

- the site of the cancer
- an histologically-proven cell type
- the grade and stage of the tumour
- the radiosensitivity of the tumour.

Individual factors that may influence the decision to use radiotherapy may include comorbidities, performance status, and lack of suitability for surgical resection or anaesthesia.

A significant proportion (approximately 50%) of the population undergoing radiotherapy are treated palliatively to manage local recurrence and palliation of unresectable tumours.[10]

Palliative indications may include:[10-12]

- treating pain from bony metastases and pathological fractures
- providing relief from symptoms caused by cerebral metastases
- relieving spinal cord compression
- superior vena cava obstruction
- control of bleeding
- reducing fungating lesions.

Learning activity	
Completed	Activities
☐	1 Access evidenced based clinical practice guidelines and describe examples of radiotherapy approaches which are used throughout the treatment trajectory for a person affected by breast or prostate cancer.

Key concepts of radiobiology

Understanding radiobiologic principles and their application to nursing care is integral to assisting optimal outcomes. Radiotherapy aims to treat cancer through delivering sufficient doses of ionising radiation to a specific area of the body to damage target DNA that eventually results in cell death.[8] Ionising radiation causes cell death either directly or indirectly.

Direct damage to the atoms that make up the DNA results in either single or double-strand breaks, faulty cross-linking of chains after breakage, damage or loss of a nitrogenous base, or breakage of the hydrogen bond between the two chains of the DNA molecule causing impaired cellular functioning or cell death.[1]

Indirect damage is caused by the interaction of ionising radiation with the molecules of the cellular fluid, resulting in toxic changes caused by the creation of unstable free radical ions that impair cellular functioning. While a direct hit causes the most lethal damage, the most common injury occurs as a result of the interaction of radiation and the water molecule.[13]

Radioactive substances emit both gamma rays and radiation particles until all their atoms are stable in a process called radioactive decay. The activity and rate of decay varies from one radioactive source to another. The most important feature of any type of ionising radiation in determining its application in radiotherapy is its penetrating power. The deeper the tumour within a patient, the higher the penetrating power required of the radiation.[14]

The basic principles of radiobiology are:[1, 13, 15, 16]

- **reoxygenation:** occurs when radiation is delivered in multiple fractions to cells that may be relatively resistant due to hypoxia; cells may become reoxygenated and therefore more radiosensitive.
- **redistribution:** is defined by cells that survive a dose of radiation due to synchronisation in resistant phases of the division cycle and redistributing into more sensitive phases of the cell cycle during subsequent doses of radiation.
- **repopulation:** describes cells responding to lethal injury by repopulating or regenerating themselves.
- **repair:** occurs following sub lethal cellular injury which represents damage to the strands of the DNA and which can be repaired by enzymatic processes.

The four Rs of radiation biology, the tumouricidal dose, and the tolerance of surrounding critical tissues determine the prescription for a site specific tumour with a particular histology and pathology.[15] To quantify the amount or dose of absorbed radiation within a recipient, the unit of Gray (Gy) is used.

1 Gray (Gy) = 1Joule of energy absorbed per kg of mass = 1J/kg.

This absorbed dose is an indicator of the level of biological effects that may occur in the different tissues of the body due to ionising radiation.[14]

Based on the principles of radiobiology, the total dose of radiation prescribed to treat a particular tumour is divided into a number of daily doses or fractions. This aims to protect normal surrounding tissue while maximising the radiation effect on the tumour.[1] Different

tissues have varying tolerance levels to radiation exposure which, if exceeded, results in high morbidity of the treatment.[1]

Learning activities		
Completed	Activities	
☐	1	Describe the chemical reaction in the cell from the effects of ionising radiation.
☐	2	Define the term 'half life', and discuss the implications of this concept to delivery of radiotherapy in cancer treatment.
☐	3	Access a current text. Identify the varying radiation tolerance levels of the following tissues and discuss the impact this has on treatment planning and delivery: • brain • spinal cord • vocal cords.
☐	4	Outline the pathophysiology of acute and chronic radiation effects.

Radiotherapy service delivery

The provision of radiotherapy services relies on a range of sophisticated, highly scientific treatment delivery systems and a variety of specialised health care professionals.[17] The specialist multidisciplinary team is required to deliver prescribed, accurate doses of radiation and ensure safe and effective care for the person receiving radiotherapy.[18]

Appropriate emotional support, reassurance and provision of appropriately targeted information and education are important elements of nursing practice for this population.[19]

Quality assurance in radiation oncology encompasses many elements including:[18]

- the accuracy of the radiation beam
- machine performance checks
- radiation safety protocols
- standards of radiation treatment protocols
- evaluation of clinical outcome data
- evidence based supportive care.

