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Incidence and risk factors for preincision hypotension in a noncardiac pediatric surgical population

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Summary

Background: Routine monitoring of blood pressure is an essential part of perioperative care in adults and children. It is however not known whether intraoperative hypotension (IOH) is clinically important in the 'healthy' pediatric patient. This may be partly due to the lack of data on the incidence and consequences of IOH in this group of patients. We utilized the Brain Trauma Foundation definition of hypotension to describe the incidence of preincision hypotension (PIH) in a large pediatric noncardiac surgical population and identified risk factors for the occurrence PIH.

Methods: We examined the electronic perioperative records of all children aged 1–17 years undergoing general anesthesia for noncardiac surgeries between January 2005 and June 2007 in our institution. Frequency and factors associated with PIH were computed. Binary logistic regression with forward step-wise algorithm was used to examine factors associated with PIH.

Results: There were 22 263 children of whom 57.6% were males. Most (94.9%) cases were elective, American Society of Anesthesiologists (ASA) I–II (79.5%) procedures. Inhalational induction was predominantly used in this cohort (67%) although 33% of patients had propofol either as a sole induction agent or as part of a 'co-induction' regime. Single or multiple episodes of PIH occurred in 35.8% of patients. PIH was more common in patients with ASA ≥ III ($P < 0.001$); those with preoperative hypotension ($P < 0.001$); and following intravenous induction ($P < 0.001$) as well as propofol co-induction ($P < 0.001$). On multivariate analysis the following were significant predictors of PIH: baseline hypotension, propofol co-induction, age, ASA ≥ III, and long preincision period.

Conclusion: Preincision hypotension is common in the pediatric surgical population undergoing general anesthesia. Factors independently predictive of PIH included high ASA status, pre-existing hypotension, propofol co-induction prolonged preincision period and adolescent age group. The importance of blood pressure monitoring,

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prompt recognition of hypotension and use of appropriate intervention is emphasized.

Keywords: hypotension; pediatric anesthesia; intraoperative

Introduction

The importance of blood pressure (BP) monitoring in children in the emergency care and intensive care unit (ICU) setting is very clear (1–3). Routine monitoring of BP is one of the recommended standards of care by the American Society of Anesthesiologists (ASA) (4). Data from adult (5) and pediatric victims of trauma (6) suggests that low systolic BP is a predictor of mortality. It is also clear from adult-derived literature that intraoperative hypotension (IOH) is a very common consequence of induction of anesthesia (7) and it may be associated with early and long-term postoperative morbidity (8) and 1-year mortality (9). The clinical significance of hypotension in 'healthy' anesthetized children is however unknown. This may be partly due to the absence of data on the incidence of IOH in this group of patients and also because determination of threshold for treatment of hypotension is not amenable to randomized controlled trials. Therefore, analyses of large prospectively collected observational databases that include BP and controls for confounding variables may be the only feasible approach to study the subject (10).

Patients are particularly prone to hypotension in the preincision period. This interval is associated with increased anesthetic workload and potential distraction from patient monitoring by the anesthesia provider (11). However, the advent of electronic anesthesia information system makes it possible to collect accurate hemodynamic trends throughout the anesthetic period (11).

Most published guidelines in children define hypotension (using the Brain Trauma Foundation guidelines) as systolic BP (SBP) below the 5th percentile for age (12). This parameter has been shown to be a better predictor of poor outcome than SBP < 90 mmHg in head injured children (13). Although there is currently no consensus on what constitutes IOH in the pediatric anesthesia literature, most clinicians will agree that hypotension is an important sign that should be promptly investigated and when necessary, treated. This study used the Brain Trauma Foundation definition of hypotension (SBP < 5th percentile for age which is roughly = 2 × (age in years + 70) to define hypotension occurring in the preincision period (PIH). We also identified some predictors of PIH.

Subjects and methods

Following Institutional Review Board approval, we examined our perioperative, clinical information system. The records of all children aged 1–17 years undergoing general anesthesia for noncardiac operations during the period of January 2005 to January 2007 were examined. Perioperative data are routinely documented in the clinical information system (Centricity®; General Electric Healthcare, Waukesha, WI, USA) by anesthesiology residents, attending staff, and nurse anesthetists. We extracted the following clinical and anthropometric information from the database: age, gender, American Society of Anesthesiology (ASA) physical status, urgency of surgery (emergent vs non-emergent), as well as, height and weight. The mode of induction of anesthesia (inhalational vs intravenous) was noted. Use of inhalational induction accompanied by documented IV bolus of propofol in the preincision period was defined as 'propofol co-induction'. The main focus of the present study was the preincision period, identified from each anesthetic record as the interval between documented 'patient in room' time and 'surgical incision time'. Our anesthesia 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, and anesthesia end times.

