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OUT OF THEATRE ANAESTHESIA
THE RADIATION ONCOLOGY SUITE
"Beam me up…"

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OUT OF THEATRE ANAESTHESIA, THE RADIATION ONCOLOGY SUITE "BEAM ME UP…"

INTRODUCTION

The role of the anaesthesiologist has grown in recent times to service an expanding need for the provision anaesthetic services beyond the confines of the operating room. These out of theatre (OOT) anaesthetics pose a unique set of challenges, both expected and unexpected. Hence, they often require additional foresight, planning, vigilance and sometimes creativity on the part of the attending anaesthetist.

The challenge lies in preserving and applying the standards and principles that underpin safe anaesthetic practice outside of the familiar comforts of theatre, in what are considered relatively 'hostile' environments. [1,2] The anaesthesiologist must tailor his or her approach based on a firm understanding of the patient's pathophysiology, the intended procedure and its implications, available resources and the risks and benefits of different anaesthetic techniques.

[1] In most institutions, paediatric patients remain the commonest patient subgroup for whom procedural sedation or anaesthesia is called upon, both for diagnostic and therapeutic purposes. A significant demand does exist for adult patients as well, particularly for those with developmental disabilities, claustrophobia or those limited by pain or ability to comply with the strict requirements of a motionless patient held in a specific position for extended durations of time.[3,4]

Aims of peri-procedural drug administration:

1. To provide adequate analgesia, sedation, anxiolysis, and amnesia during the performance of a diagnostic or therapeutic procedure.
2. To control unwanted motor activity that interferes with optimal performance of the diagnostic procedure or image guided intervention.
3. To be able to rapidly return the patient to a state of consciousness.
4. To minimize the risks of adverse events related to the provision of sedation and analgesia. [4]

CHALLENGES OF ANAESTHESIA IN REMOTE LOCATIONS

There are a multitude of concerns when planning to conduct an anaesthetic or sedation outside of theatre. Fore mostly, the anaesthetist must contend with an unfamiliar environment, where appropriate anaesthetic equipment may be scarce, outdated or absent. This may necessitate repeated set up and quality checks each morning, which is both time consuming and increases the likelihood of equipment errors. The room layout itself is not primarily designed in a way that is conducive to providing an anaesthetic. [4] Limited space, bulky equipment and restricted access to the patient add to difficulty.

[1]Adequate electrical points may not be close at hand for anaesthetic apparatus, and provision may not be made for piped medical gas, scavenging or suction.Interventions are often conducted in isolated areas such as radiotherapy suites, day-case oncology units and radiology/imaging departments.[2, 5,6] This physical distance from main theatre adds further anxiety, as immediate assistance may not be readily available, as well as additional drugs or back up equipment. [7] Inconsistent staffing may add to the challenge.

Suboptimal assistance with lines, difficult airways, or anaesthetic emergencies or recovery may make for greater distress in already trying circumstances.[5,8,9] The patients that you may be called upon to anaesthetise may not always have undergone a preoperative assessment, and in some instances will present as day cases. This may result in patients with significant comorbidities presenting for anaesthesia without a prior thorough evaluation of fitness.

The large proportion of paediatric patients presenting for radiotherapy pose their own particular challenges. Low ambient temperatures required for cooling of high powered equipment can result in hypothermia, compounded by long procedures or those that require patient exposure. [1] Compatibility of all equipment with the remote location equipment must be confirmed before using any such device to avoid injury to personnel or patient. [7]

Monitoring challenges may hinder response time in the case of an adverse event, and physical barriers such as the patient positioning and immobilization devices make intervening immediately difficult to impossible.[1] A variety of complications may occur, including: death, hypothermia, airway difficulty, hypoventilation, aspiration, hypovolaemia, anaphylaxis, procedure-related complications, and exposure to staff (waste inhalational anaesthetics, radiation exposure).

[5]In 2009, the American Society of Anaesthesiologists (ASA) scrutinised their Closed Claims records over a 20 year period to ascertain the risk and safety of anaesthetic practice in remote locations.[3] Procedures for acute or chronic pain or obstetric indications were excluded. In this retrospective review 87 remote location claims and 3,287 theatre claims were examined.

Monitored anaesthesia care (MAC) was found to be utilised more in the out of theatre setting, compared to operating room claims. The most common respiratory complications out of theatre was hypoventilation and desaturation Inadequate oxygenation and ventilation was the most common respiratory claims event (21%) compared to only 3% of claims occurring in the operating room. 30% of these remote location claims could be attributed to an absolute or relative overdose of sedative, hypnotic, or analgesic drugs, with consequent respiratory depression. Other respiratory events included oesophageal or difficult intubation, and aspiration of gastric contents. Monitoring ventilation in these patients has been identified as one of the two key elements, along with pulse oximetry, in preventing serious complications such as hypoxia, brain injury, and death. [1, 5]

FUNDAMENTALS OF RADIATION THERAPY

In the USA, cancer is the most common cause of non-accidental death among children between the ages of 1 and 14 years, with a reported incidence around 16.7 per 100 000, carrying a mortality rate of 2.6 per 100 000. [3] In the UK there are about 1500 new cases of childhood cancer diagnosed each year, with cancer accounting for around 20% of deaths in the same age category. [6] The main therapeutic tools used in the treatment of cancer are chemotherapy, radiotherapy and surgery with benefits of prolonging longevity and enhancing quality of life. [8]

External beam radiation therapy (XRT) forms one of the cornerstones of the therapeutic armamentarium of paediatric oncological disease. Children with brain tumours, malignancies of bone and soft tissue, neuroblastoma, nephroblastoma, and Hodgkin lymphoma are commonly treated with radiation therapy .[3] Radiotherapy exerts its cytotoxic effects by the generation of free radicals that damage DNA. Well vascularised and oxygenated tissues, as seen in rapidly proliferating tumours, tend to provide better conditions for free radical formation.

