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Anesthesia for Frameless, Real-Time, Surface Imaging-Guided Radiosurgery in a Pediatric Patient

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Abstract

Open face, frameless stereotactic radiosurgery (SRS) with surface imaging-guided (SIG-RS) technique was used for the treatment of brain metastases for a child with intracranial neuroblastoma. This setup provides more comfortable treatment arrangement than the customized immobilization full-faced mask, with equivalent accuracy. As this technique requires the surface features of the face to be fully exposed it is not compatible with all types of anesthesia setups. This report describes the anesthetic technique used in SIG-RS for children.

INTRODUCTION

Stereotactic radiosurgery (SRS) is a highly precise, non-invasive method for delivering high-dose radiation to an area of the body to treat various pathological conditions, most commonly cancer. It is often used for intracranial pathology, including primary brain tumors, brain metastases and arteriovenous malformations (1-5). SRS is an important treatment modality for these pathologies since open surgical removal can carry high morbidity and some intracranial cancers are not amenable to surgical excision. SRS focuses photon beams from multiple directions to treat a precise area, allowing for less radiation exposure to the remainder of the brain during treatment and leading to less neurocognitive morbidity when compared to whole-brain irradiation (6).

Early SRS delivery required immobilization with a head frame and rigid, skull-based screw fixation. These initial systems had disadvantages including fractionation limitations as well as considerable discomfort to the patients. As these systems have evolved frameless image guided SRS systems were created, relying on infrared fiducials on or near a patient who was immobilized with a rigid mask. Although an improvement over prior techniques, several disadvantages remained, leading to the creation of surface imaging-guided systems (SIG). Using facial landmarks throughout the treatment, SIG-RS delivers precise treatments without the use of a full frame mask. Due to the requirement of reproducible facial landmarks, the face must remain immobilized with an open facemask, but free of any additional equipment, such as oxygen facemasks, straps, tape or other items common during anesthesia. Set up and treatment can vary in length, with the amount of time and the requirement for immobility making it very difficult to tolerate in pediatric patients. We present the case of a 6-year-old boy with metastatic neuroblastoma who underwent surface image guided (SIG) frameless SRS with subsequent discussion of the anesthetic implications of this new and upcoming radiation oncology treatment modality.

CASE REPORT

A 6-year-old male with stage IV neuroblastoma presented for SIG frameless SRS of a metastasis in the sphenoid and clivus following subtotal resection. After subtotal resection and given the radiosensitive nature of his cancer, the decision was made to treat the residual lesion with SRS of four fractions for a total dose of 30 Gy. For treatment planning, the patient underwent computed tomography (CT) simulation under anesthesia with formation of a SIG-RS custom foam cushion and molding of an open-faced mask. During this step care was taken to optimize his airway during the hardening of the plastic by providing chin lift. The ‘built in’ chin lift improved airway patency during the treatments. Due to his age and the requirement for immobility, general anesthesia was the only option for the treatments.

For induction of anesthesia, the patient’s port-a-cath, which was placed as part of his cancer treatment, was accessed while awake. After an initial bolus of 2 mg/kg of propofol, general anesthesia was maintained with a propofol infusion of 150 mcg/kg/min. To increase the fraction of inspired oxygen, nasal cannula was utilized to allow the sensors to monitor the face. Anesthetic depth was adjusted to optimize the patency of the airway, ensure optimal spontaneous respiration and minimize any patient movement. End-tidal carbon dioxide was monitored utilizing a dedicated monitoring port built into the nasal cannula. Once the patient was stable, the open face frameless apparatus was moved into place, immobilizing the head (Figure1).