Learning activities		
Completed	Activities	
☐	1	Identify the following radiotherapy MDT members and outline their roles and responsibility in cancer care: • dosimetrist • physicist • radiation oncologist • radiation therapist • radiation oncology nurse.
☐	2	Critically discuss the role of clinical practice guidelines to support evidence based nursing practice in radiation oncology.
☐	3	Describe the role of safety protocols and/or procedures which ensure the wellbeing of the person affected by cancer as they receive external beam radiotherapy in the following areas of care: • immobilisation and positioning • monitoring of the individual during treatment.
☐	4	Refer to your local policy and procedures and outline the actions required in the case of a medical emergency involving a person who has received an unsealed radioactive source.

Principles of radiation safety

Radiation safety principles aim to limit exposure to ionising radiation for radiation therapy personnel, people affected by cancer and the general public. Wherever there is known risk of exposure to ionising radiation, health professionals must be guided by the ALARA (as low as reasonably achievable) principles of radiation safety for time, distance and shielding.[8, 20]

Time

The less time spent near a radiation source, the less radiation absorbed. This is especially important for personnel such as radiation therapists and physicists preparing radioactive sources, and for nursing staff when caring for individuals who have a radioactive source in a body tissue or cavity. For inpatients, the nurse should restrict direct contact to 30 minutes per eight-hour shift.[20]

Distance

The inverse-square law states that radiation exposure and distance are inversely related. That means that as the distance from the source increases, the intensity of radiation decreases. To calculate exposure, the rule to use is that the amount of radiation exposure at one metre from the radioactive source equals the amount of radiation exposure at any distance from the source times the distance squared.[21]

Shielding

The type of shielding device used depends on the range of emission of the radioactive source. Standard shielding devices include lead aprons, thyroid shields, and eye shields. Rooms that house x-ray generating equipment are shielded using specified materials. Radioactive sources need to be transported by licensed personnel in lead containers.[20] Brachytherapy procedures are undertaken in a specialised unit or ward with appropriate facilities, and individuals are generally isolated in a single room.

Departments are designed with radiation protection and shielding at the forefront of planning. Radiation therapy workers are required to wear thermoluminescent dosimetry (TLD) badges, monitored by regulatory authorities to measure radiation exposure. Other radiation measurement devices such as Geiger counters are used to monitor areas where radioactive sources are used. Appropriate signage must be in place in the presence of any radioactive substance, and education and information provided to all individuals who may be impacted.[8, 20]

Spill management

In the event of a radiation incident, such as the loss of a source or a spill, appropriate procedures and notifications must be followed. These should be clearly outlined in the clinical environment as part of radiation safety and hospital policy.

After ingestion of a radioactive substance, 'spills' generally refer to the loss of body fluid, either urine or vomit, and can be classified as major or minor. A significant amount of fluid loss (vomit or urine) within the first 24 hours would be defined as a major spill.[22]

Learning activities	
Completed	Activities
☐	1 Summarise how the ALARA principles are implemented in the care of individuals after the following treatments: • iodine-131 swallow for thyroid cancer • permanent seed implants in the prostate • caesium-137 insert for cervical cancer using a remote afterloading device.
☐	2 Refer to your local policy and procedures and review spill management for a radioactive substance. Conduct a teaching session for novice nurses.

The treatment journey

There are three phases of the person's radiotherapy treatment journey.[23]

1. Treatment planning and preparation
2. Treatment delivery
3. Treatment completion and management of responses to radiotherapy

Treatment planning and preparation

Treatment planning is essential to ensure accuracy and reproducibility of the radiotherapy.[1, 23] This procedure determines the dimensions, shape, and appropriate number of radiation beams (or treatment fields) required to treat the tumour while limiting the dose to the surrounding normal tissues. Through this process, radiotherapy treatments are tailored to the individual.[24]

Positioning and stabilisation

The chosen treatment position depends on the site of the person's tumour. Individuals are positioned to avoid unnecessary irradiation of normal tissues. The position needs to be easily reproducible each day. Stabilisation devices include face masks and custom made positioning supports for different areas of the body (e.g. neck, arms, pelvis, and knees). Such devices help the person maintain the required position during treatment.[25]

Simulation

A simulator 'simulates' the movement and set-up parameters of the linear accelerator involved in radiotherapy treatment delivery.[26, 27] Virtual simulation may be completed using results from imaging procedures imported into a 3D treatment planning computer. Virtual representation of the person may be generated through:

- Computed tomography image (also called a planning CT)
- Magnetic resonance imaging (MRI) or positron emission tomography (PET) scans (provides enhanced anatomical or metabolic tumour information, supplementing the planning CT scan through the process of image fusion)[28]
- 4D or respiratory-gated planning CT scans (tracks the movement of a lung or abdominal tumour during breathing to ensure the tumour is always in the path of the treatment fields)[29]

The simulation process determines placement of external marks on a person that are used to accurately direct the treatment fields each day of the person's treatment. External treatment marks are often small tattoos, usually the size of a small freckle. Some stabilisation devices such as face masks also allow for the treatment marks to be placed on the device rather than the person's skin to avoid embarrassing marks on the face.[25]