Blood pressure data

Preoperative SBP data were obtained from the baseline values documented in the preanesthesia review record. Intraoperative BP measurement is done automatically using either the oscillometric method (with an appropriate size cuff) or intra-arterial catheters. The resident or nurse anesthetist under direct supervision of an attending pediatric anesthesiologist determines appropriateness of BP cuff size. The guiding principle is that the inflatable portion of the cuff should encircle 75% or greater of the limb circumference, and the length of the cuff should be at least two-thirds of the length of the upper limb segment (14). Where both oscillometric and invasive BP readings were available, we used the invasive BP readings for analysis.

Intraoperative BP data were acquired from our, electronic physiologic monitors (Solar 9500®; General Electric Healthcare). BP values were automatically recorded every minute for patients with arterial catheters and every 3 min for patients with noninvasive BP cuffs. We divided each intraoperative anesthetic record into successive 10-min epochs. The median SBP for each 10-min epoch on the anesthesia chart was calculated. The use of a median value over a defined time period filters out monitoring artifacts and clinically insignificant, transient hypotension (8). These median SBP values were compared with age-dependent cut-off points for hypotension as previously described (12). The numbers of hypotensive epochs during the preincision period were computed for every patient.

Statistical analysis

Data analysis was performed with SPSS v.15.0 for Windows (SPSS Inc., Chicago, IL, USA). Basic descriptive statistics, including mean ± SD (for continuous variables) and percentages (for categorical variables) were used to summarize the demographic, clinical and anthropometric data. Prior to performing multiple logistic regression analyses, we examined the univariate predictors for multiple co-linearity by first creating a correlation matrix and scanning for highly correlated variables (≥0.7). We then examined the maximum variance inflation factor (VIF) produced for each predictor variable and used the value of 10 suggested by Myers (15) as our cut-off for highly collinear variables. Variables found to have a high level of co-linearity were either removed from the full model logistic regression model or collapsed into a single relevant variable. The remaining variables were entered into a logistic regression full model fit. All variables deemed to be significant in the full model fit ($P < 0.05$) were established as independent predictors. A propensity score was developed for each patient for predicted probability (ranging from 0 to 1). Each variable was also assessed for effect size using hazard ratios comparing the likelihood of PIH among patients with and without the risk factor. The resulting model's predictive value was evaluated using a receiver operating characteristic (ROC) and area under the curve (AUC). ROC curves are characteristically plotted to demonstrate the discriminatory power of a diagnostic test over the entire range of test results. A good test will have its curve skewed to the upper left corner (16). The area under the curve (AUC) defines the diagnostic power of a test; a perfect score will have an AUC of 1, while an AUC of 0.5 means the test performs no better than chance (16).

We treated the occurrence of PIH as a dichotomous dependent variable (hypotension yes/no). We stratified the children into three age groups based on published guidelines for hypotension limits (17) and well-recognized developmental periods for functional and physiological transitions (18). Pearson Correlation coefficients were computed for the relationship between baseline SBP, age, and the anthropometric parameters. The incidence of IOH between induction methods was compared with Pearson's chi-squared test. *A priori* statistical significance was defined as two-sided P-value of <0.05.

Results

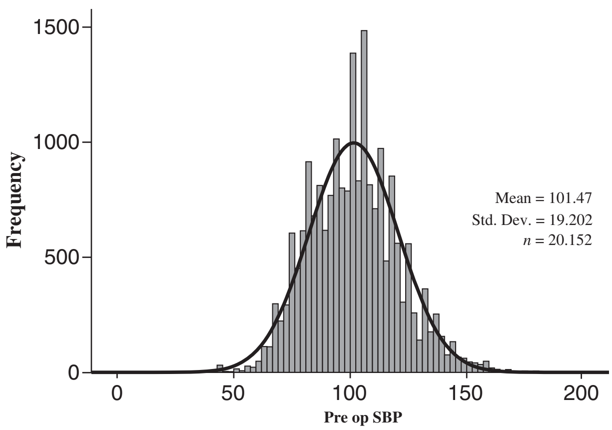
A total of 23 699 perioperative records were reviewed and we excluded 1406 records due to missing surgical incision time. Therefore 22 263 patients constituted the study population of whom 12 816 (57.6%) were males and 9447 (42.4%) were females. Most of the patients were ASA I–II (79.2%), undergoing elective (95.3%) surgical procedures. The mean age for the entire study population was 7.40 ± 4.96 years. The demographic and clinical distribution of patients by age groups is shown in Table 1. Majority (44.4%) of patients were preschoolers. Older patients (adolescents) were more

