Anaesthesia for Paediatric Radiotherapy

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KEY POINTS

- Radiotherapy is a common treatment modality in paediatric cancer.
- Advancements in radiotherapy techniques have improved efficacy whilst reducing damage to normal tissue.
- Anaesthesia for radiotherapy is mostly required for anxiolysis and immobility.
- There are a number of specific considerations for the provision of safe paediatric anaesthesia for radiotherapy.

INTRODUCTION

Paediatric cancer contributes to less than 1% of all diagnosed cancers and demonstrates characteristic patterns of tumour type and incidence.[1] Despite being rare, after accidents, it is the second leading cause of death in children ages 1 to 14.[2,3] The UK National Cancer Registration and Analysis Service cites that the most common types of paediatric malignancies are leukaemia, central nervous system cancers, and lymphoma. This is a pattern that is seen not just in the United Kingdom, but also worldwide.[3] Radiotherapy is an important modality in the curative and palliative management of many paediatric malignancies: 40% to 50% of children with amenable types of cancer receive radiotherapy as part of their initial treatment.[4] Treatment with radiotherapy can be in isolation or in combination with chemotherapy and surgery.

Sedation and/or general anaesthesia is commonly utilised to facilitate radiotherapy treatment in children. Precise positioning and immobilisation of the patient during treatment is essential to ensure that high-energy radiation can be delivered to the tumour, whilst minimising exposure to healthy surrounding tissues.[5] Anaesthesia for paediatric radiotherapy poses its own unique set of challenges. This article aims to detail the different types of radiotherapy and corresponding anaesthetic considerations.

WHAT IS RADIOTHERAPY?

Radiotherapy is the treatment of disease with ionising radiation. It has been used in the treatment of cancer since the early 20th century and has evolved technologically over the last 100 years. Modern radiotherapy techniques are sophisticated and effective, resulting in minimal damage to healthy nondiseased tissue and fewer side effects.[6]

Types of Radiotherapy

Broadly speaking, there are 3 different types of radiotherapy used for paediatric patients. Two are external-beam therapies: photon beam radiotherapy and proton beam radiotherapy. A third type, brachytherapy, is a short-distance method.

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Photon Beam Radiotherapy

Photon beam radiotherapy is a form of ionising radiation composed of high-energy electromagnetic waves. As photons travel through the body, they deposit energy when interacting with electrons of both diseased and healthy tissue.[7] This transfer of energy leads to cellular death by 2 distinct mechanisms: (1) direct cellular DNA damage, which results in single- and double-stranded DNA breakage, leading to cell death, and (2) indirect damage by generation of cellular free radicals leading to single- and double-strand DNA breakage and subsequent cell death.[8]

Three-dimensional conformal radiation therapy and intensity-modulated radiation therapy are now the treatment standards in most hospitals for photon beam therapy:[9]

Three-dimensional conformal therapy uses images from computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography scans to plan a treatment area—a process called 'simulation' or 'planning'.[10] This information allows precise irradiation of the tumour whilst minimising damage to nondiseased tissue.

- Intensity-modulated radiation therapy is a subtype of 3-dimensional conformal therapy and enables radiation beams to be aimed at the tumour from a number of different angles. This allows manipulation of the radiation dose, concentrating it in certain areas of the tumour.[10]
- Despite advances in beam conformity and target accuracy, photon radiation therapy has limitations. A photon's peak dose deposition occurs shortly after entering the body and decreases exponentially until it exits.[11] With target tumours located at a depth greater than 3 cm,[12] each photon delivers more radiation to healthy tissue than to the target tumour.[7] Consequently, there is a high risk of physical side effects, as detailed later in this article.

Proton Beam Radiotherapy

In proton beam radiotherapy, charged hydrogen particles or protons[7] are accelerated at a target tissue. With a similar mechanism of cell death to photon therapy, proton radiation possesses physical properties that make it superior in minimising side effects. Protons travel in a straight line and deposit their energy consistently as they travel towards a target tissue. Due to a unique physical characteristic called the Bragg peak, there is a steep fall-off of energy when the beam stops.[13] The resulting outcome is concentrated radiation in the tumour, which does not travel any farther through the body.[7]

This is particularly relevant when treating tumours that are in close proximity to critical organs. Ionisation of healthy tissue is reduced, as is the total dose of radiation. Proton beam is an evolving therapy and the number of treatment centres is increasing worldwide. See Figure 1 for a comparison of photon versus proton therapy.