Once the simulation process is complete, dose calculations determine the amount of radiation to be delivered each day. The isodose curve is the basis of all calculations,[14] and is used:

- to determine the daily dose
- to show the total distributed radiation dose in an individual for the intended course of treatment
- to act as a record of the treatment delivered[14]

Information provision and education

Planning and preparation may be a lengthy process that adds to the anxiety and concerns of people undergoing radiotherapy. Providing an orientation to the treatment area, information and education, and assessment of levels of anxiety and depression before radiotherapy may reduce anxieties and enhance adherence with therapy.[30] Tools have been developed by eviQ to ensure a consistent approach to assessment and education:

- Radiation Therapy Patient Education Checklist. eviQ, 2014
- Radiation Therapy Nursing Assessment. eviQ, 2012

Learning activities	
Completed	Activities
☐	1 Discuss the role of the SCN during the radiotherapy treatment planning and preparation processes.
☐	2 Outline supportive care interventions you could give to a person affected by cancer to prepare them for a course of radiotherapy.

Treatment delivery

There are a variety of external or internal cancer treatment delivery methods including:

1. Gamma Knife
2. External beam radiotherapy (EBRT)
3. Brachytherapy
4. Combined modality treatment.

This enables a range of radiotherapy schedules that best suit the tumour type and stage of a cancer to be considered.16, 17

Gamma Knife

Gamma Knife® technology delivers a highly precise form of radiosurgery called stereotactic radiosurgery. It is a non-invasive alternative to neurosurgery which uses radioactive sources to predominantly treat brain tumours. Malignant or benign brain tumours may be treated with the Gamma Knife, and can be performed on an outpatient basis, thus reducing the risk of complications and side effects. Multiple lesions can also be treated simultaneously and accurately[64]. At present, Gamma Knife radiosurgery is available in Australia at the Princess Alexandra Hospital, Brisbane, Brisbane, and at Macquarie University Hospital, Sydney, Sydney. A patient information video on Gamma Knife discusses the mechanism and benefits of Gamma Knife technology.

External beam radiotherapy (EBRT)

EBRT is delivered via a linear accelerator. The linear accelerator is an ionising, radiation-generating machine capable of producing radiation energies 1000 times greater than a conventional diagnostic x-ray unit. X-rays (also called photons) used in radiotherapy are in the magnitude of mega-volts (MV - millions of volts).[27] Electrons, the most common particle beam produced by linear accelerators, are used to treat superficial disease.[14] Photon or electron beams produced by a linear accelerator can be projected into a person from any angle. Photons, significantly more penetrating than electrons, are used to treat deep tumours.[14]

Types of EBRT

3D conformal radiotherapy (3DCRT) is used to tailor a conformal dose to a tumour, reducing the exposure of proximal normal tissues to as low a dose as possible.[32, 33] This technique is always planned using a planning CT scan and a 3D treatment planning system. The complexity of treatment field arrangements and dose calculations for this type of treatment means significantly more time must be spent to complete the planning procedure.

Intensity-modulated radiotherapy (IMRT) is a specialised EBRT technique ideally suited to delivering radiation to tumours that are close to or surrounding highly radiosensitive critical organs, such as the spinal cord, optic nerves or the rectum.[34-36] Treatment of these tumours with 3D conformal radiotherapy requires extremely complex field arrangements that require lengthy planning and may still not be able to deliver a high enough radiation dose to the tumour without risking unacceptable morbidity to proximal normal body tissues.[33, 34]

The most common conceptualisation of IMRT is multiple 'beamlets' added together for each treatment field, which results in a radiation beam with varied intensities. IMRT is delivered using a linear accelerator. Prostate and head and neck cancers are more commonly being treated with IMRT.[34]

Image guided radiotherapy is the term used to describe images taken before and during treatment.[22, 37] Image guided radiotherapy for prostate cancers can involve the implantation of gold seed markers directly into the prostate before treatment planning and treatment. Gold seed markers can be seen on the pre-treatment images and are used to track the position of the prostate relative to the treatment field positions to ensure that the tumour is accurately targeted throughout treatment.[38]

Total body irradiation (TBI) delivers a relatively uniform amount of radiation to the whole body, and can be used as part of the conditioning regimen for individuals before haematopoietic stem cell transplantation.[39]

Hemibody radiation delivers radiation to a large proportion of either the upper or lower body, in either a single fraction or over several fractions.[39] Uses include:[39]

- the management of individuals with widespread bony metastases
- the management of uncontrolled pain
- disseminated diseases such as mycosis fungoides.