Table 1
Demographic, clinical and anthropometric distribution of the patients by age group

	Preschool *(1–5 years)* (n = *9870*)	*Grade school* *(6–11 years)* (n = *6706*)	*Adolescence* *(≥12 years)* (n = *5687*)
Male (%)	58.8	56.6	56.5
Age (years)	2.7 (1.4)	8.3 (1.7)	14.4 (1.7)*
Height (m)	0.94 (0.1)	1.3 (0.2)	1.6 (0.2)*
Weight (kg)	14.8 (4.6)	32.2 (13.4)	59.4 (20.9)*
Preoperative SBP (mmHg)	91.8 (15.8)	104.1 (16.8)	114.7 (18.3)*
Baseline hypotension	8.8	2.9	1.6*
ASA ≥ III (%)	20.1	17.6	24.7*
Emergency (%)	3.5	5.2	6.4*
IV induction (%)	19.1	21.1	59.8*
Propofol co-induction	21.8	28.9	49.2*

SBP, systolic blood pressure.
Values are mean (SD) unless otherwise stated.
**P*-values < 0.001 (group comparisons done with one way ANOVA for continuous variables or Pearson's chi-squared test for categorical variables).

likely to be in the higher ASA group and were more likely to be having emergency surgery ($P < 0.001$). Baseline SBP record was available in 20 152 patients. The distribution is shown in Figure 1. The baseline SBP showed a moderate positive correlation with age ($r = 0.52$, $P < 0.001$) and height ($r = 0.50$, $P < 0.001$). The incidence of baseline hypotension was 5.2%. There was no significant difference in the incidence of baseline hypotension between elective and emergency cases (5.2% vs 5.0%; $P = 0.87$). As expected, intravenous induction was used more often for emergency cases than for electives (74.2% vs 24.0%; $P < 0.001$) and in older compared with the younger age groups (Table 1). The predominant IV induction agent was propofol (used in 94%) of patients. Intraoperative BP data were available in 20 413 patients and were recorded with the oscillometric method in 91.2% of patients, while 8.8% had intra-arterial catheters. Single or multiple epochs of PIH occurred in 35.8% of patients. Three or more episodes of PIH occurred in 1488 (7.3%) of patients. The preincision period ranged from 5 to 140 min and had a mean (SD) of 12.5 (7.2) min. PIH showed a moderate positive correlation with duration of the preincision period ($r = 0.34$, $P < 0.001$) indicating that long preincision period is associated with more frequent epochs of hypotension.



SBP = systolic blood pressure.

Figure 1
Distribution of preoperative systolic blood pressure (SBP) in the study population.

Factors found to be associated with PIH on univariate analysis are shown in Table 2. Preincision hypotension (PIH) was slightly more frequent in males and with emergency surgeries. PIH was strongly associated with preinduction (baseline) hypotension, older age group, use of intravenous induction method and high ASA category ($P < 0.001$ for all variables; Table 2).

Multivariate logistic regression indicated that the factors detailed in Table 3 were associated with the

Table 2
Univariate analysis of factors associated with and proportion of patients with or without PIH

Risk factors	*PIH present* (%) n = *7979*	*No PIH* (%) n = *14 284*	P-*value*
Male/female	34.9/37.1	65.1/62.9	0.001
Age groups (years)			
1–5	27.0	73.0	<0.001
6–12	39.7	60.3	
>12	46.7	53.3	
ASA groups			
I–II	32.6	67.4	<0.001
III–V	42.2	57.2	
Urgency of surgery			
Emergency	37.3	62.7	0.028
Elective	34.0	66.0	
Induction technique			
Inhalational induction	30.87	69.2	<0.001
Intravenous induction	43.4	56.6	
Propofol co-induction	64.1	35.9	
Preinduction BP category			
Baseline hypotension	61.0	39.0	<0.001
Baseline normotension	33.0	67.0	

PIH, preincision hypotension.
All *P* values generated with Pearson's chi-squared test.

