Propofol Anesthesia for Children Undergoing Magnetic Resonance Imaging: A Comparison with Isoflurane, Nitrous Oxide, and a Laryngeal Mask Airway

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BACKGROUND: Both propofol infusions with oxygen delivered through nasal cannula and isoflurane/N₂O (nitrous oxide) delivered via a laryngeal mask airway (LMA) are used to provide anesthesia for children undergoing magnetic resonance imaging scans. We compared the incidence of adverse events and perioperative physiologic responses in children anesthetized with these 2 regimens.

METHODS: One hundred-fifty healthy children, ages 1 to 10 years, were randomized to receive either a propofol infusion (starting at 300 µg kg⁻¹ min⁻¹) with oxygen via nasal cannula (n = 75) or isoflurane with 70% N₂O in oxygen delivered via an LMA (n = 75), both after a sevoflurane/N₂O/oxygen induction. Adverse airway events, as well as hemodynamic, respiratory, and other physiologic responses were recorded during the magnetic resonance imaging scans and in the postanesthesia care unit by a single research nurse who was blind to the treatments. All parents were contacted postoperatively to complete a postanesthetic follow-up.

RESULTS: All 150 children completed their scans. The frequency of all adverse airway events during emergence and recovery after propofol (3.2%) was significantly less than that after isoflurane/N₂O/LMA (49%) (95% confidence interval for the risk difference was 23%–50%) (P = 0.0001). Hemodynamic responses and recovery times for the 2 treatments were similar. Early recovery, defined as the time interval from admission to the postanesthesia care unit until eye opening and wakefulness (modified Aldrete score >5), after propofol was more rapid than that after isoflurane/N₂O/LMA (P = 0.0001 and P = 0.0012, respectively). No scans had to be repeated.

CONCLUSIONS: The frequency of adverse airway events during emergence and recovery after propofol infusion with oxygen by nasal cannula is less than with isoflurane/N₂O/LMA in children.

(Aesth Analg 2015;120:157–64)

Anesthesia or deep sedation is usually required for children who are scheduled for magnetic resonance imaging (MRI) to facilitate a satisfactory completion of the scan. An adequate depth of anesthesia ensures the absence of movement during the scan and attenuates the anxiety and auditory stimulation that result from being in the scanner core. Several IV anesthetic regimens have been used in children to prevent movement during the scans including propofol, ketamine, and dexmedetomidine. MRI-compatible anesthetic workstations have also made it possible to use inhaled anesthetics for MRI scans. In our institution, 2 regimens are commonly used to provide maintenance anesthesia for MRI scans in children after a sevoflurane induction: (1) IV anesthesia with a continuous infusion of propofol and oxygen delivered by nasal cannula, and (2) isoflurane anesthesia delivered via a laryngeal mask airway (LMA). Continuous propofol infusions facilitate a smooth rapid recovery, although maintaining a patent airway and hemoglobin oxygen saturation requires that the child’s respiratory efforts and adequacy of ventilation are maintained. To deliver isoflurane during maintenance, an LMA is commonly used, although it requires a greater depth of anesthesia and may increase the risk of perioperative adverse airway events compared with a natural uninstrumented airway. Our clinical experience suggested that both strategies are safe and effective and that most adverse events with both regimens are minor, although a rigorous analysis of the clinical outcomes during and after these 2 regimens has not been reported.

The frequency of perioperative complications during and after anesthesia may increase after the airway has been instrumented and in the presence of a recent upper respiratory tract infection (URTI) and asthma. Hence, some prefer to eschew LMAs to minimize adverse airway events after MRI scans.

In addition, MRI scans are often performed to investigate whether a lesion within the brain can explain the presence of cognitive impairment (CI) or seizures. These children may be at greater risk for adverse events after anesthesia because they are either more sensitive to the anesthetics or at risk for airway obstruction and hypoxia, although this has not been formally evaluated.

The primary purpose of this study was to compare the frequency of periesthetic airway events after propofol infusion and oxygen by nasal cannula with that after...
Propofol or Isoflurane with a LMA for MRI in Children

Isoflurane/N₂O (nitrous oxide)/LMA, in children undergoing MRI scans. The secondary purposes were to compare the cardiorespiratory responses and recovery profiles between the 2 regimens, as well as the effects of a recent history of a URI and CI on the frequency of adverse events.

