Blood pressure and heart rate changes during fibreoptic orotracheal intubation: a comparison of children and adults

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Summary
Background and objectives: Autonomic circulatory regulation and airway anatomy in children are significantly different from those in adults. There is no available published data to compare whether there is a clinically relevant difference in the haemodynamic responses to fibreoptic orotracheal intubation (FOI) under the same conditions between children and adults. In this randomized clinical study, we compared the blood pressure (BP) and heart rate (HR) changes during FOI in 40 children aged 3.5–9 yr and 40 adults aged 21–57 yr, ASA 1 scheduled for elective plastic surgery under general anaesthesia requiring orotracheal intubation. Methods: Anaesthesia was induced with intravenous (i.v.) injection of fentanyl and propofol, and face mask inhalation of isoflurane before FOI. Noninvasive BP and HR were recorded before induction (baseline values), after induction (postinduction values), at intubation and for 5 min after intubation at 1-min intervals. The percentage changes of BP and HR at each time point were calculated. Results: In children and adults, HR at intubation and 1–3 min after intubation were significantly higher than baseline and postinduction values. In adults, BP at intubation increased significantly compared to the postinduction values but did not exceed baseline values. In children, BP at intubation and 1 min after intubation were significantly higher than postinduction and baseline values. As compared to adults, FOI caused a more significant pressor response in children. The percentage changes of BP at intubation and 1 min after intubation were larger in children than in adults. However, there was no significant difference in the percentage change of HR during the observation between children and adults. Conclusions: Under general anaesthesia, FOI might cause a more significant pressor response in children than in adults.

Keywords: INTUBATION, INTRATRACHEAL, fibreoptic bronchoscope; ANAESTHESIA GENERAL; CARDIOVASCULAR PHYSIOLOGY; CHILDREN; ADULTS; HAEMODYNAMIC PHENOMENA, blood pressure, heart rate.

Introduction
The increasing use of the fibreoptic bronchoscope (FOB) in clinical anaesthesia brings about more attention to the haemodynamic response during fibreoptic intubation. Although the haemodynamic response to fibreoptic orotracheal intubation (FOI) has been widely studied in adults [1–8], few relevant studies are available in children [9,10]. It is well known that the haemodynamic responses to tracheal intubation are mediated by both the sympathetic and parasympathetic nervous systems [11]. Physiological studies demonstrate that prepubertal children have different autonomic cardiovascular profiles with a higher parasympathetic cardiac drive and lower sympathetic vascular tone compared with adults [12]. It has been established that the baroreflex becomes functional late in gestation and its sensitivity then increases gradually after birth with age, attaining maximum value
at adolescence (11–14 yr) and starts to decline from the age of 20 yr [13]. But baroreceptor reflexes have been found to be more attenuated in both young animals and humans anaesthetized with halothane [14,15] or nitrous oxide [16,17] compared with adults. In addition, FOI may cause different airway stimuli in children and adults because of the differences in airway anatomy. Therefore, the haemodynamic response to FOI in children may differ from that of adults. To the best of our knowledge no previous study has compared the difference in the haemodynamic responses to FOI under the same conditions between children and adults. This randomized clinical study was undertaken to compare the haemodynamic responses to FOI in healthy children and adults under general anaesthesia.

Methods

With Ethics Committee approval and written informed consent 40 children aged 3.5–9 yr and 40 adults aged 21–57 yr, ASA 1, scheduled for elective plastic surgery under general anaesthesia requiring orotracheal intubation were included in this study. Exclusion criteria were a history of reactive airway disease, gastroesophageal reflux, severe craniofacial anomalies, developmental delay, use of medications known to affect blood pressure (BP) and heart rate (HR).

All patients fasted overnight and were restricted from oral intake of clear fluid for 2–3 h in children and for 4–6 h in adults. They all were normothermic. All patients were premedicated with midazolam 0.1 mg kg$^{-1}$ (maximum 5 mg) and scopolamine 0.01 mg kg$^{-1}$ (maximum 0.3 mg) intramuscularly (i.m.) 1 h before entering the operating room. In children local anaesthetic (EMLA®) was applied to the dorsum of a foot approximately 1 h before the insertion of intravenous (i.v.) cannula in the operating room. After patients entered the operating room, noninvasive BP and oxygen saturation ($S_\text{O}_2$) were continuously monitored with a multifunction monitor (Datex.Ohmeda F-CU8; Datex Instrumentarium, Helsinki, Finland). The width of BP cuff used for a patient was about two-thirds of the length of his or her upper arm. After a stabilization period of 10 min, baseline values of HR, systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial pressure (MAP) were obtained from the average of the three measurements which were obtained 2 min apart. Then a 22- or 24-G i.v. catheter in children and 18-G i.v. catheter in adults were inserted into a vein on the dorsum of a foot. A PVC Murphy-type cuffed tracheal tube (Hudson Respiratory Care Inc, Temecula, CA, USA) was used in our study. Tracheal tubes with internal diameter 7.5 mm and 7.0 mm were used for male and female adults, respectively. The suitable size of tracheal tube for a child was determined by following formula [18]: internal diameter (mm) = (age/3) + 3.5. In this study a fiberoptic bronchoscope with outer diameter of 3.1 mm (Olympus LF-DP, Tokyo, Japan) and 5.5 mm (Olympus LF-TP, Tokyo, Japan) were used for children and adults, respectively.