Table 3
Independent predictors of preincision hypotension

	AOR	*95%* CI	*P*-value
Baseline hypotension	5.52	4.78–6.38	<0.001
ASA ≥ III	1.80	1.17–2.01	0.001
Preincision duration	1.50	1.52–1.60	0.001
Propofol co-induction	1.33	1.23–1.44	0.001
Age group	1.60	1.53–1.68	0.001

CI, confidence interval; BMI, body mass index; ASA, American Society of Anesthesiology physical status.
AOR, adjusted odds ratio: the odds of the outcome variable (hypotension) occurring after adjusting for possible contributions from other variable included in the model.

occurrence of at least one episode of PIH. The ROC curve analysis of this model showed an AUC of 0.76 ± 0.03 (Figure 2). Preinduction (baseline) hypotension was associated with the highest odds of PIH. Specifically, when controlling for the other covariates in the model, baseline hypotension was associated with fivefold higher odds of PIH [odds ratio (OR) = 5.52; 95% confidence interval (CI) = 4.78–6.38, $P < 0.001$). Furthermore, the odds of PIH were increased by 33% for children who had propofol co-induction of anesthesia (OR = 1.33, 95% CI = 1.23–1.44, $P < 0.001$). Interestingly, when we controlled for other factors, the odds of PIH was not significantly different between emergency and elective surgeries (OR = 1.03; 95% CI = 0.87–1.20, $P = 0.76$).

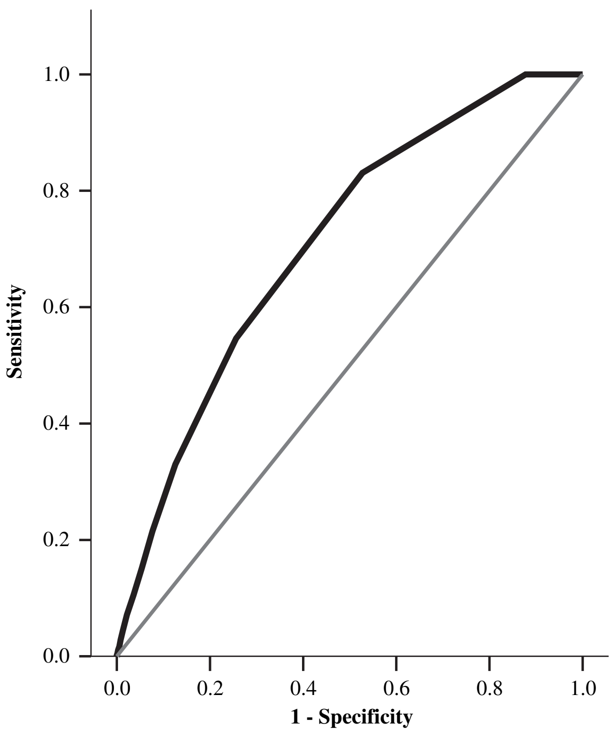


Figure 2
A receiver operating characteristic (ROC) curve evaluating the sensitivity and specificity of risk factors for PIH is shown. Four independent predictors were identified ($P < 0.05$): baseline hypotension, propofol co-induction, high ASA status and age. The ROC curve is based on the propensity score calculated for each patient using the logistic regression full model fit. The area under the curve for the predictor ROC curve was 0.76 ± 0.03. Area under the ROC curve indicates the usefulness of a test in predicting a binomial outcome (hypotension yes/no), and 0.76 is considered 'fair' in most texts.

Discussion

Routine measurement of BP is an integral part of every anesthetic and an essential component of all clinical examination. Although there is a large body of literature on pediatric hypotension in the critical care and surgical journals (6,17–19), very little data exist in the pediatric anesthesia literature (20). All these studies were focused on the patient with head injury. Although pediatric anesthesiologists daily monitor BP during anesthesia, there is no data on the incidence of hypotension in the noncardiac pediatric surgical population undergoing general anesthesia. This is therefore the first study to document the incidence of hypotension in this cohort of patients. Data from adults suggests that hypotension following induction of general anesthesia is a frequent phenomenon. Reich *et al.* (8) in a cohort of about 4000 adult patients observed an incidence of hypotension of 9% following induction of general anesthesia. Miller *et al.* (20) reviewed data on 108 children with traumatic brain injury undergoing decompressive craniotomy and found that 52% of children had IOH. However, these authors did not specifically study the preincision period. PIH was observed in 36% of children in our study. We focused on the preincision period because hypotension occurring during this period is largely due to anesthetic or pre-existing patient factors. This also filters out the effects of intraoperative blood loss and varying surgical stimulation during the course of anesthesia on the patient's BP. Our data may therefore have greater external validity when describing the incidence of hypotension associated with induction of general anesthesia in children.