METHODS

With local IRB approval and informed written consent from the Children and Youth Institutional Review Board, Woman and Children's Hospital of Buffalo, 150 children who were ASA physical status I or II, fasting and unpremedicated, and scheduled for elective MRI under anesthesia, approximately 1 hour in duration, were recruited. Exclusion criteria are listed in Table 1.

After consent was obtained from the parents or guardian (and assent from children >6 years of age), each child was randomized to receive either propofol anesthesia with oxygen delivered via nasal cannula (n = 75) or isoflurane/N₂O anesthesia delivered via an LMA (n = 75). Randomization was determined before the study commenced using random number tables that were prepared by an individual who was not involved in the study. The randomization assignment was concealed until the parents signed consent for their child's participation. The randomization was not blocked for either recent URI or CI. The research nurse (observer) was blind to the treatment assignment until the entire study was completed.

In addition to a routine preanesthetic assessment, each parent was questioned about the presence of signs or symptoms of a recent URI (including runny nose, yellow/green discharge, postnasal drip, cough, fever, and wheezing). Each child's CI (none, mild, or moderate/severe) was assessed by the same research nurse using the following 3-point grading score: mild: learning disability or emotional/behavioral disorder; moderate: needs considerable support in school and at home; severe: requires more intensive support and supervision throughout the day.

Standard monitors including a continuous single-lead electrocardiogram, automated arterial blood pressure (cycled every 5 minutes), and continuous pulse oximetry and capnography were applied. Baseline cardiorespiratory measurements were recorded with loss of consciousness. After an inhaled induction with 8% inspired sevoflurane in 70% N₂O and 30% oxygen, IV access was established. The door to the scanner was then closed, and the child was positioned for the anesthetic, out of the view of the research nurse. All anesthetics were administered by a single anesthesiologist.

Propofol Treatment

After IV access was established, sevoflurane was discontinued and a propofol infusion was commenced at 300 μg/kg·min⁻¹. The infusion pump was situated in the MRI control room at the anesthesiologist's desk, delivering propofol through narrow bore tubing that passed into the scan room through a waveguide. After 10 minutes, the infusion rate was reduced to 250 μg/kg·min⁻¹ for the remainder of the scan. The infusion rate was adjusted in 25 μg/kg·min⁻¹ increments up or down depending on whether the anesthetic was judged clinically to be too light or too deep, or the systolic blood pressure increased or decreased >25% from baseline, respectively. Supplemental boluses of IV propofol (0.5 mg/kg) were permitted if the child moved or if cardiorespiratory signs of light anesthesia were present. When the scan was complete, the propofol infusion was discontinued and the IV tubing was flushed with balanced salt solution to eliminate any evidence that propofol had been used.

Supplemental oxygen (2 L/min) was administered during propofol anesthesia via septate nasal cannula (Salter Labs 47025, Arvin, CA) with continuous nasal capnography sampled through the other cannula (MEDRAD Inc., Indianola, PA). The children were positioned on the MRI table with a roll under their shoulders and cervical spine to maintain a patent airway. At the end of the scan, the shoulder roll was removed before the child left the MRI scan room. Emergence from the scanner room was delayed 1 or 2 minutes to maintain a similar schedule as that of the children in the LMA group (i.e., to account for the time to remove the LMA).

The quality of the scan images was assessed by the MRI technician after each sequence, and if needed the sequence was repeated before completion of the study.

Isoflurane/N₂O/LMA Treatment

After IV access was established, a disposable LMA that was weight-appropriate was inserted in the hypopharynx, using the inverted insertion technique. Sevoflurane was then discontinued, and isoflurane 1.5% (inspired concentration) was introduced in a fresh gas mixture of 2 L/min N₂O and 1 L/min oxygen. The inspired concentration of isoflurane was increased or decreased by 0.25% if the depth of anesthesia was judged clinically to be too light or too deep or the systolic blood pressure increased or decreased >25% from baseline, respectively. A "dummy" propofol syringe was loaded into the pump at the anesthesiologist's desk in the control room but was not infused into the IV to maintain the observer's blindness. At the end of the scan, the isoflurane concentration was increased by 1% to maintain a deep level of anesthesia. After the child breathed 100% oxygen for several minutes, the LMA was removed. The airway was not suctioned routinely to avoid triggering laryngospasm or coughing. Nasal cannulae were applied before emerging from the scanner room.

