High BMI in children as a risk factor for intraoperative hypotension
Olubukola O. Nafiu, Sarah Maclean, James Blum, Sachin Kheterpal, Andy Cowan and Kevin K. Tremper

Introduction
Childhood obesity is a risk factor for many perioperative complications. Hypotension is a well described complication of general anaesthesia in both adults and children. This observational study compared the incidence of preincision hypotension (PIH) between children with high BMI and lean controls.

Methods
Children aged 2–17 years undergoing noncardiac procedures were classified into high or normal BMI groups. The incidence of PIH was then compared between the two groups using SBP data abstracted from our electronic anaesthesia monitoring system. Binary logistic regression was used to examine factors associated with the likelihood of PIH.

Results
The study population was 19,400 children (54% boys) with a mean (SD) age of 8.3 ± 4.7 years and BMI of 19.3 ± 5.7 kg m⁻². Most (94.7%) of the patients were elective American Society of Anesthesiology I–II (79.7%) procedures. Single episode of PIH occurred in 36.8% of patients, whereas 8.3% had at least three episodes of PIH. PIH was more frequent in children with high BMI than their lean peers (40.9 vs. 31.4%, \( P < 0.001 \)). Independent predictors of PIH were high BMI, high American Society of Anesthesiology status, propofol coinduction, baseline hypotension, age and preincision duration.

Conclusion
These results imply that children with high BMI have a higher incidence of hypotension than their lean peers following induction of anaesthesia for noncardiac procedures.

Eur J Anaesthesiol 2010;27:000–000

Keywords: BMI, childhood obesity, general anaesthesia, hypotension

Participants and methods
Following Institutional review board approval, we analysed our perioperative, electronic clinical information system. The records of all children aged 2–17 years undergoing general anaesthesia for noncardiac operations during the period of January 2005 to January 2007 were examined. Perioperative data are routinely prospectively documented in a computerized database (Centricity; General Electric Healthcare, Waukesha, Wisconsin, USA) by anaesthesiologist residents, attending staff and nurse anaesthetists. We extracted the following clinical and anthropometric information from the database: age, sex, American Society of Anesthesiology (ASA) status, urgency of surgery, as well as height and weight. BMI was calculated as weight in kilograms divided by the square of the height in meters (kg m⁻²). The mode of induction of anaesthesia [inhaled vs. intravenous (i.v.)] was noted. The preincision period was identified from each anaesthetic record as the interval between documented patient in-room time and surgical incision time. Our anaesthesia information system has case-based default ‘scripts’ for various types of surgical procedures. The caregiver has to select ‘patient in room’ from the pick list for physiologic data capture to begin. Other mandatory selections from the pick list include surgical incision time, surgery end time and anaesthesia end time.

Blood pressure data
Preoperative systolic blood pressure (SBP) data were obtained from the baseline values documented in the preanaesthesia record. Intraoperative blood pressure (BP) measurement is done automatically using either the oscillometric method or intravenous catheters connected to a transducer system. When both preincision...
oscillometric and invasive BP readings are available, the invasive BP readings were used for analysis.

Intraoperative BP data were acquired from an automated, electronic physiologic monitor (Solar 9500; General Electric Healthcare). BP values are automatically recorded every minute for patients with invasive arterial catheters and every 3 min for patients with noninvasive BP cuffs. Each intraoperative anesthetic record was divided into successive 5-min epochs. The median SBP for each 5-min epoch on the anesthesia chart was calculated. The use of a median value over a defined time period filters out monitoring artefacts and clinically insignificant, transient hypotension.8 These median SBP values were compared with age-dependent cutoff points for hypotension: age below 10 years, hypotension is 2n + 70 mmHg (where n = age in years); for children older than 10 years, hypotension equals SBP less than 90 mmHg. This is in accordance with previously described guidelines in anesthetized children for hypotension by the Brain Trauma Foundation.11 The number of epochs below these defined cutoffs during the preincision period were computed for every patient.

### Statistical analysis

Data analysis was performed with SPSS v15.0 for Windows (SPSS Inc., Chicago, Illinois, USA). Basic descriptive statistics, including means ± SD (for continuous variables) and percentages (for categorical variables) were used to summarize the demographic, clinical and anthropometric data. BMI was treated as a dichotomous variable, thus normal vs. high. High BMI was defined as age and sex-specific value of at least 85th percentile from the 2000 Centers for Disease Control and Prevention growth charts.12 We also chose to dichotomize BMI because there was no significant difference in the incidence of hypotension between overweight and obese children upon initial univariate analysis (28.2 vs. 27.9%, P = 0.62). Prior to performing multiple logistic regression analyses, we examined the univariate predictors for multicolinearity by first creating a correlation matrix and scanning for highly correlated variables (≥0.7). We then examined the maximum variance inflation factor produced for each predictor variable and used the value of 10 suggested by Myers13 as our cutoff for highly collinear variables. Variables found to have a high level of collinearity were removed from the logistic regression model. We treated the occurrence of PIH as a dichotomous-dependent variable (hypotension: yes, no). Factors associated with the occurrence of PIH were first identified by univariate analysis using Pearson’s χ² test for categorical variables or one-way analysis of variance as necessary. Variables identified as pertinent by univariate analysis were then included in a multivariate method using a full model fit logistic regression to determine independent predictors of PIH.