Radiotherapy may serve as primary therapy, or as adjuvant or neoadjuvant therapy, and may serve curative or palliative purposes. [6,8] Benefits described include decreased pain, preserved organ function, and relief of obstruction in hollow organs. While the procedure itself is painless, optimal and safe delivery does require the patient to remain still, and alone in the radiation treatment room, for multiple daily treatments for up to 6 weeks.

The process can induce significant anxiety which demands the provision of sedation or anaesthesia, especially in younger age groups.[3,8] Advances in radiation therapy and newer modalities like proton beam therapy have enabled radiation oncologists to target tumours more successfully, while avoiding damage to normal tissues. Anaesthesiologists are increasingly being asked to provide sedation or anaesthesia to ensure a completely immobile patient during radiation therapy.[3]

The safety, preparation, and well-being of patients should represent the shared responsibility of a team encompassing the anaesthesiologist, oncologist, radiation therapists, and nursing staff. [8] Older children are often able to comply with these demands without the use of anaesthesia or sedation, and simple measures such as parental encouragement, diversion techniques and possibly the enticement of a small reward may be enough motivation to remain still. Younger children and infants may not be so reliably compliant or receptive. These are the patients that represent the majority of anaesthetic cases. Indicators that suggest the need for anaesthesia include young age, anxiety, treatment complexity (e.g. prone position), emotional immaturity for age, and a history of noncompliance [8]

THE ONCOLOGY PATIENT

The oncology patient population poses several considerations that will ultimately inform risk in terms of patient morbidity and aid in anaesthetic planning and technique. The disease process itself may pose certain implications, largely dependent on type, site and physiological imposition on functional reserve. [6] Further considerations centre on the effects of cytotoxic treatments and comorbid conditions. Patients may be debilitated either as a consequence of their cancer or as a result of their treatments. [4] The cancer itself may have consequences secondary to a mass effect, metabolic effects, metastatic involvement.

General:
Malnutrition, weight loss, anaemia, fatigue, skin lesions, and hair loss in the area of treatment may occur.

Airway:
Primary tumours directly involving the airway are relatively rare in children, though if present, may complicate airway maintenance and may only be unmasked when supine or anaesthetised. Similarly, enlarged tonsils and adenoids or large cervical lymph nodes secondary to leukaemic infiltration may cause stridor or obstructive sleep apnoea with its associated problems.

Mucositis associated with chemotherapy may lead to delicate, friable mucosa prone to bleeding if instrumented. Immuno-compromised children are also at risk of opportunistic infections of the upper airway.[6] Should the patient have serious intercurrent evidence of upper respiratory infection, the risks of proceeding with anaesthesia should be balanced against the benefits of the radiotherapy and implications of postponing it.

The possibility of cancellation should be discussed in advance with the radiation oncologist and parents in the event of related complications during the course of therapy. [3]Anterior mediastinal masses require careful consideration. Lower airway and vascular compromise may occur.

Patients with compressive effects on the respiratory (dyspnoea, wheezing), or cardiovascular systems (superior vena cava syndrome) are particularly high risk, and postural effects must be noted.

Central nervous system and neuromuscular:
Neurocognitive changes or leukoencephalopathy can occur.
Acute neuroendocrine dysfunction resulting from irradiation of the hypothalamus or pituitary (chronic dysfunction is associated with younger age at commencement of treatment) [3]. Brain lesions may be associated with raised intracranial pressure [6] Para-neoplastic syndromes like Eaton–Lambert may occur.

Gastrointestinal:
Total body irradiation and radiation to the abdomen can lead to nausea, vomiting and diarrhoea. Delayed gastric emptying is also associated with chemotherapy and the effects may be additive. [6]

Respiratory:
Malignant pleural effusions if present may require therapeutic thoracocentesis to allow the patient enough symptomatic relief to assume an appropriate position for the procedure.

Chemotherapy-Induced Lung Disease:
This may occur in around 10% of patients on chemotherapy. Commonly implicated drugs include busulfan, bleomycin, methotrexate, cyclophosphamide, and carmustine. Patients may present with dyspnoea with a non-productive cough and fever. Bleomycin can lead to broncholitis obliterans with organising pneumonia (BOOP), eosinophilic hypersensitivity and more commonly bleomycin-induced pneumonitis (BIP) which can progress to pulmonary fibrosis.