Stereotactic radiosurgery is a 3D technique that targets intracranial lesions and delivers a desired dose in one fraction.[40] Radiosurgery techniques use a stereotactic frame fixed to the persons skull to provide immobilisation and accurate landmarks for localisation of the intracranial targets.[41] High doses of radiation are delivered to small or multiple intracranial lesions via the gamma knife, a cyclotron producing charged particle beams, or modified linear accelerator.[42, 43]

Intraoperative radiation therapy (IORT) is a single-fraction, external beam radiation treatment or high-dose-rate brachytherapy administered at the time of surgery. IORT enables a surgically exposed tumour or tumour bed to be treated while protecting surrounding organs and tissues. IORT may be used for tumours which cannot be resected effectively.[44]

Stereotactic body radiotherapy (SBRT) is a hypofractionated delivery of radiotherapy. The total dose of radiation is delivered in only one to five treatments. Defining characteristics of SBRT include:[38]

- precise immobilisation
- the ability to reproduce accurate position from simulation to treatment
- the ability to minimise normal tissue exposure
- precise accounting of organ motion
- extremely accurate targeting of the tumour and surrounding critical structures to avoid using stereotactic coordinates within the tumour or on the individual
- ablative dose fractionation delivered with sub centimeter accuracy.

Prominent sites of treatment studied to date include medically inoperable stage 1 NSCLC, as well as lung, liver and spinal metastases. Further clinical trials are needed to determine the optimal prescription, dose distribution and normal tissue constraints.[38]

Learning activities	
Completed	Activities
☐	1 Describe the rationale for TBI in conditioning regimens before haematopoietic stem cell transplantation.
☐	2 Outline components which would be included in an education session with a person before TBI.
☐	3 Summarise the common acute and chronic effects of TBI and interventions to prevent and manage these effects.
☐	4 Discuss the implications of new radiotherapy procedures which reduce treatment duration and consequently nursing contact with the person affected by cancer.
☐	5 Access High-dose-rate remote afterloaders for intraoperative radiation therapy[44] and: • complete the questions at the end of the article • outline the indications for IORT • discuss why IORT may be considered a good example of multidisciplinary team functioning. Justify your response with literature.

Brachytherapy

Brachytherapy is the temporary or permanent placement of a sealed or unsealed radioactive isotope into a body tissue or cavity. The rationale for using brachytherapy includes preservation of vital organ function, reduction of damage to surrounding tissues, improvement in control of local disease, and treatment of areas that may be at high risk for recurrence.[8]

Brachytherapy may be used for cancers of the endometrium, breast, cervix, lung, head and neck, colon, prostate, thyroid, and ocular melanoma.[45] Individuals receiving brachytherapy may be treated as an outpatient or inpatient, depending on the type of therapy to be delivered.[46] Due to the nature of the delivery of the radioactive source, specific safety precautions and procedures must be adhered to.

Brachytherapy types and techniques

Afterloading interstitial and intracavity brachytherapy systems[47]

- Guide wires are introduced into a cavity and iridium-192 wires are passed into the guide wires.
- Treatment generally takes five days.

Remote-controlled afterloading brachytherapy systems[47]

- An applicator is positioned adjacent to the cancer.
- Low dose machine uses a cesium source.
- High dose machine uses an iridium source.

Permanent seed implant (PSI)[42, 47, 48]

- Refers to the placement of radioactive seeds directly into a tumour, commonly within the prostate, using needles guided by imaging techniques.
- Iodine-125 or Palladium-103 are the radioisotopes commonly used, and they gradually release their radioactivity over a period of 6 to 12 months.
- The seeds become inert over time and remain in the prostate indefinitely.

Radiopharmaceuticals[47, 49]

- Unsealed radioactive source given by ingestion, inhalation or absorption.
- Used to concentrate a radioactive substance in a particular part of the body, to allow investigations or to elicit a treatment effect on the body area.
- Administered orally or by intravenous injection.
- Following administration, all body fluids are radioactive.
- Iodine-131 is used in the treatment of thyroid cancer and is given as a capsule which is soluble in water and excreted in the urine.

Learning activities		
Completed	Activities	
☐	1	Outline the education you would provide for a person admitted for treatment with iodine-131 for thyroid cancer to promote safety for the person and health workers.
☐	2	Describe interventions the SCN may use to ensure the psychosocial well-being of a woman having brachytherapy for cervical cancer.

Combined modality treatment (CMT)

In combined modality treatment (CMT), antineoplastic agents are delivered at specific, prescribed intervals with radiation treatment to elicit a targeted response.[50, 51] The treatment approaches may be termed:[52]

- neoadjuvant chemotherapy (administered before local radiation to shrink a tumour)
- concomitant therapy (administered during radiation to enhance or increase radiation cell kill)
- adjuvant therapy (administered after a course of radiation to control micrometastases and subclinical disease).