Figure 1

Open face frameless apparatus

At the start of the treatment the patient was then set up with the surface imaging system, AlignRT, using three camera pods with 3 cameras in each pod. This multi-camera setup allows for precise setup, identifying optimal positioning and ensuring less than 1mm movement in 6 different dimensions. Once proper positioning was confirmed, additional movement of 1 mm would result in an Automatic Trilogy bean or manual TrueBeam hold. The use of general anesthesia avoided this complication, shortening the length of the treatment. Throughout the treatment, the patient was tracked from the control room using standard ASA monitors and a control area television camera. Once the treatment was completed, the faceless apparatus was removed, propofol was discontinued and the patient was taken to the recovery room to completely emerge from anesthesia. This process was repeated three times, for a total of four treatments.

DISCUSSION

Brain tumors are the second most common form of malignancy in the pediatric population (7). Surgical resection is the standard treatment for these malignancies. For non-resectable primary brain tumors, brain metastases, and arteriovenous malformations stereotactic radiosurgery (SRS) can be effective. SRS provides very high dose of conventional radiation to provide local tumor control. The use of SRS has evolved over the past 30 years, with the most recent advancement including SIG SRS. The first version of SRS required screws to be implanted into the skull for placement of a reproducible frame. The invasive nature of this method was difficult for patients, especially children, to tolerate and it was replaced by a “frameless” technique. With frameless SRS, the patient no longer required screws to be placed into the skull, but reproducible landmarks were still necessary to ensure proper delivery of the high dose radiation. A large full-faced customized mask is the standard apparatus used to provide immobilization, so the treatment can be accurately delivered to the tumor. Serial CTs are performed to ensure proper patient alignment. This technique is effective, but can be claustrophobic for many patients. Additionally, radiation regulatory agencies have mandated the principal of keeping radiation exposure as low as reasonably achievable during all medical treatments. Surface image guided systems with faceless masks represent the newest advance in radiosurgery. This technology uses cameras and lasers to detect structures of the face to monitor the patient for movement, and improve accuracy, with equivalent treatment success (8,9). An open-faced mask is formed and provides an uncovered facial surface for which this technology can work (Figure 1). In addition, this technology decreases the amount of imaging radiation.

Many pediatric patients requiring SRS will require general anesthesia to provide immobility for the duration of the treatment. When examining the technique used for proton and photon radiation treatments, general anesthesia with a native airway is the preferred method within centers across the United States (10). Propofol provides an ideal anesthetic as it is easily titratable while allowing the patient to maintain spontaneous respiration throughout the duration of the treatment. Propofol also leads to quick recovery, a high priority for these patients that need to undergo multiple daily anesthetics. This is the standard anesthetic used at our institution for standard pediatric radiation therapy and was used for this patient.

When performing SRS under general anesthesia using full-face immobilization masks, simple oxygen facemasks are usually used to provide supplemental oxygen. Propofol causes respiratory depression and decreases pharyngeal tone, potentially leading to mild oxygen desaturations. Supplemental oxygen decreases the incidence of oxygen desaturations and allows for maintenance of ventilation throughout the treatment via an end-tidal side port. However, a full simple oxygen facemask cannot be used with SIG technology because of the need to keep the face clear for the cameras. Nasal cannulas are small enough to allow for full facial recognition. To fully integrate the nasal cannula it should be utilized during the CT-Simulation, which is used for the treatment planning. To optimize airway patency, attention to the position of the chin during mask creation is essential for success in all of the treatments. The open faced plastic mask can help optimize a patent airway. As the plastic mask is hardening, the chin should be elevated. Once the plastic mold has completely hardened a chin lift is created. The 'built in' chin lift improves airway patency during the treatments. It is preferred that this built in chin lift is used as it avoids further instrumentation of the airway. Consistency is key for reproducible, consistent facial features. If an oral airway is required due to the patient's underlying pathophysiology, it should be used for every treatment as well as during the CT simulation planning.

SRS is a new treatment with equivalent success for non-resectable primary and metastatic brain tumors as well as arteriovenous malformations. Although similar anesthetic techniques general anesthesia with a native airway can be used, care must be taken to reproduce similar facial features throughout each treatment as the facial features serve as landmarks in this new technology. Built in chin lifts and the use of the same airway landmarks during every treatment are essential to achieve optimal reproducibility.

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