Acute non-cardiogenic pulmonary oedema (bleomycin, interleukin-2), bronchospasm (vinblastine, methotrexate) and pleural effusion (methotrexate) may occur. Late onset disease is more common and usually manifests as pulmonary fibrosis (bleomycin, mitomycin, bulsulfan). [6]

Radiation-Induced Lung Injury:
Radiation pneumonitis may present acutely within 6 to 8 weeks of radiotherapy and presents in a similar fashion to chemo-induced lung injury. Resolution generally occurs within 6 to 8 weeks. Pulmonary fibrosis, if it develops is localized to the area irradiated. Radiotherapy and chemotherapy may be synergistic in producing pulmonary toxicity. Functional assessment of respiratory affectation (pulmonary function tests) may show a mild reduction in forced vital capacity (FVC). A reduced diffusing capacity of lung for carbon monoxide (DLCO) may be evident as well.

Cardiac:
Chemotherapy-Induced Cardiac Disease
Chemotherapeutic agents may precipitate arrhythmias, myocardial ischemia, endomyocardial fibrosis, cardiomyopathy, and congestive cardiac failure as well as pericardial disease. Paclitaxel - asoociaated with Ventricular tachycardia/ bradyarrhythmias/ heart block. 5FU- associated with myocardial ischaemia
Anthracyclines- known inducers of a cardiomyopathy [4, 6]

Radiation-induced cardiac injury- Radiation therapy to the thorax can damage the pericardium, myocardium, heart valves and coronary vessels. [6] Some malignancies may be associated with other medical conditions (e.g. Down's syndrome) which carry increased risk of cardiac anomalies. Tumor Lysis Syndrome may occur after the initiation of chemotherapy. The breakdown and release of intracellular contents result in hyperkalaemia, hyperuricaemia, hypocalcaemia, cyanosis, circulatory collapse, and acidaemia.

Psychological:
Cancer and its treatment can have significant psychosocial fallout for afflicted children and their families.[3] Anxiety and depression are common diagnoses in this patient population. Organic disorders or delirium as a result of pain medicines or chemotherapeutic agents can occur as well.[5,10]

Elderly Patients:
Up to 70% of new cancers are diagnosed in the elderly population who generally have comorbidity or degenerative diseases requiring their own therapeutic management. [6,11]

THE RADIATION ONCOLOGY SUITE

A basic understanding of what occurs and what is required in the oncology suite can assist the anaesthetist in planning and lessen the anxiety of working in this foreign environment. [8] The goal of the radiation therapy is to deliver tumouricidal doses of radiation to areas of tumour while limiting damage to adjacent normal tissues.[3] Radiotherapy in paediatric patients is indicated for three main groups of cancers:

- Brain tumours: gliomas and medulloblastomas
- Tumours outside the central nervous system, e.g. neuroblastoma, lymphoma, rhabdomyosarcoma, nephroblastoma
- Leukaemia e.g. cranial irradiation in ALL. [6]

The most prominent piece of equipment in the radiation oncology suite is the linear accelerator. Within it, electrons are accelerated to very high energy states in a vacuum and upon colliding with a material such as tungsten, emit energy in the form of X-rays. [3,8] This energy is then focused on specific sites within the patient in an effort to degrade the genetic material within the tumour cells.

The energy absorbed by the tissues is quantified in units of gray (Gy), which has replaced the old unit of rad. 1Gy = 1 J/kg = 100 rad units. The radio sensitivity of any cell is determined by its phase in the cell cycle and its nutrient and oxygen content. In general, normal tissues have a greater capacity to repair the ionizing effects of radiation, but require time to do so.

To provide time for healthy tissues to recover, the total dose of radiation is therefore divided into a series of fractions over days or weeks. Fractionation also allows tumour cells that were in a relatively radio-resistant phase of the cell cycle during one treatment to cycle into a sensitive phase. Photons (X-rays and g-rays) and particle radiation (electrons, protons, neutrons, a-particles, and b-particles) are the two major types of ionizing radiation.

Different types of lesions may respond better to a certain subatomic particle beam therapy which is selected by the radiation oncologist. Advancements in three dimensional imaging and computing power have produced modalities such as 3D conformal radiation therapy (3D-CRT) and intensity-modulated radiation therapy (IMRT) which help concentrate the energy beams on the tumour while decreasing radiation of normal tissue.

[3]This is of particular importance in children, where long-term detrimental effects of radiation to the developing tissues and the risk of secondary cancers raise concern. [3]The anaesthetic considerations are the same. [3,8]Toxicity from the effects of radiation therapy is unavoidable, and the developing tissues of children are particularly susceptible to acute and late effects from radiation.

Factors that determine the degree of toxicity include the total and fractionated dose received, the sensitivity of the tissue, the extent of tissue irradiated, and the time course of treatment. Recent surgery and concurrent chemotherapy also impacts toxicity. Damage to all organ systems, eyes, ears, teeth, and musculoskeletal deformities can occur, depending on the anatomical regions being irradiated.

Radiation therapy exposure is also associated with increased chance of developing secondary malignancies such as tumours of the CNS, soft tissue bone, and thyroid. [3] After a child is accepted as a candidate for XRT, a treatment planning session, called a simulation is often undertaken first. The physical set-up of the simulation suite is very similar to the XRT suite.