The goal of CMT is to achieve a greater therapeutic gain than can be obtained by using either therapy alone. Improved 'cell kill' in the oesophagus, rectum, lung and head and neck have been reported with CMT.[4, 53-55] Radiation effects are augmented in normal tissue when an antineoplastic agent is added to the treatment regime, causing normal tissues to become increasingly vulnerable to both acute reactions and chronic late sequelae. The inclusion of the antineoplastic agent(s):[54]

- creates a synergism with the local effects of the radiation therapy and sensitises the cells to the radiation cell kill
- improves tumour oxygenation and cell kill
- protects normal tissues in the radiation pathway,therefore allowing an increase in radiation dose
- plays a role in eradicating micrometastases due to systemic effects.

The impact and complexity of effects for people receiving this treatment may be increased, requiring targeted education and a range of specific supportive care interventions.[4, 56]

Learning activities	
Completed	Activities
☐	1 Discuss occupational health and safety considerations and the SCN responses to ensure safety for staff and the person undergoing treatment during concomitant therapy.
☐	2 Identify a CMT regimen, and: • identify the treatment approach • outline the therapeutic effects of CMT regimen • outline the acute and chronic effects related to the combined effects of radiation and the antineoplastic agent(s).

Treatment completion and management of responses to radiotherapy

Radiotherapy effects may have a debilitating impact on an individual's quality of life, and the severity and frequency of adverse effects may affect treatment delivery. The effect of radiation is a complex series of interactions that can occur within a fraction of a second or several years after treatment.[57]

While radiotherapy affects all body tissues in the path of the radiation treatment beam, every person will react differently to the radiotherapy due to a range of treatment factors and individual characteristics.[58] Factors influencing responses to ionising radiation include:[7]

- body site
- treatment intent (curative/palliative)
- dose
- treatment volume
- machine energy
- neoadjuvant chemotherapy.

People affected by cancer may experience varying degrees of emotional distress associated with the cancer itself, changing social roles and relationships, or existential concerns.[59] The individual's emotional response to radiotherapy may be impacted by:

- the severity of symptoms and specific side effects of treatment[60, 61]
- the need to be accommodated away from home for the duration of the radiation treatment
- difficulties managing in an unfamiliar environment, separated from supports
- long distance travel for treatment each day[62, 63]
- limited knowledge or resources to manage these problems[19, 64, 65]

Radiation treatment effects can be divided into acute and late reactions. Acute radiotherapy reactions occur within days to weeks after commencing treatment, and late effects occurring from weeks to years after completing treatment.[66] Healthy tissue responds to radiotherapy with an inflammatory response. The greatest adverse effects occur in tissues that are radiosensitive such as the skin and mucous membranes.[7, 23] The severity of effects is related to the cumulative radiation dose over time.[67, 68]

It has been identified that there is a lack of standardised assessment in the monitoring of radiation side-effects and cancer treatment toxicity. Symptoms develop in several stages, further compromising effective assessment and monitoring of toxicities associated with radiotherapy.[30]

Learning activity	
Completed ☐	Activity 1 Appraise current assessment tools in your health care facility for their capacity to effectively assess the following effects: • radiation skin reactions • xerostomia • psychological distress.

Acute effects

The following list outlines common acute radiation toxicities associated with specific treatment sites:[69]

Site	Common acute physical effects
Brain	• alopecia and scalp erythema • ear and external auditory canal • cerebral oedema • nausea and vomiting • somnolence syndrome.
Eye	• conjunctival oedema and tearing.
Head and neck	• oral mucositis • oral candidiasis • oral herpes • xerostomia • oesophagitis and pharyngitis • taste changes (dysguesia, ageusia) • laryngitis • dental caries.
Breast	• skin reactions • oesophagitis.
Chest and lung	• oesophagitis and pharyngitis • taste changes • pneumonitis.
Abdomen and pelvis	• nausea and vomiting • diarrhoea and proctitis • cystitis • vaginal dryness.

Learning activities		
Completed	Activities	
☐	1	Explain why some tissues are more prone to radiation effects than others.
☐	2	Discuss similarities and differences in the management of nausea and vomiting associated with radiotherapy from that associated with chemotherapy.

Managing acute treatment related effects

Individuals receiving radiation treatment often have multiple and complex care requirements and supportive interventions are required to maximise well-being and quality of life. Common effects specifically associated with radiotherapy include:

- fatigue
- radiation enteritis
- radiation skin reactions
- sexual dysfunction
- mucositis.

Fatigue

Fatigue is a significant symptom associated with radiotherapy. Affected individuals experience tiredness, weakness, exhaustion, lack of energy, malaise, and impaired ability to concentrate and complete activities of daily living.[69]

The incidence of moderate to severe fatigue following radiotherapy has been reported at between 32% and 59%.[30] The incidence and severity of fatigue is known to fluctuate over the treatment trajectory. The pattern of fatigue following radiotherapy differs depending on the site and disease.

Factors influencing the occurrence of fatigue include:[30]

- adjuvant therapy - hormone, chemotherapy, recent surgery
- age
- frailty and functional status
- site of radiotherapy
- dosage of treatment
- fractionation regimen
- advanced disease.