Before intubation, the tracheal tube was adequately lubricated with a lidocaine gel and was threaded over a FOB.

After 5 min preoxygenation, anaesthesia was induced with fentanyl 2 µg kg$^{-1}$ and propofol 2 mg kg$^{-1}$ in adults and 2.5 mg kg$^{-1}$ in children, respectively, injected i.v. over 15–20 s. Neuromuscular block was produced with vecuronium 0.1 mg kg$^{-1}$ injected i.v. When any response to verbal command was lost, patients were ventilated via a face mask with 1% isoflurane and 100% oxygen. If any difficulty was encountered in performing face mask ventilation after induction of anaesthesia, the patient was withdrawn from the study. The FOI was performed 2 min after vecuronium injection. Before the intubation procedure, patient lay supine on the operating table with a towel roll underlying the shoulders and the head was placed in the sniffing position. All tracheal intubation procedures were performed by anaesthetists experienced in using the FOB, all of whom had performed fiberoptic tracheal intubation in more than 150 patients, including at least 40 children, prior to this study.

After the intubation was successfully completed, the tracheal tube was connected to the circle breathing system of an anaesthesia machine for intermittent positive pressure ventilation. Anaesthesia was maintained with 1% isoflurane in 60% nitrous oxide and 40% oxygen. During the observation, a fresh gas flow of 1.5 L min$^{-1}$ was used and the end-tidal carbon dioxide partial pressure was maintained at 35–40 mmHg. Inspired and end-tidal concentrations of oxygen, nitrous oxide, isoflurane and carbon dioxide were measured continuously and displayed digitally.

The maximum and minimum values of BP and HR measured by the multifunction monitors during the observation were recorded. The percentage changes of BP and HR at each time point (measurement value – baseline value/baseline value × 100%) were calculated. The intubation time, namely the period from reinitiation of ventilation through a tracheal tube, to reinitiation of manual ventilation using a face mask was recorded using a stopwatch.

During observation HR of <60 beats min$^{-1}$ was considered as a bradycardia and SBP of <70% of its baseline was considered as hypotension. The FOI was discontinued and assisted ventilation was immediately applied via a face mask with 100% oxygen if the $S_\text{O}_2$ was <90%. Patients requiring more than 60 s or more than one attempt to achieve successful tracheal intubation were also excluded from statistical analysis of the data.
All data were stored and analysed with SPSS statistical software (Version 11.5; SPSS Inc., Chicago, IL, USA). The comparison of male/female distribution between the two groups was done using a χ²-test. The comparisons of general data, BP and HR, and their percentage changes at each time point between the two groups were made using an unpaired t-test and Mann–Whitney tests as appropriate. The comparisons of BP and HR within groups were done using a repeated-measures analysis of variance and a Student–Newman–Keuls’ test. Power calculation indicated that 40 subjects in each group would be required to demonstrate 20% difference (SD = 60%) in the percentage changes of BP and HR, with α = 0.05, β = 0.2. All quantitative data are expressed as mean ± SD. A P-value <0.05 was considered as significant and a P-value <0.01 as highly significant.

Results
The tracheal intubation was successful at first attempt in all patients and no patient had an intubation time of more than 60 s. There were significant differences in the patient characteristics data between the two groups (Table 1), but the two groups were similar with respect to intubation times (35.6 ± 12.7 s, range 14–57 in children vs. 35.2 ± 7.3 s, range 24–52 s in adults).

After anaesthesia induction, BP decreased significantly in both groups compared to the baseline and HR remained stable in adults but became lower in children. In adults, BP at intubation was significantly higher than the postinduction values but did not exceed baseline values. In children, BP at intubation and 1 min after intubation were significantly higher than the postinduction and baseline values. The maximum values of BP were not significantly different from the baseline values in adults, but were significantly higher than the baseline values in children. In children and adults, HR at intubation and 1–3 min after intubation and the maximum value of HR were significantly higher than baseline values (Table 2).