The incidence of baseline hypotension in the pediatric surgical patient was previously unknown. About 5% of children in our database had documented hypotension by the Brain Trauma Foundation criteria during the preoperative examination. Our result suggests that it is crucial to identify children with baseline hypotension prior to induction of general anesthesia because this group has a very high (approximately five times) odds of PIH. This confirms one of the classic teachings in anesthesia: preoperative hypotension is accentuated by induction of general anesthesia (21,22). It has been suggested that there may be a lack of awareness and anticipation of preoperative hypotension in children or that clinicians may simply tolerate lower BP nadir in children than in adults (20). Whereas the child with decompensated hypotension (shock) may be relatively easy to identify, hypotensive children without any other clinical signs may be easily overlooked during a busy pediatric preoperative review. It is essential to recognize that, due to their considerable physiologic reserve and ability to maintain normal BP in the face of significant volume loss, hypotension in children is often a late sign of intravascular volume depletion (17,23). Therefore, the presence of hypotension during the preoperative assessment (even in an apparently 'stable' child) should prompt a search for a possible cause and anesthetic care should be modified accordingly. Possible steps include: delaying surgery to correct the underlying cause, prompt establishment of IV access for fluid and drug administration, and selection of relatively cardio-stable drugs like ketamine and etomidate for induction of general anesthesia. One possible etiology for baseline hypotension in these children is dehydration from mandatory preanesthetic starvation. It is conceivable that the longer the nil per oris period, the higher the likelihood of dehydration particularly in small children. Presence of dehydration is likely to be associated with difficult venous access precluding timely administration of IV fluids. Additionally, difficult venous access could make for a rather prolonged preincision period and increased likelihood of task-oriented distraction by the anesthesia care giver (10). Unfortunately, we do not have data on the preoperative fasting duration, hydration status or ease of venous access in these children.

Another factor that contributes to the occurrence of PIH is 'propofol co-induction'. This involves the induction of general anesthesia with a volatile anesthetic and then giving a bolus of propofol once an IV is established either to complete the induction process or prior to performing a stimulating procedure like direct laryngoscopy. Propofol (24,25) and Sevoflurane (26) have become the most common IV induction and inhalational agents respectively in pediatric anesthesia and are often used as part of a co-induction regimen as described above. The hypotensive effect of propofol is well known because of its lowering of the systemic vascular resistance, cardiac output or direct myocardial depression (27). In their retrospective study of adult patients, Reich *et al.* (8) concluded that propofol use in the induction period was a strong predictor of postinduction hypotension. Although 'propofol co-induction' appears to be a common practice, there's very little data on the consequences of this technique. Our data from this large cohort of children suggests that it's an important risk factor for PIH.

The effect of age is interesting because it appears that older age group is a predictor of PIH. This is probably because older children are more likely to have IV induction as well as require propofol supplementation (co-induction) following inhalational induction (Table 2).

We were somewhat surprised that emergency surgery was not a statistically significant predictor of PIH particularly given that use of IV induction was proportionately higher during emergency surgeries and IV induction was associated with a higher incidence of PIH (Tables 2 and 3). Clinical experience indicates that many patients presenting for emergency surgery would have an IV line in place and would have been on maintenance fluids for some period and so are more likely to be volume replete at induction of anesthesia. Also prior availability of IV access means that hypotension can be promptly treated with fluids or pharmacotherapy.

Study limitations

This study has some limitations that merit discussion. The BP data were collected as part of routine clinical care by various practitioners making it impossible to standardize the anesthetic induction techniques. It was also impossible to standardize or determine the appropriateness of BP cuff used to generate the data. Additionally, mechanisms used to explain the risk factors and association with PIH from a retrospective database analysis can only be speculative. However, one of the unique advantages of large database analysis is that they provide opportunities for studying conditions that are not ethical to study prospectively. For example, randomized controlled trial of hypotension and outcome are impossible for obvious ethical reasons but, large database analysis like ours can provide a template upon which future observational outcome studies can be built to carefully detail the consequences (if any) of PIH in the pediatric surgical population.

Despite these limitations, our study provides pediatric anesthesiologists with clinically useful information about risk factors for PIH and highlights the importance of identifying hypotensive children prior to inducing general anesthesia.

In conclusion, this study describes the incidence of PIH in a large pediatric surgical population and concludes that hypotension is very common in children undergoing general anesthesia. We also identified factors independently predictive of PIH and stress the importance of screening for preoperative hypotension as this is associated with a fivefold increased risk of PIH. Although IOH may not have the same cardiac and neurologic consequences in children as in adults, it is a physiologic aberration that needs to be prevented and perhaps promptly treated. Future prospective studies should examine early and long-time (neuro-cognitive?) consequences of isolated or prolonged IOH in children. For obvious ethical reasons, such studies can only be retrospective. It is also imperative to have future studies that will address the development of a usable consensus definition for pediatric IOH, a common perioperative event.

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