It is important to prepare people affected by cancer for the possibility of fatigue related to their radiotherapy. To prevent further anxiety, they should also be prepared for the potential severity and extended duration of fatigue following completion of treatment.[30]

Assessment is important in managing fatigue, which needs to be differentiated from depression. Anaemia related to disease, radiotherapy or adjuvant therapies also needs to be excluded. Subjective assessment using a 0 to 10 scale is recommended.[30]

Due to the lack of clear aetiology and mechanism of radiation-induced fatigue, interventions are mainly based on behavioural or psychosocial strategies. It appears that fatigue management needs to be individually tailored. Physical exercise and psychosocial interventions have been associated with positive effects against fatigue both during and after treatment for cancer.[70]

Evidence Summary - Fatigue

Key resources

NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines). Cancer-Related Fatigue Version 1.2013. National Comprehensive Cancer Network. 2013

Peter Mac: Practical ways of dealing with cancer related fatigue

Cancer Council (Victoria) 'Fatigue, coping with fatigue caused by cancer treatments' fact sheet

ONS Putting Evidence into Practice: Fatigue

Learning activity	
Completed	Activity
☐	1 Summarise evidence based recommendations for the prevention and management of cancer and radiotherapy related fatigue.

Radiation enteritis

Radiation enteritis is a common effect of radiotherapy with fields that involve the pelvis or abdomen. Symptoms include nausea, diarrhoea, abdominal cramps and proctitis.[71]

Acute symptoms of nausea, diarrhoea and abdominal cramps can be attributed to the inherent sensitivity of the epithelial cells in the intestinal mucosa caused by rapid cell division. Damage is manifested in the stem cells and the intestinal villi become shortened, reducing the tissue surface available for absorption. Malabsorption of bile acid and of carbohydrate products and neuroendocrine stimulation are mechanisms associated with radiation enteritis.[30]

Diarrhoea is the most common acute side effect of radiation to the abdomen and pelvis and may vary from mild to severe. Diarrhoea may be a treatment-limiting side effect and requires careful monitoring and swift treatment. The individual may also experience abdominal cramping, tenesmus, and proctalgia.[53]

These effects may be severe and impact on well-being, both physically and emotionally, as pain and discomfort and frequent trips to the toilet can interfere with sleep and rest patterns, and may limit normal activities.[71] Education, reassurance, a low residue diet and anti-diarrhoeals are beneficial in managing this symptom.[72]

Key resource:

Resource Document - Treatment Induced Diarrhoea. eviQ, 2014

Learning activity	
Completed	Activity
☐	1 Provide evidence based rationale for the following interventions in the management on acute radiation enteritis: • low-fat diet • low-residue diet • anti-diarrhoeal medication • sucralfate.

Radiation skin reactions

The skin response to radiation depends on numerous radiation- and individual-related factors and may vary in intensity and duration.[50, 73] The single most important factor is the location of the radiation field.[69] Nursing interventions are targeted at the assessment of skin reactions, teaching skin care and managing skin breakdown if it occurs.

Acute effects of radiation skin reactions are visually assessed and defined in stages from erythema to dry or moist desquamation.[69] Digital photography has been shown to be an effective tool for recording skin erythema.[30] Tools have been developed to ensure a consistent approach to assessment:

- Radiation-induced skin Reaction Assessment Scale (RISRAS). eviQ, 2014
- Skin Toxicity Assessment Tool (STAT) Radiation Oncology. eviQ, 2014

Education on the basic principles of skin care in radiation oncology includes avoiding mechanical, thermal and chemical irritation. Radiation treatment has a drying and irritant effect on skin, and recent studies have supported the application of a moisturising cream to the treated area at least twice a day from the beginning of treatment.[20, 67, 74]

The goals of skin care management are to enhance comfort, promote healing, minimise trauma and prevent infection if skin breakdown occurs.[69]

Dressings

Dressings are required once the skin has broken. Exposure of superficial nerves may cause moderate to severe pain. Sera may be released from damaged cells, and dressings need to be moist and non-adherent so that new epithelial cells are not separated from the vascular bed. A wound with serous loss is a potential site for infection, and the dressing needs to maintain cleanliness and prohibit the growth of damaging microorganisms.

Dressings to broken skin areas also need to protect against the friction of clothes and other irritants. Hydrogel and hydrocolloid wound dressings can provide protection, and maintain a moist, healing environment.[67, 72, 75]

Key resource:

Resource Document – Management of Radiation Induced Skin Reactions. eviQ, 2014

Learning activities	
Completed	Activities
☐	1 Describe the clinical presentation and physiological rationale to the following tissue responses to radiation: • erythema • pruritus • hyperpigmentation • dry desquamation • moist desquamation.

☐	2	Appraise the effectiveness of current tools in your health care facility to assess radiation skin reactions.
☐	3	Summarise current evidence based information you would give to a person affected by cancer regarding a skin care regimen during radiation therapy.
☐	4	Summarise evidence based recommendations in the treatment and management of the following radiation skin reactions: • erythema • dry desquamation • moist desquamation.