It serves as a kind of practice run for the actual treatment, to determine ideal patient positioning (as well as cooperation/tolerance) and allows the chance to take radiographs of the treatment field, plan radiation doses and points of entry.[8]This involves CT imaging, multiple measurements, and plotting of points on the child's body which serve as guides for future treatment.

These markings will remain on the patient for the duration of the therapy and may be reapplied by the therapist as necessary. Most patients can be treated in the supine position; however, craniospinal axis radiotherapy will often necessitate prone positioning throughout therapy, and is an important consideration for anaesthetic management [8]

An immobilization device is also moulded at this stage.[3] Immobilization casts of the head and/or body are employed to maintain immobility throughout the treatment sessions, to allow accurate directed therapy and hopefully limit damage to surrounding healthy tissue. The mould is comprised of a sheet of thermoplastic material, which is applied when warm, and as it cools it hardens, assuming the contours of the body part, usually the head.

The mould should support the head in a position that does not compromise the airway and airway devices are rarely required. A bite block can be inserted between the teeth as a spacer so as to be able to accommodate an oropharyngeal airway or a LMA later if required. [6] Inadequate immobilization can result in treatment failure as well as unnecessary damage to normal tissue [8] Radio-opaque shields if available may be positioned over radiosensitive organs (e.g., kidneys and eyes).

The final decision about the need for anaesthesia can often be made after the simulation. The simulation session may last between 20 to 90 minutes, depending upon the level of cooperation of the patient and the number and location of the fields that need to be delineated. Sub therapeutic levels of radiation are utilised at this stage, so the anaesthetic team can remain with the patient if desired with protective gear.

Acceptable positioning of the anaesthetic machine can be decided so as to be positioned out of the path of the lateral X-ray fields. Often this is toward the foot end. Circuit extensions and long gas sample lines are required. The first treatment session may follow the simulation or the patient may return within the next day or two. Therapeutic doses range between 25 and 80Gy, with a median value of 60Gy.

Lower doses are used for haematological cancers (leukaemia and lymphoma) and seminomas and higher doses are reserved for solid tumours such as sarcomas and gliomas. The total dose of radiation is typically divided or fractionated into 30 equal sessions and administered once daily, five days a week over consecutive weeks. Certain patients may benefit from more frequent dosing or ‘hyper fractionated’ irradiation involving more than one sessions a day.

Each field receives up to 90 seconds of irradiation. Thereafter, radiotherapists must adjust the position, reset the coordinates of the linear accelerator, and arrange the blocks so that the next field can be treated. Depending upon the number of fields (usually up to four), the entire treatment may take between 5 to

20 minutes. Total body irradiation (TBI) takes longer and involves prone positioning for half the treatment. At specified time intervals (usually once per week), the therapists will perform recheck radiographs to confirm accuracy of the targets and redirect the beam accordingly, which may add another 5 minutes to the procedure.[3,8]

ANAESTHETIC MANAGEMENT

Patient Assessment

All patients should be assessed. Ideally, the attending physician should evaluate the patient's medical condition to confirm suitability for the specific procedure and refer the patient to a pre-anaesthetic clinic, accompanied by a detailed referral letter and relevant investigations for further consideration by the anaesthesiologist.

[11]In reality, the vast majority of these patients however, are children scheduled as outpatients, limiting the amount of time for anaesthetic assessment. [7] A checklist-questionnaire outlining relevant information has been utilised in some units to gather important history regarding relevant patient data and chemotherapeutic and radiation information. Any cardiorespiratory compromise should be evaluated to ascertain the degree of physiologic reserve, tolerance of positioning, airway, anxiety levels, and aspiration risk.

The patient's ASA status should be determined as a guide to the patient's baseline functional capacity [2,4] A physical examination should include assessment of general, as well as focused cardiopulmonary and airway examination. In children, level of maturity, height and weight are important. The patient or parents are to be advised to continue routine medication, including all pain medications.

Older patients are instructed to be accompanied home and not to drive or be involved in any major decision-making for 24 hours after sedation [4] Parents are advised to follow fasting guidelines typical for all ambulatory surgical cases. If the tumour or medical condition is impairing gastric emptying, stricter guidelines may need to be enforced. Parents are encouraged to allow infants and children to ingest solid food and breast milk up to 6 hours before the procedure, and clear liquids are generally permitted up to 2 hours beforehand [3,8]

Preparation

It is well worth spending some time to familiarize oneself with the layout of the area and assess the adequacy of equipment and compliance with local guidelines and regulations. [11] All standardised monitoring, medications and equipment normally required for anaesthesia in theatre should be readily available.

This may often necessitate bringing these items from theatre on a daily basis or storing it close by, in the recovery area if possible. This includes clearly labelled, recently checked and easily accessible emergency equipment. A functional ambubag is important in case of ventilator failure. Universal precautions should be adhered to, and availability of gloves and masks where required and safe disposal of sharps are mandatory. [2] A portable suction should be available at all times. [1, 6,11].If a paediatric case, all appropriately sized paediatric equipment should be available.