Pearson correlation coefficients were computed for the relationship between baseline SBP, age and the anthropometric parameters. The incidence of intraoperative hypotension (IOH) between high and healthy BMI was compared with Pearson’s χ² test. A priori statistical significance was defined as a two-sided P value of less than 0.05.

### Results

The study population was 19,400 children (56% boys) with a mean (SD) age of 8.3 ± 4.7 years and BMI of 19.3 ± 5.7 kg m⁻². Most (94.7%) patients were elective ASA I–II (79.7%) procedures. The descriptive characteristics of the study population by sex are shown in Table 1. The overall prevalence of high BMI was 30.7%. Boys were more likely to belong to the high BMI group than girls. Inhalational induction with sevoflurane was used in the majority (71.0%) of patients, whereas propofol coinduction was used in 36.7% of patients. Single episode of PIH occurred in 36.8% of patients, whereas 8.3% had at least three episodes of PIH. PIH was more frequent in children with high BMI than their lean peers (40.9 vs. 31.4%, P < 0.001). At the same time, children with high BMI were more likely to have had i.v. induction (29.5 vs. 25.3%, P = 0.003), propofol coinduction (38.6 vs. 34.1%, P = 0.02), rapid sequence induction (RSI; 2.3 vs. 0.6%, P < 0.001) and longer preincision period (P = 0.003) (Table 2). Subgroup analysis of children who had propofol coinduction (n = 7119) showed that hypotension was more frequent in children with high BMI than their lean peers (15.5 vs. 10.6%, P < 0.001). Similar pattern was noted for children who had i.v. induction or RSI. Of interest, hypotension following inhalational induction was more frequent in lean patients than in those with high BMI. The cumulative propofol dose administered during the preincision period was not significantly different between the children in the high BMI group compared with the lean group (2.1 vs. 2.3 mg kg⁻¹, P = 0.683).

Data on 16,901 patients was used to construct a model to predict the occurrence of PIH based on factors identified by univariate analysis (baseline BP data was missing in 2499 patients). The response variable for this model was hypotension (yes/no). All the variables in the model were treated as categorical apart from preincision duration, which was treated as a continuous variable. Prior to constructing the model, all potential predictors were assessed for nonindependence (collinearity diagnostics). The model was evaluated using the Omnibus tests of
Clinical characteristics of the study population by BMI category

<table>
<thead>
<tr>
<th>Factors</th>
<th>Normal BMI</th>
<th>High BMI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASA ≥III</td>
<td>18.4</td>
<td>17.8</td>
<td>0.268</td>
</tr>
<tr>
<td>Emergency surgery</td>
<td>3.5</td>
<td>4.1</td>
<td>0.005</td>
</tr>
<tr>
<td>Baseline hypotension</td>
<td>13.6</td>
<td>10.1</td>
<td>0.001</td>
</tr>
<tr>
<td>Inhalational induction</td>
<td>60.9</td>
<td>39.1</td>
<td>0.001</td>
</tr>
<tr>
<td>RSI</td>
<td>0.6</td>
<td>2.3</td>
<td>0.001</td>
</tr>
<tr>
<td>Propofol coinduction</td>
<td>34.1</td>
<td>38.6</td>
<td>0.002</td>
</tr>
<tr>
<td>Preincision duration (min)</td>
<td>8.7</td>
<td>14.6</td>
<td>0.001</td>
</tr>
<tr>
<td>Single PIH</td>
<td>31.4</td>
<td>40.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Multiple PIH</td>
<td>6.4</td>
<td>9.6</td>
<td>0.001</td>
</tr>
<tr>
<td>PIH with i.v. induction</td>
<td>37.1</td>
<td>48.3</td>
<td>0.001</td>
</tr>
<tr>
<td>PIH with RSI</td>
<td>34.4</td>
<td>46.0</td>
<td>0.03</td>
</tr>
<tr>
<td>PIH with inhalational</td>
<td>33.9</td>
<td>25.5</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Data presented as percentages unless otherwise stated. All P values generated with Pearson \( \chi^2 \) test. ASA, American Society of Anesthesiology; i.v., intravenous; PIH, preincision hypotension; RSI, rapid sequence induction.

The interaction between patient and anaesthetic factors. Whereas the clinical significance of IOH in adults is well described, there is a paucity of data on IOH in the paediatric anaesthesia literature. Therefore, a necessary first step to addressing this problem is a description of the risk factors associated with the occurrence of hypotension in children. High BMI is one of such risk factors.