Sexual dysfunction

Sexual desire, function and fertility are significantly affected during radiotherapy. The incidence of sexual dysfunction varies considerably in studies, and it is notably difficult to distinguish the causative factors.The cause of sexual dysfunction is likely to be multifactorial with radiotherapy or adjuvant therapies, disease, social and cultural factors and other symptoms affecting the individual.[30]

Women treated with radiotherapy for gynaecological cancers may experience changes in the vaginal canal and ovaries, which may lead to effects such as:[30]

- decrease in vaginal lubrication and sensation
- narrowing and lack of elasticity in the vaginal canal
- cessation of ovulation
- pain during intercourse
- post-coital bleeding.

Vaginal stenosis and adhesion may be prevented using a vaginal dilator and douche as part of sexual rehabilitation after gynaecological radiotherapy. The use of lubrication for a dry vagina reduces irritation and pain, and different positioning may reduce the discomfort associated with decreased elasticity and scarring.[30]

Men receiving treatment for genitourinary cancers may experience:[30]

- impotence
- reduction in libido
- erectile dysfunction
- cessation of sperm production
- pain on ejaculation
- permanent decrease in semen volume.

Assessment of risk and appropriate referral for sexual counselling is an essential element of the role of the nurse in the radiotherapy department.[30]

Resource link

Starting the conversation: supporting sexual wellbeing for women with breast cancer[76]
The psychosexual care of women affected by gynaecological cancers (or PSGC) website[77].
Sexuality, intimacy and cancer: a guide for people with cancer, their families and friends[78]
Resource Document - Management of Radiation Induced Vaginal Stenosis, eviQ. 2012

Learning activities	
Completed	Activities
☐	1 Reflect on previous discussions about sexual effects of treatment with people affected by cancer, and: • discuss barriers and enablers to the process • outline evidence based strategies recommended to improve communication about sexuality with people affected by cancer.
☐	2 Identify resources and referral pathways for a person at risk of sexual dysfunction in your health facility.

Mucositis

Mucositis refers to mucosal damage in the oropharyngeal cavity. Oral mucositis is an inflammatory response which occurs as a result of destruction of the mucosal or glandular cells within the head and neck area.[79]

When the salivary glands are included in the radiation treatment field, salivary secretion decreases rapidly, particularly if the parotid and submandibular glands are irradiated[80, 81]. As the radiation treatment accumulates, the mucosa becomes denuded, then ulcerated, and covered with an exudate.[81, 82]

Mucositis affects eating and nutrition and causes pain and sensations of coughing and choking. Changes in saliva, taste, and pain impact on an individual's quality of life.[30] The degree of mucositis and vulnerability of the individual depends on treatment factors such as:[30]

- radiation regimen
- dose
- fractionation
- area and volume
- anatomic location.

Individual factors that increase risk of mucositis include:[30]

- age
- oral hygiene
- smoking / alcohol
- poor dental hygiene
- traumatising agents, i.e. dentures
- large amalgam fillings
- chemotherapy
- fungal infections.

Distress from the symptoms of mucositis may be reduced by providing information, early assessment and support to provide symptomatic relief and prevent secondary infections. Assessment of the oral cavity before treatment may eliminate sources of infection and chronic irritation.[30]

Prior to radiation to the head and neck area individuals should have an assessment with a dentist, and diseased teeth should be removed. If healthy teeth remain in the treatment field, the patient should begin daily fluoride treatment to prevent the development of future dental caries.[72]

Key resource:

Resource Document – Management of Radiation Induced Xerostomia. eviQ, 2014

Resource Document – Oral Mucositis – Assessment and Treatment. eviQ, 2014

Learning activities	
Completed	Activities
☐	1 Access the eviQ Resource Document Oral Mucositis – Assessment and Treatment and: • summarise current recommendations for the prevention and treatment of oral mucositis in individuals receiving radiation therapy • Appraise the oral assessment process within your health care facility.

Late effects

Late or delayed effects of radiation treatment can become apparent months to years after radiation treatment, and are related mainly to vascular and connective tissue changes as a result of chronic inflammatory effects.[30, 72]

Skin and mucous membranes changes

Normal skin functions such as elasticity, flexibility, and protection against physical trauma may be impaired as a result of radiation damage to the skin and its appendages.[83] Late skin effects include:[75]

- fibrosis
- atrophy
- altered pigmentation
- slow healing of trauma
- telangectasia (dilated vascular channels which may be seen within one to two years after completion of treatment).

With high doses of radiation there may be:

- loss of sebaceous and sweat gland activity
- hyperpigmentation
- fibrosis of the subcutaneous tissues
- impairment of lymphatic drainage.