At the conclusion of the MRI, all children were transported to the postanesthesia care unit (PACU) in the supine position with supplemental oxygen delivered via nasal cannula and continuous monitoring by pulse oximetry. If

Table 1. Exclusion Criteria for Enrollment in This Study

<table>
<thead>
<tr>
<th>Lack of informed consent</th>
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<tr>
<td>&lt;1 year old or ≤10 kg</td>
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<tr>
<td>&gt;10 years or &gt;50 kg</td>
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<tr>
<td>Body mass index &lt;5 or &gt;95%</td>
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<tr>
<td>Requiring tracheal intubation or tracheal tube in situ</td>
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<tr>
<td>Recent exacerbation of asthma or pneumonia within past 2 weeks</td>
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<tr>
<td>Anticipated or known difficult airway</td>
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<tr>
<td>Sleep apnea (positive sleep study or documentation of apnea)</td>
</tr>
<tr>
<td>More than 2 psychotropic or anticonvulsant medications</td>
</tr>
<tr>
<td>Congenital heart disease (unrepaired)</td>
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<tr>
<td>Gastroesophageal reflux disease (symptomatic despite treatment)</td>
</tr>
<tr>
<td>Attention deficit hyperactivity disorder with treatment</td>
</tr>
<tr>
<td>Allergy or contraindication to propofol or isoflurane</td>
</tr>
<tr>
<td>Anticipated scan time &gt;1.5 hours</td>
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airway obstruction developed, a jaw thrust maneuver was applied. If that failed to relieve the obstruction, an oropharyngeal airway was inserted.

As soon as anesthesia was induced and IV access established, the blinded observer recorded all the cardiorespiratory variables (i.e., systolic blood pressure, heart rate, end-tidal pCO₂ (EtCO₂), respiratory rate, and hemoglobin oxygen saturation) every 5 minutes (Table 2) from the remote monitor in the MRI control room. The thresholds for interventions to address hemodynamic derangements were predefined (Table 3). Variability in the displayed EtCO₂ waveform was assessed visually by the observer as follows: the contour of 5 sequential waveforms was compared and if 1 or more waveforms differed from the remainder (in height or contour) or were absent, the waveforms were deemed to be variable. Anesthetic drug concentrations and airway manipulations within the MRI scan room were not visible to the observer. Any adverse airway events that occurred within the MRI scan room were reported to the observer by the anesthesiologist. Anesthesia quality, movement, image quality, and repeated scan sequences were also recorded. In the PACU, early recovery was defined as the time interval from admission to PACU until eye opening and wakefulness (modified Aldrete score >5) were recorded. The times to discharge from the same day surgery, PACU (modified Aldrete score ≥10), and hospital were also recorded. The time in the same day surgery unit was defined as the time from discharge from PACU until the child exhibited stable vital signs, tolerated fluids, no vomiting or pain, and normal behavior for that particular child in the day surgery unit. The time to discharge from hospital was defined as the time from end of the MRI scan until the child was discharged home.

Within 48 hours of discharge from the hospital, the parents were contacted by telephone by the research nurse to complete a structured questionnaire that included postoperative complications, all other problems, and the parent's overall satisfaction with the anesthetic.

### Statistical Analysis

Sample size was estimated a priori using the following assumptions based on our clinical experience of adverse airway events with both techniques and the available literature: α = 0.05, β = 0.2, a 30% incidence of adverse airway events in the children anesthetized with isoflurane/N₂O and a 10% incidence in those anesthetized with propofol. These assumptions yielded a sample size of 72 children in each group. To account for study failures and dropouts, 75 children were enrolled in each group.

The primary outcome variable, the frequency of adverse airway events, was compared using Fisher exact test and reported as the 95% confidence interval of the risk difference using Instat 3.0, 2003 (GraphPad, La Jolla, CA). Secondary outcome variables including cardiorespiratory responses were compared using 2-way repeated measures MANOVA (multivariate analysis of variance) with group (propofol and isoflurane) as the between-subjects factors and time (0-25 minutes) as the repeated measures factor. To control for experiment-wise errors, post hoc pairwise between group comparisons for systolic blood pressure, heart rate, EtCO₂, and respiratory rate were compared using the t test and reported as Bonferroni-adjusted P values.