As compared to adults, FOI caused a more significant pressor response in children. The percentage changes of BP at intubation and 1 min after intubation were significantly higher than baseline values. In adults, BP at intubation was significantly lower than the postinduction values but did not exceed the baseline values. In children, BP at intubation and 1 min after intubation were significantly higher than the baseline values (Table 2).

Table 1. Patient characteristics data (n = 40).

<table>
<thead>
<tr>
<th>Gender (M/F)</th>
<th>Children</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>6.4 ± 1.6 (3.5–9)</td>
<td>31.3 ± 10.1 (21–57)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>113.4 ± 8.9 (97–140)</td>
<td>165.0 ± 6.7 (155–180)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>20.4 ± 5.8 (12–31)</td>
<td>59.2 ± 7.8 (45–85)</td>
</tr>
</tbody>
</table>

Table 2. Changes of BP and HR associated with FOI.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Groups</th>
<th>Baseline</th>
<th>Post-ID</th>
<th>At IT</th>
<th>Post-ID, post induction</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP (mmHg)</td>
<td>Adults</td>
<td>115.2 ± 10.5</td>
<td>90.6 ± 10.2</td>
<td>108.6 ± 14.7</td>
<td>121.2 ± 15.1*</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>107.2 ± 16.2</td>
<td>70.1 ± 9.7</td>
<td>14.8*</td>
<td>116.4 ± 9.9</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>Adults</td>
<td>70.3 ± 9.7</td>
<td>51.3 ± 7.2</td>
<td>70.1 ± 10.4</td>
<td>60.8 ± 10.6</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>59.9 ± 12.3</td>
<td>43.6 ± 6.8</td>
<td>7.22 ± 14.8</td>
<td>10.25 ± 10.4*</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>Adults</td>
<td>80.7 ± 9.6</td>
<td>62.4 ± 6.9</td>
<td>86.3 ± 9.1</td>
<td>86.1 ± 10.4*</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>80.1 ± 15.3</td>
<td>76.1 ± 17.6</td>
<td>91.2 ± 15.3*</td>
<td>99.1 ± 15.8</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>Adults</td>
<td>100.7 ± 18.5</td>
<td>72.0 ± 15.3</td>
<td>7.3 s</td>
<td>64.1 ± 7.3</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>107.0 ± 18.5</td>
<td>98.5 ± 13.7</td>
<td>12.7 s</td>
<td>119.7 ± 14.9</td>
</tr>
</tbody>
</table>

Post-ID, post induction, At IT, at intubation. Data are mean ± SD except for gender data; *P < 0.05 compared to baseline values, P < 0.01 compared to postinduction values.
were higher in children than in adults (Figs 1 and 2). However, there was no significant difference in the percentage changes of HR between children and adults (Fig. 3). No patients developed bradycardia or hypotension and $S_{O_2}$ in all patients was maintained 100% during the study.

**Discussion**

Hannallah and colleagues [19] recommended that in unpremedicated children aged 3–12 yr, propofol 2.5–3.0 mg kg$^{-1}$ should be used as an induction dose to ensure a smooth transition to an inhalational maintenance technique. Manschot and colleagues [20] reported that if preceded by 5 µg kg$^{-1}$ of alfentanil, propofol 2.5 mg kg$^{-1}$ was an appropriate induced dose for children aged 3–15 yr. As our children were premedicated with midazolam and i.v. administration of fentanyl and face mask inhalation of isoflurane were also combined for anaesthesia induction, propofol 2.5 mg kg$^{-1}$ was selected as an induction dose. A previous study [21] demonstrated that this technique of anaesthesia induction not only effectively prevented the occurrence of moderate to severe postinduction and preintubation hypotension in children, but also can attenuate the pressor response to laryngoscopic orotracheal intubation.

The total body clearance and the volume of central compartment of propofol calculated on the basis of body weight are smaller in adults than in children. It is generally recommended that the lower induction dose of propofol based on body weight, e.g. mg kg$^{-1}$, is required for adults [22]. In our adults, therefore, propofol 2.0 mg kg$^{-1}$ was administered for
anaesthesia induction. A previous study [23] has demonstrated that propofol 2.5 mg kg$^{-1}$ in children and 2.0 mg kg$^{-1}$ in adults combined with i.v. administration of fentanyl 2 µg kg$^{-1}$ and face mask inhalation of 1% isoflurane can achieve a comparable level of general anaesthesia induction when a bispectral index of 50–55 is used.