A portable difficult airway cart or box is advisable. Adequate amounts of intravenous anaesthetic agents, inhalational agents, and other possibly required drugs should be available or prepared in advance.[2,4 ,11] The radiotherapy suites are often in the most geographically isolated areas of a hospital. Pipeline gases and vacuum are not always available. A checked full oxygen cylinder as well as a backup cylinder should be present. [6]

Staffing requirements:

The personnel in the procedure room will usually include a technician, a nurse, and the anaesthesiologist. [4]The technician is tasked with setting up the anaesthetic machine, circuits and monitors, while the anaesthesiologist undertakes preoperative assessment and prepares the medication. A registered nurse with anaesthetic experience should be available to provide pre-procedure, anaesthetic assistance and recovery care. [3]All should be briefed on emergency protocols and common adverse events, and be familiar with the location and use of emergency drugs, equipment, and defibrillation. Ideally, each member of the team should be trained in basic life support skills, such as maintaining airway patency and assisting ventilation.[11]

Non- pharmacological Methods of Anxiolysis

These methods may be employed on their own or as a complement to pharmacologic sedation. These involve the use of behavioural and cognitive-behavioural interventions. Techniques include distraction, desensitisation, positive reinforcement, relaxation, visual imagery, practice and education. [12]

These interventions may begin before the child even enters the XRT suite. In children older than age 7 or 8 years, it is often possible with behavioural rehearsal and distraction techniques to get through the procedure. Play therapy with mock accelerators and dolls has been attempted as well as audio-visual interventions such as picture books explaining the procedure, incorporation of toys, and a reward system for every accomplished radiation therapy session.[3]

Aromatherapy has been shown to reduce anxiety levels, particularly in the context of palliative care. [4] It is difficult to draw firm conclusions about the utility of these techniques and all have been utilised with mixed success in the ability to keep patients calm and sufficiently immobile.

Furthermore, a busy XRT service might not be able to devote the necessary time and patience to incorporate such methods.[8]

Pharmacological Methods

Sedation vs. GA?

Definitions:
Sedation is defined as the use of pharmacological or non-pharmacological means to depress level of consciousness with the aim of improving tolerability of a procedures.[4] Its encompasses a spectrum of clinical effect. The optimum level of sedation should provide both adequate anxiolysis and amnesia during the procedure with minimal untoward effects on cardiorespiratory function. At this level, patients will respond to both verbal commands and light tactile stimulation.

As depth of sedation increases, the risk of untoward cardiovascular and respiratory effects increases. Monitored anaesthesia care (MAC) is a term used to describe the provision of sedation and or analgesia by a physician qualified in anaesthetic care, with the ability to convert to a general anaesthetic, should the circumstances require it.[4] The safe administration of any drug requires knowledge of its pharmacokinetic and pharmacodynamics profiles and an appreciation of the potential complications associated with its use.

[4]Patient needs should be assessed on an individual basis but a procedural framework should exist to aid this process. [4] Procedures may be long or brief with minimal stimulation, and the anaesthesia should be tailored to facilitate conditions that allow the procedure to be performed adequately and safely.[8] MAC may be the technique of choice for many procedures in remote locations. If the patient is able to cooperate and intense stimulation is not expected and positioning poses no imposition on breathing or maintaining an airway light sedation may be all that is required.

[1]The age, body habitus, comorbidities, patient preference, available equipment, and importantly the requirements of the procedure itself, together with the skill and experience of the anaesthetist can all guide the choice of technique. This may be especially true if control of breathing is required. Diaphragmatic motion is especially an issue when targeting small areas near the diaphragm, such as the liver, kidneys adrenal glands or lung bases. [1,4] In the case of retinoblastoma, complete immobility of the globe is needed which may not be achieved with sedation alone, especially if ketamine is used (with a resultant nystagmus). [8]

Children requiring radiation therapy can experience considerable anxiety, despite the non-invasive and painless nature of the procedure. This is related to separation anxiety, the unfamiliar and potentially frightening radiation equipment and immobilization devices employed, particularly the plastic immobilization cast of the head, which fits tightly over the face.

Children may often have undergone a long painful battery of work up procedures prior to their radiotherapy treatment, and may be understandably apprehensive and suspicious of medical personel.[3,12] A study by Klosky et al, aimed at identifying demographic, medical, and psychosocial predictors of radiation therapy–related distress among paediatric cancer patients aged 2-7years found that younger age, higher pre-procedure observed behavioural distress and prone treatment position was associated with increased requirements for general anaesthesia.[12] Anaesthetic drugs that may be chosen include propofol, ketamine, volatile anaesthetics, dexmedetomidine, chloral hydrate and midazolam. [1]The ideal anaesthetic for radiotherapy should be fast onset, short duration with quick recovery, while preventing movement and maintaining airway patency and spontaneous respiration in a variety of positions.

No randomized controlled studies have proven a clear superiority of any one anaesthetic technique in the paediatric population. [6]IV access may be problematic in children on chemotherapy, compounded often by prolonged unnecessary starvation or dehydration from vomiting. In some cases children may already have a central venous access port (Hickman line) in situ.