### RESULTS

One hundred-fifty children were enrolled in the study (n = 75 children/group). Demographic data for the 2 groups were similar (Table 4). The frequency of medical conditions in the 2 groups was also similar: overall, 30 (20%) children received seizure medications, 17 (11%) were asthmatic, and 28 (19%) had a recent history of an URI. Forty percent of the children presented with some degree of CI, although the frequency of CI in the 2 groups was similar (Table 4). The distribution of the scars was: 77% brain, 14% spine, and 9%
were similar (Table 8). When the recovery times were stratified for CI, early recovery of children who were not cognitively impaired and of those who were moderately/severely impaired after propofol was significantly prolonged compared with those after isoflurane/N2O/LMA (Table 8).

The frequency of nausea and/or vomiting after propofol, 3%, was significantly less than that after isoflurane/N2O, 17% (P = 0.0049). The 95% confidence interval for the risk difference (14%) was 5.7% to 25.2%. The majority (93%) of nausea occurred in the PACU; 2 children who received propofol required ondansetron compared with 12 who received isoflurane/N2O/LMA.

Mean systolic blood pressure during the MRI decreased significantly with time and the interaction, treatment × time (Fig. 1). Seventeen children experienced a decrease in arterial blood pressure >25% below baseline: 8 who were anesthetized with propofol and 9 who were anesthetized with isoflurane/N2O. Only 1 child who received isoflurane/N2O required interventions, which included a fluid bolus and a decrease in the concentration of isoflurane by 0.25%.

Mean heart rate in both groups decreased significantly during the MRI scan; there were main effects of treatment and time, but not an interaction (Fig. 2). The slowest heart rate in the children who received propofol was 62 bpm and in those who received isoflurane/N2O was 56 bpm. Both episodes of bradycardia resolved spontaneously.

The EtCO2 increased significantly during the scanning period (Fig. 3). There were significant main effects of both treatment and time, and the interaction, treatment × time (P = 0.0086). The mean EtCO2 in the children anesthetized with propofol was statistically significantly less than the EtCO2 in those anesthetized with isoflurane/N2O (Fig. 3). The EtCO2 readings <25 mm Hg were sustained and consistent in 13 children who received propofol compared with one who received isoflurane/N2O (P = 0.001). In addition, variability in the waveform of the capnogram in children anesthetized with propofol (n = 12) occurred significantly more frequently than in those anesthetized with isoflurane/N2O (n = 3) (P = 0.03).

Respiratory rate varied significantly during the scanning period (Fig. 4). Analysis revealed significant main effects of treatment, time, and the interaction, treatment × time (P = 0.0086).
Table 6. Airway Complications Between Induction of Anesthesia and Arrival in the Postanesthesia Care Unit

<table>
<thead>
<tr>
<th>Cognitive Impairment</th>
<th>Number of children</th>
<th>Airway obstruction</th>
<th>Hemoglobin desaturation to &lt;94%</th>
<th>Airway Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propofol</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>47</td>
<td>3 (6)†</td>
<td>5 (11)</td>
<td>5 (12)‡</td>
</tr>
<tr>
<td>Mild</td>
<td>16</td>
<td>1 (6)</td>
<td>1 (6)</td>
<td>1 (6)†</td>
</tr>
<tr>
<td>Mod/severe</td>
<td>12</td>
<td>1 (8)</td>
<td>1 (8)</td>
<td>1 (8)‡</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
<td>5 (7)†</td>
<td>7 (10)‡</td>
<td>7 (10)‡</td>
</tr>
<tr>
<td>Isoflurane/N2O/LMA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>43</td>
<td>10 (23)</td>
<td>11 (26)</td>
<td>16 (37)</td>
</tr>
<tr>
<td>Mild</td>
<td>15</td>
<td>5 (33)</td>
<td>4 (27)</td>
<td>4 (27)</td>
</tr>
<tr>
<td>Mod/severe</td>
<td>17</td>
<td>3 (18)</td>
<td>2 (12)</td>
<td>8 (47)</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
<td>18 (24)</td>
<td>17 (23)</td>
<td>28 (37)</td>
</tr>
</tbody>
</table>

Data are numbers (% of children with that level of cognitive impairment (CI) within the same treatment group).
* P = 0.0068; † P = 0.043; ‡ P = 0.0001 compared with the corresponding subgroup in the isoflurane/LMA arm.
† P = 0.0064 refers to the airway intervention for mild and moderate/severe CI children combined in the propofol arm compared with the corresponding combination in the isoflurane/LMA arm.
LMA = laryngeal mask airway; Mod = moderate; N2O = nitrous oxide.