Brachytherapy

Brachytherapy is the implantation of a radioactive source in close proximity to the tumour load.[7] This method allows focal radiation delivery, whilst limiting damage to surrounding healthy tissue.[11]

There are 2 types of brachytherapy, temporary and permanent:

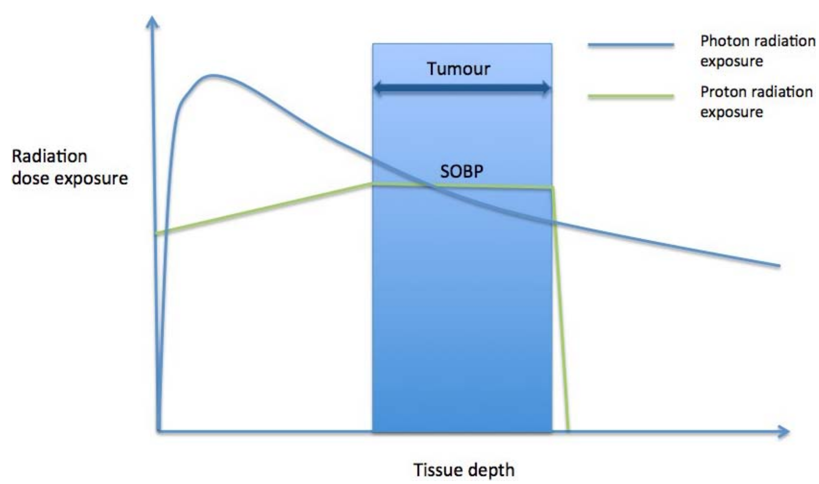

Figure 1. Comparison of ionising radiation exposure in 10-MeV photon versus proton therapy. SOBP, spread-out Bragg Peak, the therapeutic radiation distribution. Adapted from Rombi et al 2014.[12]

- In temporary brachytherapy radioactive material is placed into or near the tumour for a specific amount of time using a delivery device (catheter, needle, applicator) and then removed.
- In permanent brachytherapy a radioactive seed is placed in or near the tumour permanently. The seeds will be radioactive over a variable time period, depending on the properties of the material and rate of decay.[11]

Brachytherapy is infrequently used in paediatrics. It is sometimes used with a small tumour burden and localised disease, such retinoblastoma or sarcoma.[7]

SIDE EFFECTS OF RADIOTHERAPY

Side effects from radiotherapy may be generalised or specific to the part of the body being treated (Table 1). However, improvements in radiotherapy techniques have enabled enhanced precision and accuracy of ionising dose delivery. This maximises effective treatment, whilst minimising damage to normal tissue.[7] Damage of normal tissue can be particularly devastating in children due to their immature, developing body systems.

LOGISTICAL CONSIDERATIONS IN PAEDIATRIC RADIOTHERAPY

External-Beam Radiotherapy (Photon and Proton)

Despite being a nonpainful procedure, anaesthesia for anxiolysis and immobility in younger patients is often required for treatment planning (scans and moulding) and for daily treatment. Most patients receive a series of daily outpatient treatments (Monday to Friday). The number of treatments varies but typically lasts 3 to 6 weeks depending on tumour type, stage, location, and size and goal of treatment (palliative versus curative). Treatment time (including set-up) varies greatly from tens of minutes to several hours, depending on the area treated.

Imaging is an important component of radiotherapy planning and it is a common requirement for CT and MRI scans to be performed as well as a transfer to the therapy suite whilst the patient undergoes a single general anaesthetic. Imaging may need to be repeated during the treatment course to monitor the tumour load and allow modification of the treatment plan, if required. The logistics required for safely transferring an anaesthetised child between the various areas should be considered during anaesthetic planning.

Depending on the treatment area, a mould may be used. This is prepared during treatment planning and is typically either a mask placed over the face or a cast into which the body area is placed. Moulds hold the treatment area in a fixed position to facilitate patient set-up and accuracy of treatment.