The higher incidence of PIH in children with high BMI is probably multifactorial. Our result showed that obese children were more likely to require i.v. induction of anaesthesia with propofol as well as propofol coinduction. Children with high BMI were also more likely to have a hypotensive response to propofol than their lean peers. Although there was no significant difference in the mg kg\(^{-1}\) dose of propofol between the normal and high BMI groups, it could be that the lean weight of the study subjects was not evaluated; therefore, a slight overdose in the high BMI group is possible which could potentially explain some of the hypotension. However, we describe what is routine clinical practice in our and many other institutions, very rarely do clinicians estimate a child’s lean body mass prior to administering a drug such as propofol. The hypotensive effect of propofol is well described in adults and children. We recently showed that administration of propofol to complete the induction process during inhalational anaesthesia is an important risk factor for hypotension in children. The current data support this observation and identify children with high BMI as being particularly at risk. Obese children who had inhalational induction were more likely to require propofol coinduction and this could contribute to the higher incidence of PIH in this group of patients. Interestingly, inhalational induction does not appear to be a statistically significant risk factor for hypotension in children with high BMI. It must be noted, however, that 33.9% of children in the high BMI group became hypotensive with inhalational induction, a clinically relevant observation.

Another potential mechanism for the occurrence of hypotension in the obese patient may be possible subclinical cardiac dysfunction. Mehta et al. demonstrated an increased incidence of myocardial dysfunction in apparently healthy obese children when compared with their normal weight peers. Obese children have also been shown to have high left ventricular mass, cardiac output as well as left ventricular diastolic dysfunction. Presence of this subclinical evidence of cardiac dysfunction may contribute to increased incidence of PIH in obese children. The current study was, however, not designed to assess the preoperative cardiac function in children with high BMI. Future studies should try to correlate preoperative echocardiography findings with postinduction haemodynamic changes in children with high BMI.

We confirmed our recent finding and those of others that prolonged interval between induction of anaesthesia and the onset of surgical incision is a risk factor for IOH.
The preincision period is known to be associated with increased anaesthesia-related work and potential distraction from patient monitoring.\textsuperscript{3} The obese cohort in our study had longer preincision periods than their lean peers, which may be a factor in the occurrence of PH. Some possible causes of long preincision time in children with high BMI include difficulty with vascular access, difficult airway\textsuperscript{5} and difficulty with patient positioning. Other factors that have been shown to affect the duration of the preincision period are surgical service, age of the patient and their ASA physical status.\textsuperscript{21} However, the current study was not designed to address these causes of delay and mechanisms used to explain them can only be speculative. It is important to be aware of the contribution of the preincision period to hypotension and for increased vigilance by care providers during this period of minimal patient stimulation.

It could be argued that transient or multiple episodes of hypotension are of little clinical significance in the healthy paediatric patient unlike in the adult,\textsuperscript{7,15} or head-injured child.\textsuperscript{6} In fact, there is some evidence to show that clinicians tolerate a lower BP limit in children than they do in adults.\textsuperscript{13} There is, however, no data to support such a liberal approach to the hypotension limit in children. Given the higher prevalence of ‘adult-type’ chronic health problems such as diabetes, hypertension and subclinical left ventricular dysfunction in obese children compared with their normal weight peers, hypotension in children with high BMI may not be a benign complication. It is conceivable that there are subtle, transient (or permanent) effects of hypotension in children that have not been elucidated.

Some of the limitations of this study need to be identified. First, the BP data were abstracted from prospectively collected observational data during routine clinical care. Anaesthesia providers were not mandated to stick to a clinical protocol or to describe reasoning for their intraoperative management. Consequently, it was impossible to standardize the anaesthetic technique as well as the induction dose of any of the medications. It was also impossible to determine the appropriateness of the BP cuff used on these patients from a retrospective database. We are well aware of the importance of appropriate cuff size on BP readings. As limb circumference measurements were not recorded, we cannot prove proper cuff sizing in all patients. Additionally, data on preoperative fasting and preinduction hydration status were not collected in sufficient detail to allow for meaningful statistical analyses. We realize that preinduction volume status could be an important contributor to the occurrence of IOH. It is, however, not clear what role (if any) BMI will play in all these. Design of future prospective studies could help to answer some of these questions.

Despite the limitations outlined here, our observation is important, as it is to our knowledge the first to highlight the obese child as being at risk for PH. Whether this is a clinically important finding should be determined by future studies.

**Conclusion**

PH is common in children and high BMI is an independent predictor of its occurrence. Although hypotension in children may not have the same consequences in children as in adults, it remains to be seen whether the same argument could be made for obese children compared with their lean peers. Further studies examining the consequences of transient or persistent hypotension in children with high BMI are needed.

**References**


13 Myers R. Classical and modern regression with applications, 2nd ed. Boston, Massachusetts, USA: Duxbury; 1990.


