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# Effect of brain magnetic resonance imaging on body core temperature in sedated infants and children

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**Background.** Children undergoing magnetic resonance imaging (MRI) under sedation are at risk of hypo- or hyperthermia. The effect of brain MRI at differing magnetic field strengths on body core temperature in sedated infants and young children has not been reported previously.

**Methods.** Two groups of 38 infants and children (aged 1 month to 6 yr 5 months) underwent brain MRI for different indications related to cerebral diseases, at 1.5 Tesla (T) and 3 T MRI units, respectively. All patients received deep sedation comprising midazolam, nalbuphine, and propofol. Pre-scan and post-scan temperatures were measured at the right tympanic and at rectal sites. No active warming devices were used during the procedures.

**Results.** Body core temperature measurements were similar between right tympanic and rectal site before and after the scans. After 1.5 T scans, the median (IQR) increase from pre-scan to post-scan tympanic temperature was 0.2°C (0.1–0.3), and the median (IQR) rectal temperature increase was 0.2°C (0–0.3) ($P<0.001$). After 3 T scans, the median (IQR) tympanic temperature increase was 0.5°C (0.4–0.7), and the median (IQR) rectal temperature increase was 0.5°C (0.3–0.6) ($P<0.001$).

**Conclusions.** Body core temperature increased significantly during 1.5 and 3 T examinations; this increase was more profound during 3 T MRI. Patient heating occurred despite minimal efforts to reduce passive heat loss under sedation and without the use of warming devices.

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Successful magnetic resonance imaging (MRI) requires the patient to stay still for up to 1 h or more in a noisy and claustrophobic environment. Infants and children may not lie still for long enough, so they require sedative drugs during the examination.[1] Sedation induces impairment of thermoregulatory control.[2 3] In addition, the MRI environment requires a cool ambient temperature for proper magnet function, which further predisposes infants and children to heat loss, so they may be at risk of hypothermia. Conversely, the MRI scanner generates radiofrequency radiation (RFR), which is absorbed by the patient. Even if clinically relevant warming of the body caused by RFR is unlikely during routine MRI in adults,[4 5] the large surface area–body weight ratio of children may potentially result in an increase in body temperature.[6 7]

We designed this study to investigate the effect of absorbed RFR during brain MRI on the body core temperature of sedated infants and children. We hypothesized that the body core temperature of infants and children would increase during MRI examinations and that core temperature would increase more in 3 Tesla (T) than in 1.5 T MRI systems.

## Methods

### *Patients*

After IRB approval, 76 consecutive ASA I–II infants and children who required sedation for elective cranial MRI examinations were enrolled in this prospective study. Informed consent was obtained from the parents of all patients. Exclusion criteria were ASA status ≥III, severe pulmonary or cardiovascular disease, anatomic airway abnormalities which may interfere with deep sedation

under spontaneous respiration, body core temperature $\geq$37.5°C at baseline, and the primary requirement for general anaesthesia with tracheal intubation for MRI examination. Children with cognitive impairment or developmental delay were not excluded. Two groups were investigated: those who were scanned using 1.5 T were compared with those scanned using 3 T. Patients were allocated to the respective MRI scanner by the paediatric neuroradiologist according to the clinical indication and patient's suitability for a high-field-strength examination.

### *Procedure*

On the day of the procedure, all patients were admitted to the paediatric day care ward and an i.v. cannula was inserted. All patients wore the same kind of cotton pyjamas, delivered by the paediatric ward. In the MRI induction room, patients were pre-medicated with i.v. midazolam 0.1 mg $kg^{-1}$. Sedation was induced with i.v. nalbuphine 0.1 mg $kg^{-1}$ and followed by a loading dose of propofol 1 mg $kg^{-1}$. Supplemental doses of propofol 0.5 mg $kg^{-1}$ were administered until adequate sedation was achieved.[8]

Pre-scan rectal (Thermoval Classic, Paul Hartmann AG, Germany) and pre-scan tympanic temperature (FirstTemp Genius 3000 A, Sherwood Medical, St Louis, USA) were then recorded.[9–11] The right ear was chosen for tympanic temperature measurement in all patients.

Patients were then moved into the MRI suite, and ambient temperature was measured (TK-5110, ATP Messtechnik, Germany). Earplugs were placed in both ears. Sedation was maintained with propofol 5 mg $kg^{-1}$ $h^{-1}$ and supplemental oxygen was delivered by paediatric facemask with a gas flow rate of 2 litre $min^{-1}$. Heart rate, peripheral oxygen saturation ($Sp_{O_2}$), and end-tidal carbon dioxide ($P_{E'CO_2}$) were monitored continuously during the procedure. Non-invasive arterial pressure was determined immediately before the induction of sedation and at the end of the examination. The MRI scanner used was a 1.5 T Philips Intera (Philips, Medizinische Systeme GmbH, Austria) or a 3 T Magnetom Trio Tim (Siemens AG, Medizintechnik, Austria) with quadrate (transmit and receive), so-called 'head matrix' head coils. Brain sequences represented normal protocols used for infants and children at our institution and required contrast application with dotarem (Gd DOTA) 0.2 mg $kg^{-1}$. The number and the duration of the sequences and the specific absorption rate (SAR) values for each sequence were recorded.

After the MRI examination was completed, the propofol infusion was terminated and the patient transferred from the MRI suite to the induction room. Earplugs were then removed, and post-scan rectal and post-scan tympanic temperatures were recorded. Temperature measurements were performed by the same investigator in all patients.

In addition, sweating was evaluated qualitatively: a sweating grade of 0 was assigned when no moisture was detected, a grade of 1 when some moisture was detected, and a grade of 2 when distinct beads of sweat were visible, independent of the localization.[12]

### *Data analysis*

Groups were descriptively compared for balance on baseline potential confounding variables using standard summary statistics. Data are presented as median (IQR) or mean (SD) depending on their distribution. Normal distribution was assessed with q–q plot and Shapiro-Wilk test. Normally distributed data were analysed with two-sided unpaired Student's *t*-test; Mann-Whitney *U*-test or Wilcoxon signed ranks test was used for data sets which diverged from the normal distribution. Categorical data were analysed using Fisher's exact test. Bland–Altman analysis was performed to calculate the differences between tympanic and rectal temperatures obtained at pre-scan and post-scan assessment. The distribution of the differences was plotted against the means of both measurement sites. A *P*-value of 0.05 was considered significant. Analyses were conducted using SPSS software (SPSS Inc., Chicago, IL, USA, Version 12.0.1).

### *Sample size consideration*

The single similar study reported that mean tympanic temperatures in older children increased 0.5°C after 1.5 T MRI of the brain.[6] We assumed a difference of 0.5°C between the two groups (1.5 and 3 T) as clinically important. Power analysis indicated that 26 patients in each group would provide a 95% chance of identifying a statistically significant difference between the groups at a two-tailed alpha level of 0.05. We therefore planned to study a minimum of 52 patients.

## Results

We approached 80 consecutive infants and children (aged 1 month to 6 yr 5 months) who underwent elective MRI examinations of the brain during a 3 month period (July 2008–September 2008). During this period, four patients were excluded because body core temperature was $\geq$37.5°C at baseline. Data were obtained from the remaining 76 patients. Patients were classified as ASA grade I (48% of patients) or ASA II (52%). The indications for MRI were epilepsy (22 patients), cerebral tumour staging (47 patients), investigation for retardation (6), and investigation for autism (1). Patients were divided into two groups, depending on in which MRI scanner the examination was performed: group 1.5 T and group 3 T (Table 1).

All scheduled MRI examinations were completed without any failure of sedation. No patient moved during