Strict aseptic technique is crucial when accessing these lines and administering drugs to prevent line sepsis in these immuno-compromised patients. [3]Large case series estimate the risk of sepsis between 7- 15%. While intramuscular agents such as ketamine can prove effective, the recurring trauma of a painful jab daily for up to 6 weeks is often worse than the prospect of the XRT therapy. If peripheral intravenous access is obtained (EMLA can greatly facilitate this or alternatively placed after gas induction), it should be secured well and flushed in an attempt to maintain its functionality throughout the week of treatments.

Methods used:

Many anaesthetic techniques and agents have been utilised over the years to sedate or anaesthetise children during radiation therapy. Agents such as ketamine, midazolam, chloral hydrate or a combination were often used for sedation. Radiologists and paediatricians have traditionally relied upon oral and rectal preparations of either chloral hydrate or barbiturate/ketamine combinations, with varying success. The increasing input of the anaesthetist and the advent of short-acting sedative agents have decreased the prevalence of such practices.

A prospective study of a large cohort of children (n = 922) presenting for neuroimaging, reported significant differences in the quality and outcomes of sedation when provided by non-anaesthesiologists as compared to anaesthesiologists. A higher incidence of failed procedures and a higher risk of hypoxaemia was noted in those conducted by non-anaesthesiologists.

A subsequent study reported by the same group demonstrated a higher incidence of prolonged recovery, and protracted side-effects such as motor imbalance, agitation, gastrointestinal upset, and restlessness post discharge. [4, 7] General anaesthesia can be administered by means of inhalational or intravenous routes, alone or in combination. The safe provision of inhalational anaesthesia demands adequate monitoring of inspired and expired gases, ventilation and oxygenation.[4]

Inhalational techniques usually necessitate repeated instrumentation of the airway. The use of a supraglottic airway (eg.LMA) if practical may result in less subglottic swelling as associated with repeated daily intubations. If used, airway devices must be secured well and air entry checked before and after positioning the patient. There are additional concerns with regards to adequate scavenging of anaesthetic gases and pollution. [6]

Propofol has gained wide popularity as the drug of choice for deep sedation/ anesthesia.[3, 13] The appeal of propofol lies in its favourable pharmacokinetic profile providing rapid onset and awakening, together with a lower incidence of nausea. Early concerns of tolerance to propofol developing with repeated administrations have largely been disproven by recent studies that monitored dosing requirements and anaesthetic depth over the course of treatment. [14,15] The technique may obviate the repeated instrumentation of the airway and daily exposure associated with volatile induction and maintenance of anaesthesia unless.

Analgesia is not generally required as radiotherapy is not painful and opioid use especially can increase the incidence of respiratory depression and apnoea. Induction takes place within the treatment suite with the child either on the bed or on the parent's lap. The goal is to provide adequate sedation while preserving spontaneous ventilation. One such approach is an initial propofol bolus in the range of 0.5–0.8 mg/kg, up to 3–5 mg/kg of propofol given via a pump over 1–2 min (larger doses and more rapid injection was associated with increased incidence of apnoea).

A maintenance infusion is commenced usually at a rate of 10 mg/kg/hour and is titrated to response. [6,15] The patient is gently moved into position on the treatment table and the immobilization mask applied. Once in a satisfactory position, respiratory efforts and adequacy of ventilation are carefully observed. A capnography catheter secured peri-nasally can provide a continuous assessment of ventilation and deliver supplemental oxygen.

The technique described has also been applied successfully to prone patients. [6] A continuous infusion of propofol at 200 mcg/kg/min has been utilised in some centres, with low rates of upper airway obstruction. A nasal or oral airway is suggested in the event of upper airway obstruction.[7] Spontaneous eye opening was noted within 4 minutes of discontinuing the above infusion.

McFayden et al describes a similar technique of inducing anaesthesia with a 2 mg/kg bolus of of propofol followed by an infusion of 250mg/kg/min to good effect, providing sufficient depth of anaesthesia to provide immobility while maintaining spontaneous respiration and a patent airway. Small holes, cut into the plastic face mould during the simulation session accommodate for the placement of the nasal cannula. A retrospective study of propofol-based anaesthesia for 3833 radiation therapy procedures in 177 patients at St. Jude Children's Research Hospital in Memphis found a complication rate of 1.3%.

Minor airway complications were the most common. No episodes of laryngospasm occurred and no endotracheal intubation was required. The significant risk factors were procedure duration, total propofol dose, the use of adjunct agents with propofol, and simulation (vs. radiation therapy). There is considerable inter-individual variation in the dose of propofol required to ensure adequate immobility.

[3]The utilisation of the α-2 agonist dexmedetomidine in the XRT suite has been described although it has not been widely adopted. The most likely reasons for its infrequent use are the time required to deliver the initial loading dose (which can be as long as the procedure itself), the fact that paediatric administration of the drug constitutes an off label usage, as well reasons of cost efficacy. A case study by Shukry and Ramadhyani described its use in a 21-month-old child with malignant teratoid rhabdoid tumour of the posterior fossa.

It was used to provide sedation for a total of 12 radiotherapy sessions. It was described as providing smooth induction, reliable sedation with minimal respiratory depression and quick recovery. Given its limited effects on respiratory function, dexmedetomidine may be a useful agent for sedation while avoiding the need for airway manipulation. ASA standard monitoring as well as video monitoring were used and vitals and observations taken every five minutes.