Table 7. Airway Interventions Stratified for a History of URTI or Asthma

<table>
<thead>
<tr>
<th>Airway Interv</th>
<th>Propofol (n = 76)</th>
<th>Isoflurane/N2O/LMA (n = 76)</th>
</tr>
</thead>
<tbody>
<tr>
<td>URTI</td>
<td>2</td>
<td>13 (17%)</td>
</tr>
<tr>
<td>No URTI</td>
<td>5</td>
<td>51 (67%)</td>
</tr>
<tr>
<td>Asthma</td>
<td>0</td>
<td>9 (12%)</td>
</tr>
<tr>
<td>No asthma</td>
<td>7</td>
<td>69 (90%)</td>
</tr>
<tr>
<td>Total</td>
<td>7 (10%)</td>
<td>58 (90%)</td>
</tr>
</tbody>
</table>

Data are number of subjects (% of children). The frequency of airway intervention with an URTI or asthma did not differ significantly between treatments.
URTI = upper respiratory tract infection; LMA = laryngeal mask airway; N2O = nitrous oxide.

Table 8. Study Times According to Treatment and Level of Cognitive Impairment

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Level of CI</th>
<th>Induction of anesthesia (min)</th>
<th>Scan time (min)</th>
<th>Time to eye opening (min)</th>
<th>Time to full wakefulness (min)</th>
<th>Time to discharge from PACU (min)</th>
<th>Time spent in same day surgery (min)</th>
<th>Time to discharge from hospital (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>3 (3-6)</td>
<td>41 (34-55)</td>
<td>21 (15-27)</td>
<td>29 (20-32)</td>
<td>30 (30-40)</td>
<td>35 (32-40)</td>
<td>75 (69-85)</td>
</tr>
<tr>
<td>Propofol</td>
<td>Mild</td>
<td>3 (4-7.9)</td>
<td>32.5 (31-56.25)</td>
<td>18 (15-22.75)</td>
<td>25 (20-26)</td>
<td>30 (30-35)</td>
<td>30 (32-40)</td>
<td>70 (61.25-78.15)</td>
</tr>
<tr>
<td></td>
<td>Mod/sev</td>
<td>3 (3-6)</td>
<td>35 (29.5-30.25)</td>
<td>23 (11.25-29.5)</td>
<td>25 (20-26)</td>
<td>30 (30-35)</td>
<td>30 (27-35-38)</td>
<td>70 (61.25-78.15)</td>
</tr>
<tr>
<td></td>
<td>Total (n = 75)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>4 (3-5)</td>
<td>39 (32-54)</td>
<td>20 (15-25)</td>
<td>26 (20-31)</td>
<td>30 (30-35)</td>
<td>35 (30-40)</td>
<td>75 (65-77)</td>
</tr>
<tr>
<td></td>
<td>Mild</td>
<td>4 (3-5)</td>
<td>39 (35-49)</td>
<td>15 (9.25-25.75)</td>
<td>26 (19.6-29)</td>
<td>30 (30-40)</td>
<td>30 (30-50)</td>
<td>75 (70-87.5)</td>
</tr>
<tr>
<td></td>
<td>Mod/sev</td>
<td>4 (3-5)</td>
<td>37 (30-47.5)</td>
<td>9.5 (2.75-16.25)</td>
<td>19.5 (13.5-25)</td>
<td>30 (20-31.5)</td>
<td>30 (30-40)</td>
<td>70 (65-75)</td>
</tr>
<tr>
<td></td>
<td>Total (n = 75)</td>
<td></td>
<td></td>
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</tbody>
</table>

Data are medians (interquartile range), induction time is the time from start of the inhaled induction until successful placement of IV cannula. Eye opening is the time from admission to PACU until the eyes are open spontaneously. Full wakefulness is the time until the PACU score was >5. Statistical significance is depicted for isoflurane compared with Propofol at the same level of CI.
CI = cognitive impairment; mod = moderate; sev = severe; PACU = postanesthesia care unit; LMA = laryngeal mask airway; N2O = nitrous oxide. *Statistical significance compared with Mild CI within the same treatment group using the Mann-Whitney U test with a Bonferroni correction for post hoc comparisons.