Late effects of radiation to the oral cavity may result in tooth decay and changes in the structure of the gums. Trismus is the reduced capacity to open the mouth due to the result of scar formation following surgery which leads to contraction of the muscles of mastication.[84]

Tooth decay and caries may occur as a result of the decreased saliva and from radiation damage. The ultimate radiation insult to the structure of the mouth is osteoradionecrosis.[72]

Bowel dysfunction

Late effects of radiation enteritis occur from six to 18 months following treatment. Symptoms may be insidious in onset and include colicky abdominal pain, weight loss, or bleeding from the rectum, or diarrhoea. Late effects include proctitis, colitis, enteritis, ulceration, fistular formation, and obstruction.[30]

Genitourinary dysfunction

Radiation to the female pelvis may result in:[85]

- inflammation
- mucosal atrophy
- lack of elasticity
- ulceration of the vaginal tissue
- vaginal stenosis.

Vaginal stenosis is a late effect following external beam and/or brachytherapy radiation and occurs as a result of the formation of adhesions and fibrosis of upper vaginal tissues, which in

turn leads to contraction of the vaginal vault, and finally to a shortened vagina. This may result in discomfort and difficulty with penetration in sexual intercourse, and can hinder medical examination of this area of the body during routine follow up.[86]

Learning activities		
Completed	Activities	
☐	1	Access the article Management of Radiation Wounds[87], and summarise the chronic effects of radiotherapy on skin and wound healing.
☐	2	Access a current text, and: • describe the pathogenesis of osteoradionecrosis of the mouth • summarise prevention and management strategies of osteoradionecrosis.
☐	3	Provide evidence based rationale for the following interventions in the management on chronic radiation enteritis: • antibiotics • steroids
☐	4	Access the article A study to investigate women's experiences of radiation enteritis following radiotherapy for cervical cancer[88] , and summarise the impact of chronic radiation enteritis and the role of nurses in managing this symptom.
☐	5	Outline information resources you could give to a woman following treatment for a gynaecological cancer to prevent vaginal stenosis.
☐	6	Access a current text and describe the late effects associated with the following sites: • central nervous system • chest.
☐	7	Discuss the role of the MDT in the management of late effects.

Glossary of terms used in radiation oncology

Term	Description
3-dimensional conformal radiotherapy (3DCRT)	A form of external beam radiotherapy delivered by linear accelerators where a 3D CT data set and a 3D computer planning system are used to define and calculate treatment fields to deliver a conformal dose to a tumour.
Afterloading	Remote loading of the radioactive isotopes after positioning of the applicators during surgery; used for brachytherapy.
Beam's eye view (BEV)	An image generated by a 3D treatment planning system that is similar to a conventional simulator radiograph with the field dimensions (including shielding) added to the image.
Brachytherapy	The use of radioactive isotopes inserted into either tissue (interstitial) or body cavities (intracavity) to deliver radiation close to a tumour bed.
Computed tomography (CT)	A form of radiographic imaging whereby multiple axial sections of a patient are scanned. The images are displayed in a greyscale and are a useful tool for viewing cross sectional anatomy. These sections can be viewed slice-by-slice or combined to form a 3D image of the patient.
Dose	The amount of radiation in the form of Gys to be delivered to the target.
Digitally reconstructed radiograph (DRR)	An image generated from a 3D CT scan of a patient that looks like a conventional radiograph.
Electron	The smallest particle of negative electricity. Electrons have a useful property of limited penetration of tissue as opposed to the exponential absorption that occurs with x-rays.
External beam radiation therapy (EBRT)	Radiation therapy delivered at a distance from the body, most commonly by a linear accelerator. (Also called teletherapy.)
Field	An area treated by the radiation beam at a particular angle. A radiotherapy treatment can be delivered using a single field or multiple fields at different angles.
Fractionation	The total dose of radiation to be delivered is divided by the daily dose (daily fraction) which gives a cumulative effect to the tumour but enables normal surrounding tissue to repair.
Gamma radiation	A photon produced from radioactive material.
Gray (Gy)	The modern unit of radiation dosage, equivalent to the deposition of one joule of energy per kilogram of tissue.

Image guided radiation therapy (IGRT)	The use of imaging technologies on the linear accelerator to enable accurate daily treatment delivery.
Intensity modulated radiotherapy (IMRT)	A form of EBRT where each treatment field is designed to have a highly varied (or modulated) intensity to treat tumours to a high dose that are adjacent to or surround radiosensitive normal tissues.
Linear accelerator (Linac)	A radiation treatment machine which produces beams of x-rays or high energy electrons that are focused on to a tumour within the body. Linear accelerators deliver millions of volts of radiation (MeV), depending on the type of machine and output.
Megavolts (MV)	A megavolt (millions of volts) is the unit of measurement of photons greater than 1 MeV energy. These are produced by Cobalt-60 apparatus and linear accelerators.
Photon	Energy produced by either gamma or x-rays. Commonly used to treat deep-seated tumours.

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