Short-Term Side Effects
Emotional upset (patient and family) Fatigue Nausea and vomiting Altered taste Diarrhoea Hair loss Headache Blurry vision Skin changes, including radiation burns Mucositis
Long-Term Side Effects
Claustrophobia Regression in behaviour Tissue scarring Hormonal dysfunction Fertility impairment Abnormal growth Neuro-cognitive deficit Urinary and bladder changes Induction of secondary malignancy Risk of vascular complications such as stroke and heart disease

Table 1. Examples of short- and long-term side effects.[14]

Figure 2. A child receiving proton beam therapy to the posterior fossa. The position of the head is away from the anaesthetic machine. An extended circle circuit is used to deliver oxygen via the laryngeal mask. A warming blanket is applied over the body.

Anaesthetic technique varies from sedation to general anaesthesia depending on the age of and cooperation by the child (Figure 2). Oxygen may be delivered via nasal tubing, face mask, or laryngeal mask, with the face mould (if in use) modified to accommodate. Endotracheal tubes are avoided unless clinically necessary (see Specific Anaesthetic Considerations). Maintenance of anaesthesia can be attained by using a volatile or total intravenous anaesthesia technique. The patient's head is typically positioned away from the anaesthetic machine on a mobile table. Extended-length oxygen and suction tubing, anaesthetic circuits (circle and Mapleson F), and a stepladder may be required to safely manage the patient's airway. Extended-length intravenous giving sets may also be a consideration when using total intravenous anaesthesia.

Brachytherapy

Unlike external-beam radiotherapy, brachytherapy is a stimulating procedure. Local anaesthetic infiltration and/or analgesia are often necessary. However, brachytherapy is not painful once the delivery device is removed or the permanent seeds are implanted. The aim of anaesthesia is immobility to facilitate accurate insertion of radioactive material. Anaesthetic choice (local, regional, or general) is dependent on the body area requiring treatment, the type of brachytherapy, and the anticipated duration of the procedure:

- Permanent implants require a 'day-case' procedure for insertion, which may take several hours for accurate placement.
- Temporary implants may use either high- or low-dose rates.
  - High-dose-rate implants may be a single 'day case' procedure or consist of daily treatments over the course of 1 to 2 weeks. It may take several hours to accurately place the delivery instruments. Radiation is typically delivered over 10 to 20 minutes, and the source is removed at the end of the procedure.
  - Low-dose-rate implants are very rare in children. When used, the radiation source is kept in place for several days. Anaesthesia required for insertion and, sometimes, removal.

SPECIFIC ANAESTHETIC CONSIDERATIONS

Environment

Basic considerations are as follows:

- 'Remote-site anaesthesia' with restricted access to the patient: Especially during imaging (CT and MRI) and radiation delivery (high-dose-rate or external-beam treatment), staff members leave the room and the patient is observed using video and monitoring screens.
- Loud ambient noise: For some imaging and in the external-beam treatment area, ear protection should be considered.
- Radiation safety: There should be protection and monitoring for staff.

- Reduced mobile phone and wireless Internet reception. This inconvenience is a consequence of the buildings structural design, a safety feature that reduces the escape of electromagnetic radiation. It conversely reduces interference with patient monitoring.

Patient

Communication Between Treatment Centres

Treatment centres may treat patients from a wide catchment area. Good communication with referring centres is essential for patient safety. Previous medical and anaesthetic records and information regarding complex cases should be shared with the anaesthetic team.

Staff Selection

Patients requiring sedation or general anaesthesia should be cared for by paediatric-trained anaesthesia providers, anaesthetic assistants, and recovery staff.

Patient Health Considerations

Children receiving radiotherapy should not be regarded as otherwise healthy 'ASA 1′ patients. In addition to local and systemic effects of the tumour, many of these children are receiving concurrent chemo- and radiotherapy, with associated toxicities and side effects of both treatment modalities.

- Patients often have delayed gastric emptying (from opioids, comorbidities, stress, and/or chemotherapy). They are at an increased risk of gastric content aspiration.
- Radiotherapy is not an elective procedure. Children may have infections or illnesses that carry an increased risk of complications under general anaesthesia. There must be careful consideration of the risk/benefit of proceeding versus delaying treatment. Choice of airway adjunct (endotracheal tube versus supraglottic airway device) should be decided upon assessment of the patient and their current state of health.

Additional Considerations Specific to External-Beam Radiotherapy (Photon and Proton)

Long-Term Intravenous Access

This is often required to avoid the need for daily cannulation and facilitate safe provision of anaesthesia. Strict attention to maintaining line asepsis is paramount in these typically immunosuppressed children. The line should be flushed at the end of the procedure to ensure that any residual drug is removed, minimising the risk of inappropriate drug administration.