0.019). The respiratory rate in those who received propofol during the MRI was significantly less than the rate in those who received isoflurane/N2O (Fig. 4).
Two children in the isoflurane/N2O/LMA group developed transient apnea before placement of the IV. In both children, the apneic resolved spontaneously. Neither hyperventilation nor hypercapnia was diagnosed in any child during the MRI scan or in the PACU. Hemoglobin oxygen saturation did not differ significantly between the 2 treatments either during the scan or recovery.
In the PACU, there was a significant effect of treatment only, for systolic blood pressure and heart rate. Overall, the systolic blood pressure (P = 0.00001) and heart rate (P = 0.00001) in the children anesthetized with propofol were less than those anesthetized with isoflurane/N2O. These differences were not clinically significant and required no
Propofol or isoflurane with a LMA for MRI in Children

**Systolic blood pressure**

![Graph showing systolic blood pressure over time for propofol and isoflurane with LMA. Data are means ± SD, *P = 0.002, \#P = 0.00006, \#\#P = 0.00004 compared with respective baseline.](image)

**Respiratory Rate**

![Graph showing respiratory rate over time for propofol and isoflurane with LMA. Data are means ± SD, *P = 0.029 compared with respective baseline, \#P = 0.0083 compared with isoflurane/N₂O (nitrous oxide/aryngal mask airway (LMA)).](image)

**Heart Rate**

![Graph showing heart rate over time for propofol and isoflurane with LMA. Data are means ± SD, *P = 0.022 and with time (P = 0.00002) compared with respective baseline, but not the interaction of treatment × time. Data are means ± SD.](image)

**End-tidal pCO₂**

![Graph showing end-tidal pCO₂ over time for propofol and isoflurane with LMA. Data are means ± SD, *P = 0.0086, \#P = 0.00002 compared with respective baseline, \#\#P = 0.0083 compared with isoflurane/N₂O/LMA.](image)

scanned 1 week apart, the scans lasted <1 hour in duration, and they were without notable complications by the healthcare team. The rashes were not reported by the nurses in PACU and thus must have developed after discharge from PACU. The rashes were evident on the face only and were not pruritic, raised, or blotty according to the parents. They were not in areas where tape had been applied and were not deemed to be drug reactions. Monitoring wires were not near or on the face, a common cause of burns during MRI. Both parents gave their children diphenhydramine without improvement. By the first postanesthetic day, the skin rashes had disappeared. We were advised that the new 1.5 Tesla MRI scanner was the most likely cause for the rashes. The manufacturer’s technical support staff investigated the scanner and concluded it was operating properly. No further explanation for the burns was provided. All parents were satisfied with the anesthetic technique that their child had received.

**DISCUSSION**

The primary purpose of this study was to compare the frequency of adverse events after propofol anesthesia with oxygen by nasal cannula with those after isoflurane with 70% N₂O delivered via an LMA in children undergoing MRI scanning. We determined that the frequency of adverse events, in particular adverse airway events, during emergence/recovery from propofol anesthesia with a nasal cannula to deliver oxygen was significantly less than that after isoflurane/N₂O/LMA. With respect to the secondary outcomes, cardiorespiratory responses were similar between the 2 treatments, although the frequency of vomiting after propofol was significantly less than after isoflurane/N₂O/LMA. All clinical indices of recovery were similar for the 2 treatments including the time to discharge from hospital and unexpected hospital admissions.

The difference in the frequency of adverse airway events between the 2 anesthetic regimens was greater than expected (Tables 5 and 6). However, the frequency of adverse airway events is consistent with those reported for the 2 anesthetics. In the case of propofol with nasal cannula, avoiding a supraglottic airway may reduce the frequency of upper airway adverse events. Furthermore, in a model of
upper airway irritability using saline to trigger apnea and laryngospasm, the incidence of acute airway responses during propofol anesthesia was significantly less than during sevoflurane anesthesia, independent of the depth of anesthesia. A similar model with isoflurane has not been evaluated, but isoflurane is known to irritate the upper airway in children. Furthermore, we removed the LMA at a deep level of anesthesia, a maneuver that has been associated with fewer adverse airway events than its removal in the awake state. This may have further decreased the difference in the rates of adverse airway events between the 2 treatments. The smaller frequency of desaturation after propofol may be attributed, in part, to the limited atelectasis reported after propofol anesthesia in spontaneously breathing children.

