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Short communications

Anesthetic management for magnetic resonance imaging of children

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Magnetic resonance imaging (MRI) has been performed in Hokkaido Children's Medical Center since 1993. MRI requires absolute immobilization of patients during the procedure, which lasts approximately 40 min. Children undergoing MRI examination therefore require deep sedation or general anesthesia with tracheal intubation [1,2]. The high magnetic field created by MRI interferes with monitors and ferromagnetic components of commonly used anesthetic equipment [3,4]. Moreover, the narrow and deep confines of the MRI tunnel limits access to monitor patients. Thus, adequate equipment and monitors are essential for MRI examinations. In this paper we describe our anesthetic management of children with an MRI-compatible anesthesia machine, a ventilator, and monitoring devices. Satisfactory monitoring of ECG, percutaneous O_2 saturation (SpO_2), end-tidal CO_2 tension ($PETCO_2$), and the concentrations of the anesthetic gases was obtained. All scans were diagnostically adequate and none of the monitoring techniques described interfered with MR function or produced image artifacts.

Indications for MRI under general anesthesia in our institution are: (1) patients who have severe upper airway obstruction, high intracranial pressure, or epilepsy, and (2) critically ill patients who are being mechanically ventilated. Informed consent for MRI under general anesthesia was obtained from the patient's parent or guardian. We studied 20 patients, which include 15 in neurosurgery, 2 in abdominal surgery, 2 in cardiac surgery, and 1 in pediatrics. The mean age and body weight were 14.0 months (range 2 months to 14 years) and 7.2 kg (range 2.5–30 kg), respectively. No premedication was given.

Anesthesia was induced with nitrous oxide, oxygen, and sevoflurane in the prescanning room, which allowed us to use conventional anesthetic apparatus and equipment. After placement of an intravenous catheter, a muscle relaxant, vecuronium 0.1 mg·kg^{-1}, was infused when necessary, and the trachea was intubated with an RAE endotracheal tube (Mallinckrodt, New York, NY, USA), except for one case under tracheostomy. The RAE tube provided secure airway management in the narrow confines of the MRI tunnel. The patient was then carried into the MRI scanning room on a non-ferromagnetic stretcher. The MRI scan was performed using a 1.5 Tesla (T) self-sealed MR scanner, MRT-200/FX III (Toshiba, Tokyo, Japan). Anesthesia was maintained with nitrous oxide, oxygen, and sevoflurane, and vecuronium was given when necessary. In the MRI scanning room, we used an Excell MRI-Compatible Anesthesia System (Ohmeda, Madison, WI, USA), which is used as a 1.5-T machine [5]. We used an Ayre's T-piece circuit system, modified by a Jackson Rees circuit (F-circuit, Mera, Tokyo, Japan). An F-circuit has a structure of duplicate ducts, which consist of an internal inspiratory duct (diameter 15 mm) and an external expiratory duct (diameter 22 mm). The patients were ventilated either manually or by an MRI-compatible mechanical ventilator (VentiPAC 5 MRI Anesthetic Ventilator, pneuPAC, Bedfordshire, UK), which functions in a 1.5-T field. The VentiPAC 5 MRI, which is equipped with a Newton valve, works as a pressure generator [6]. Intravenous solutions, warmed to approximately 37°C, were infused with a Terufusion syringe pump STC-521 (Terumo. Tokyo, Japan) or by dripping from bottles hanging on a non-ferromagnetic pole. The syringe pump was placed beyond the 50-Gauss line and an extension tube was required. A disposable heat and moisture exchanger (Thermovent 600, Portex, Kent, UK) was used to reduce the loss of heat and moisture from the airway. We kept patients warm

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by covering the body with towels and placing a woolen cap on the head. We put non-ferromagnetic disposable temperature strips (Stat Temp, Trademark Corp, Fenton, MO, USA) on the forehead to monitor body temperature. When the MRI scan was completed, the patient was carried to the prescanning room and the trachea was extubated.

During the procedure, we continuously monitored the ECG, SpO_2, $PETCO_2$, and the concentrations of the anesthetic gases. An ECG monitor which has non-ferromagnetic skin electrodes combined with carbon fiber leads was used (Life scope 6, Nihon Kohden, Tokyo, Japan). The ECG transmitter is available in a 1.5-T field strength. The ECG monitor itself was placed outside the MRI scanning room and could be seen through the radiofrequency screen window. Although the ECG was occasionally affected by high-frequency noise from the MRI scanner during rapid radiofrequency pulsing, the level of noise was not significant. The concentrations of the anesthetic gases, SpO_2, and $PETCO_2$ were continuously monitored by a 5250 RGM respiratory gas monitor (Ohmeda), which is sensitive to a ferromagnetic field. This was also placed outside the MRI scanning room and viewed through the radiofrequency screen window. To prevent degradation of the MRI signal, an 8-m cable from the SpO_2 probe was passed through radiofrequency filters. The probe was placed on the distal extremity, as far as possible from the scanning site. There was little loss of signal quality by filtering. We found that the SpO_2 was the most useful monitor because it provides information about heart rate and oxygenation very rapidly. An 8-m sampling tube for measuring both $PETCO_2$ and the concentrations of anesthetic gases was connected to the endotracheal tube adapter to minimize dead space. The 8-m-long tube did not reduce the sampling flow rate, but caused a delay of approximately 3 s compared with the usual 3-m-long tube. The sensitivity of this monitor was maintained, with little dumping of the waveform.

We conclude that the apparatus, equipment, and monitoring techniques described are useful for anesthetic management for MRI of children.

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