Airway Oedema and Swelling

Near-daily airway instrumentation may be required for this therapy, with associated soft tissue damage and oedema. The risk of airway swelling increases if the airway is within the treatment field (eg, tumours of the head and neck). Laryngospasm is a recognised complication, particularly if there is soiling of the airway following instrumentation in patients with significant chemotherapy-induced mucositis. Recurrent endotracheal intubation carries the additional risk of subglottic stenosis.

Pressure Care

The treatment table is typically hard and long treatment times leave patients vulnerable to pressure damage. Skin within the treatment field is particularly vulnerable.

Maintenance of Normothermia

The child may need to partially undress to facilitate positioning by aligning markings (eg, on the skin or mould) with lasers (Figure 3). Clothing, blankets, and/or warming devices may not be permitted near the target radiotherapy site as they may cause radiotherapy deflection, scattering, or dampening. Raising the ambient temperature and using warming devices (applied to outside of the treatment field) should be considered.

Avoidance of Drug Double-Dosing

Many patients take regular antiemetics and analgesics and therefore a careful drug history must be taken on each treatment day to avoid potential double-dosing.

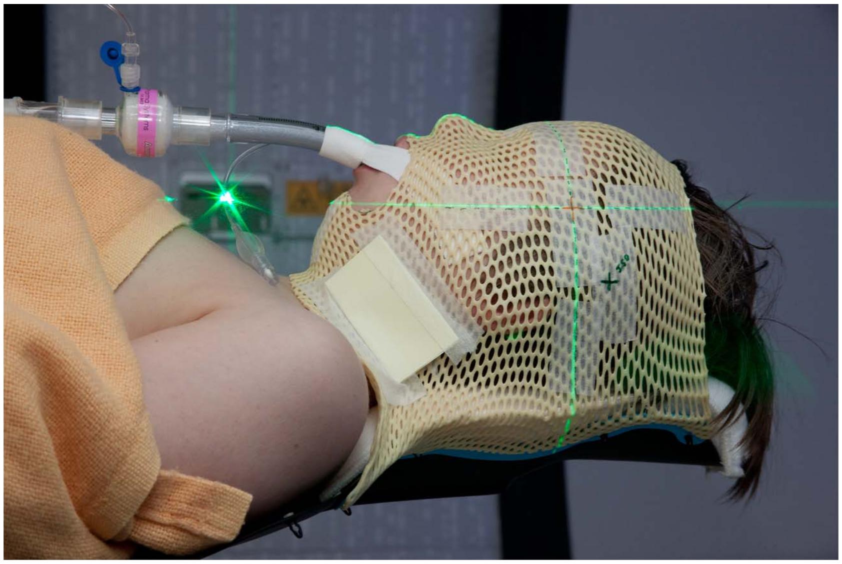

Figure 3. Demonstrates a typical face mould and the use of lasers to facilitate accurate positioning.

Laboratory Values

Laboratory values should be monitored at regular intervals (eg, full blood count, renal function), the frequency of which should be agreed between the clinical oncology and anaesthetic teams. The minimum acceptable 'count' levels (eg, of haemoglobin and platelets) should be confirmed with the clinical oncologists not only for reasons of safety, but also for efficacy of treatment.

Face Moulds

These moulds, applied over face, neck and shoulders, may pose the following challenges. They may

- interfere with airway patency,
- disrupt the position of any airway device in situ,
- obstruct the movement of the chest with ventilation,
- delay immediate access to the airway in an emergency, and/or
- result in skin damage or pressure sores.

SUMMARY

Over the last 25 years there has been much improvement in cancer care for children. Advances in radiation therapy techniques (such as 3-dimensional conformal therapy, intensity-modulated radiation therapy, and proton beam therapy) and improved availability of radiotherapy centres have meant that an increasing number of paediatric cancer patients are able to access increasingly safe and effective radiotherapy treatment.

Paediatric radiotherapy is an area of practice that possesses its own unique challenges. An understanding of the types of radiotherapy, planning and treatment regimens, environmental considerations required for its safe delivery, and associated distinctive anaesthetic challenges are essential for delivery of safe anaesthesia.

ACKNOWLEDGEMENTS

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