The frequency of airway complications in children with CI in the current study was similar to those without CI (Table 6), although a previous study reported a 3-fold greater frequency of hypoxia between those with and without CI. This was not a primary outcome of the current study and could reflect a type II statistical error.

In the present study, none of the scans had to be repeated because of movement. This contrasts with several published studies in which children who were sedated with propofol required repeat scans because the children moved. The larger dose of propofol used in the current study is the most likely explanation for this difference in the incidence of movement.

Although both anesthetic regimens provided an adequate depth of anesthesia to complete the scans, lack of movement and respiratory and circulatory indices cannot distinguish which anesthetic regimen provided a greater or lesser depth of anesthesia than the other. A single measurement using a depth of anesthesia monitor after egress from the scan room or the use of a sedation scale might have provided some evidence that one of the regimens maintained a different level of anesthesia from the other, but these assessments were not undertaken in the current study.

In contrast to previously published studies, we did not find a significant difference in the frequency of adverse airway events in children with a history of a recent URTI or asthma in either group compared with those without these diseases. The absence of a statistically significant difference in the frequency of adverse respiratory events may be explained by several factors including the anesthesiologist's skills, the definition of a URTI and asthma, the criteria used to cancel an anesthetic, and the small sample size that might have introduced a Type II statistical error.

A blunted, distorted, or absent nasal capnogram did not present a major problem for respiration in those who were anesthetized with propofol. Nasal capnography has limitations in spontaneously breathing children, and even though 18% of the children who were monitored with nasal cannulae showed either a diminished, irregular, or absent capnogram trace, oxygen saturation was maintained and the scans were unaffected. Shifting breathing from the nose to the mouth is common in children who are anesthetized with propofol and breathing spontaneously. Such a finding is easily diagnosed and resolved by repositioning the nasal cannula between the lips. A second very important cause of a diminution in the nasal capnogram is an interruption in respiration, either breath-holding or apnea. In both instances, examination of the child’s breathing pattern will usually help to diagnose mouth breathing, for which the nasal cannulae should be moved to lie between the lips. If the airway is obstructed, a jaw lift should be applied and the neck position adjusted. If apnea is diagnosed, the dose of anesthetic should be reduced.

There are several weaknesses in this study that merit comment. The dose of propofol selected for the infusion rate was based on our personal experience to achieve as close to 100% success in completing the scans without movement. Smaller infusion rates may have abbreviated the emergence and recovery times, although they may have resulted in movement during scans particularly in younger children and in those who have CI.

A second weakness relates to the use of only 1 anesthesiologist to provide the patient care and airway management and to 1 observer to evaluate and record all events and data, practices that might be viewed as limiting the external validity of the results. Although these criticisms are valid, standardization of technique and practice in a research investigation ensures homogeneity in the study execution and data acquisition. In effect, the rigidity of the protocol precluded modifications by individual practitioners. In this particular study, the single anesthesiologist was equally familiar with both anesthetic regimens that were used for the MRI scans and regarded both techniques with equipoise. Finally, we posit that our results are actually strengthened by using 1 observer and avoiding inter-individual variability in the assessment of the outcome measures.

CONCLUSIONS
Adverse events, most notably airway events, after propofol anesthesia with nasal cannula were less frequent than after isoflurane/N₂O/LMA, although hemodynamic responses and recovery characteristics were similar. These data favor the use of a propofol infusion with supplemental oxygen by nasal cannula for healthy children without active URTIs undergoing anesthesia for MRI scans and other nonpainful procedures approximately 1 hour in duration, particularly in remote locations.

DISCLOSURES
Name: Christopher Heard, MBChB, FRCA.
Contributions: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Attestation: Christopher Heard has seen the original study data, reviewed the analysis of the data, approved the final manuscript, and is the author responsible for archiving the study files.
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Contribution: This author helped design the study, analyze the data, and write the manuscript.
Attestation: Jerrold Lerman has seen the original study data, reviewed and analyzed the data, approved the current manuscript, and is the author responsible for archiving the study files. This manuscript was handled by: Peter J. Davis, MD.

ACKNOWLEDGMENTS
We thank Dr. Timothy T. Houle, PhD, Associate Professor, Department of Anesthesiology, Wake Forest Medical School, Winston-Salem, NC, for his expert advice and contributions to the statistical analysis of the data in this study.

REFERENCES