A loading dose of 1 mcg/kg was infused over 10 min followed by a maintenance rate of 0.7–0.8 mcg/kg/hr. An empiric decision was made to treat heart rate <90 b/min with atropine 10–20 mcg/kg in concordance with local practises.After achieving the desired level of sedation, supplemental oxygen via nasal cannula was administered at 2 L/min. EtCO2 was sampled from one port of the cannula. The patient's head was immobilized with a mesh plastic mould over the face which was subsequently fixed to the table.

Treatment durations lasted between 20 and 40 min. Dexmedetomidine was the sole agent used in 9 out of 12 therapy sessions with additional propofol 'rescue' (propofol 5–10 mg) required in the other three. In treatment session 6, the patient responded abruptly to the application of a facemask and prompted supplemental sedation.

A heart rate of 90 bpm or less was noted in nine of the 12 procedures and treated with atropine 0.1–0.2 mg, though no haemodynamic instability was observed. No adverse effects such as significant bradycardia, hypotension, hypoventilation apnoea, or hypoxemia were noted. Time spent in recovery was less than 30 minute. [10]

Ketamine is another drug that has been commonly and successfully employed in the XRT suite, usually in combination with a midazolam pre-treatment. Ketamine can be given as a continuous infusion, but the *α*-phase serum half-life of 11 minutes and the short duration of these cases often make this unnecessary. An initial dose of 0.5–0.75 mg/kg given at the start of therapy is often all that is required to accomplish the procedure.

If the patient becomes agitated during the treatment, a supplemental dose of 0.25 mg/kg can be given to extend the period of cooperation. At some institutions, the use of ketamine has become so ubiquitous, it is often undertaken without the presence of an anaesthetist. In contrast to propofol, tachyphylaxis is not uncommon with ketamine.

Dose requirements have been noted to even double by the fifth or sixth week of therapy to achieve the same initial clinical effect, as well as shorter recovery times being seen in the latter phase of therapy suggesting that metabolism may be enhanced. Fospropofol, a pro-drug of propofol, has recently been granted FDA approval for use as a sedative agent, to be administered by those practised in anaesthesia.

Similar to dexmedetomidine, paediatric use is currently deemed an off-label usage, although its pharmacodynamic profile lends itself easily to paediatric oncological cases. Fospropofol is metabolised via alkaline phosphatase to produce propofol, phosphate and formaldehyde. Clinical studies suggest that an initial dose of 6.5mg/kg, followed by a re-dose of 1.5–2mg/kg if needed four minutes later, provides adequate sedation for minimally painful procedures with low incidence of side effects (desaturation, hypotension, burning on injection).

A tingling or burning sensation in the genital and perianal area has been reported. Future clinical studies will determine its suitability in the XRT suite .Where general anaesthesia is required, the brevity of the procedure must be borne in mind when selecting an induction agent. Neuromuscular blockade is often not necessary (the exception, as stated before, is XRT for retinoblastoma, which requires paralysis of the extra-ocular muscles).

Antiemetic agents as either therapeutic or prophylactic therapy can be considered as the emetogenic effects of XRT can compound the nausea associated with chemotherapy or stress and result in vomiting in the recovery area. Ondansetron 0.1 mg/kg is perhaps the agent of choice for most practitioners, but steroids have also reportedly been used with good effect [8]

Monitoring

Monitoring should be consistent with the ASA's Standards for Basic Anaesthetic Monitoring. [1,2,11]:

Often the foremost stated recommendation, i.e. the mindful presence of a trained anaesthetist during the procedure, is not attainable in the XRT suite, as the high levels of radiation require the patients to be isolated and shielded.
Thus, the XRT area is unique in that remote monitoring takes place by closed circuit television. [3,8] The usual configuration involves two cameras, one trained on the patient, giving an indication of breathing or alerting to movement and the other on the monitor, zoomed in so as to clearly depict the vital parameters. [10] A microphone may also be present to transmit the pulse oximeter tone.
The room is evacuated during radiation, though it is possible to enter between doses, and if necessary, the treatment can be terminated to allow entry in an emergency. Continuous pulse oximetry as a measure of oxygenation, and capnography were identified as two of the most important means of detecting aberrant breathing patterns and inadequate ventilation.

In July 2011, the ASA recommended that ''during moderate or deep sedation the adequacy of ventilation shall be evaluated by continual observation of qualitative clinical signs and monitoring for the presence of exhaled carbon dioxide unless precluded or invalidated by the nature of the patient, procedure, or equipment''. [1]
Disconnection alarms must be present if mechanical ventilation is being used. Continuous electrocardiogram and blood pressure measurement every 5 minutes should be performed on every patient.

Temperature monitoring may be required.[4]
All monitors should be secured well, with enough slack so as not to be pulled off. Documentation should be completed from the initiation of sedation until the patient is recovered. [6,8,11]

Patient transport and recovery

XRT in Alternate Sites

Patients may require transfer from between the radiation oncology suite to different procedure rooms. For example, CT-guided interstitial brachytherapy requires transfer between the procedure room where the insertion occurs to the MRI or CT scanner to confirm the position, all while under sedation or general anaesthesia.

Brachytherapy or the intra -cavity implantation of radiotherapeutic material (e.g., radioactive prostate seeds and intrauterine isotopes) is a technique that requires the concerted efforts of surgeons, radiation oncologists, and anaesthesiologists. This method may be utilised for tumours which cannot be fully resected or have a high probability of local recurrence.

Treatment begins with surgical exposure or debulking of the tumour in theatre, after which the wound is covered, and the patient then transported to the XRT suite to receive high dose external beam radiation directly to the exposed tissue. Thereafter the patient is returned to the operating room for closure of the surgical site. Transport of the patient with an open surgical site requires careful attention to maintaining a sterile field as well as continued provision of anaesthesia and analgesia.

The patient should be stable from a cardiovascular and respiratory standpoint prior to leaving any controlled environment, and full monitoring, airway, and emergency provisions should accompany the patient during the transit. Stereotactic radiosurgery is another emerging radiation therapy modality where anaesthetic services may be required.

This procedure may be applied in the management of malignancies, arteriovenous malformations, acoustic neuromas, and trigeminal neuralgia. The most widely used device, the Gamma Knife (Elekta Instruments Inc., Stockholm, Sweden), focuses 201 beams of gamma radiation (derived from cobalt-60) upon the lesion. Anaesthetic management is much like what has been described for traditional XRT.

A stereotactic frame, which involves having four anchoring screws placed into the soft tissue of the head can usually be accomplished with local anaesthetic and sedation with a small dose of ketamine or propofol immediately beforehand will make the procedure less traumatic. Then MRI images will be taken of the patient's brain with the external frame in place. MRI safety protocols should be adhered to. Since the frame will limit access to the patient's airway, it is imperative that the patient is transported with the appropriate tools to quickly dismantle the frame in case airway access is necessary.

If a vascular lesion is present, the child may also be taken to the neuroangiography suite for a diagnostic cerebral angiogram to further elucidate the anatomy. Afterward, a 3D reconstruction of the MRI is made, outlining the coordinates that will most effectively target radiation to the intracranial pathology. Multiple doses of radiation are administered (each lasting from 4 to 10 minutes). Upon completion, the stereotactic frame is removed, antibiotic ointment is applied to the puncture sites left by the screws, and the patient is transported to the recovery area.[8]

POSTPROCEDURE RECOVERY

Similar caveats that govern safe recovery in the theatre setting apply too to extubation in a remote location. Appropriate monitoring, emergency drugs, airway equipment, suction and a reliable oxygen source should be available. This emergency equipment should accompany the patient during transit to the recovery area as well.

A dedicated recovery area in close proximity is preferable.[1] In the case where the post anaesthesia care unit is a considerable distance from the anaesthetizing location, options include keeping the child anaesthetized during transfer, with emergence and extubation occurring in the recovery area, or transporting a child who is emerging from anaesthesia. Personal preferences and judgement of the anaesthesiologist is often the main determinant.[7]

Continued observation, monitoring, and establishing predetermined discharge criteria are thought to decrease adverse outcomes after moderate and deep sedation. Oxygenation and respiratory and cardiovascular status should be assessed regularly. Oxygen should be administered until patients are considered to be no longer at risk from hypoxia.

Discharge timing depends on the procedure performed, and the level of sedation involved. Patients are ready to be discharged when they fulfil the criteria of returning to the pre-anaesthetic baseline for respiratory and circulatory function, saturation and consciousness, with any pain controlled and PONV absent.[11]

ASA discharge criteria recommendations include:

1. Recovery to baseline level of consciousness.
2. Vital signs are stable and within acceptable limits.
3. Appropriate amount of time (up to 2 hours) should have passed since administration of reversal agents like naloxone or flumazenil to make certain that re-sedation wont outlast their effect.
4. Day cases should be discharged home accompanied by a responsible adult, charged with care and reporting any post procedural adverse effects.
5. Written instructions pertaining to diet, medications, activities (e.g. not to drive or operate machinery for at least 24 hours) should be provided, as well as a phone number to call in case of emergency.[4]

CONCLUSION

Anaesthesia in remote locations is frequently fraught with the perils of distant, small dark rooms, bulky older equipment, and personnel who are not always familiar with emergency equipment and procedures. It falls on the expertise of the anaesthesiologist to ensure that despite these challenges, the conduct of anaesthesia for these patients takes place in the safest possible way.

Standard ASA monitoring, thorough preparation, a reliable medical team, and a safe anaesthetic plan form the key elements in any procedural sedation or anaesthesia. An understanding of the procedure and the pathophysiology and comorbidities of the patient population help in meeting these goals and providing a safe service in this otherwise intimidating environment, making for a ultimately rewarding experience.[1, 3]

Overall, differences in anaesthetic technique do not seem to impact on patient safety as long as the principles of safety and monitoring are followed.7 Paediatric oncology patients represent a unique patient group. Although they often require anaesthesia for relatively ‘minor’ procedures, the potential for serious deterioration under anaesthesia is very real. The anaesthetic team often form an integral part of their long and protracted treatment regimens, and it cannot be overstated that the contribution we as anaesthetists make to these young patients is significant, by making this difficult time in their lives less unpleasant.[3,6]

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