Our results showed that after anaesthesia induction, BP decreased significantly in all patients and HR remained stable in adults but became lower in children compared to the baseline value. However, BP and HR in both groups were all within the physiological range. These results are in agreement with the results of previous studies on adults [24,25] and children [10,19–21,26,27] receiving propofol-opioid anaesthesia induction. This suggests that anaesthesia induction attenuates sympathetic tone and depresses baroreceptor reflexes. It can contribute to the combined depressant effects of propofol, fentanyl and isoflurane on sympathetic activity and baroreceptor reflexes [28–32]. Although a direct comparison of baroreflex sensitivity in both groups was not performed, the difference in HR change after anaesthesia induction may also be a reflection of a more significant baroresponse impairment in children than in adults.

Due to the developmental changes, the children we studied have significantly higher baseline HR and lower baseline BP than adults [33]. Therefore, the haemodynamic responses to FOI in both the groups were compared by the percentage changes of BP and HR in contrast to their baseline values rather than their absolute value in our study.

Our results showed that FOI resulted in a more severe pressor response in children than in adults. The reasons for this result may be multifactorial. Firstly, when the FOB or the tracheal tube is inserted into trachea, the anatomical differences in airway anatomy between children and adults, e.g. in children – relatively short neck and large size of tongue, larger and stiffer epiglottis, and its greater angulation with laryngeal aperture, more cephalad position of larynx, etc., [33] may cause a stronger friction or stimuli against the pharyngolaryngeal structures in children than in adults, thereby intensifying the haemodynamic responses to FOI in children. Secondly, as compared with a larger-diameter FOB (5.5 mm) used for adults, the distal bending section of a narrow-diameter FOB (3.1 mm) used for children was less able to resume its natural straight position by itself. As a result, the distal end of a narrow-diameter FOB may be at higher risk of being snagged when it is advanced into the child’s trachea compared to a larger-diameter FOB running along the adult’s trachea. Furthermore, the internal diameter of the trachea is much smaller in children than in adults. This probably induces a greater stimulus to the child’s trachea. Some studies have demonstrated that the tracheal stimulus is another main cause of the haemodynamic responses to tracheal intubation [4,5,34]. Thirdly, because HR is a determinant of stroke volume and of cardiac output, it plays a major role in BP regulation. The modulatory influence of HR driven by the autonomic nervous system is in turn regulated by the baroreflexes [35]. Physiological studies have established that baroreflex control of HR is primarily mediated by the cardiac parasympathetic response [36]. As above-mentioned, anaesthesia induction caused more baroreflex depression in children than in adults. This may bring about a greater increase in the sympathetic afferent activity to stimulation of airways mechanoreceptors caused by the FOI procedure in children because of less parasympathetic antagonism.

Fentanyl exhibits excellent cardiovascular stability and has frequently been used as an adjunct to propofol and barbiturate induction [19–22,29,37–39]. Fentanyl has been shown to reduce sympathetic and increase vagal neural tone [30]. Many studies have also reported a beneficial effect of fentanyl on the adverse haemodynamic responses to intubation [11]. Adachi and colleagues [5] reported that fentanyl 2 µg kg$^{-1}$ administered i.v. immediately before induction of anaesthesia with propofol 2 mg kg$^{-1}$, infused at 250 µg kg$^{-1}$ min$^{-1}$ for 8 min, could completely abolish the haemodynamic responses to FOI in adults aged 19–70 yr. But our results showed that in adults the maximum values of SBP, DBP, MAP and HR increased by 5.2%, 3.1%, 10.3% and 27.7% of the baseline values, respectively. This suggested that in adults fentanyl 2 µg kg$^{-1}$ in conjunction with propofol 2 mg kg$^{-1}$ bolus injection could effectively blunt the pressor response to FOI, but not the tachycardiac response. This different result may be related to the differences in selection of study objects, times and methods of fentanyl and propofol administered i.v. between Adachi and colleagues and our studies. Ko and colleagues [37] confirmed that during anaesthesia induction the optimal time of injection of a small dose of fentanyl (2 µg kg$^{-1}$) for attenuating the circulatory responses to laryngoscopic orotracheal intubation was 5 min before intubation.

In our children, the maximum increases of SBP, DBP, MAP and HR were 26.2%, 52.3%, 42.1% and 29.2% of the baseline values, respectively. This suggested that in children fentanyl 2 µg kg$^{-1}$ in combination with propofol 2.5 mg kg$^{-1}$ could not effectively suppress the circulatory responses to FOI. This may contribute to insufficient doses of fentanyl and propofol, and inadequate time of fentanyl administered i.v. Braga [38] found that in children aged 1–8 yr and weight 10–30 kg, fentanyl 3 µg kg$^{-1}$ administered i.v. 5 min before anaesthesia induction with propofol 3 mg kg$^{-1}$ could provide adequate
laryngoscopic orotracheal intubation conditions without any significant haemodynamic change. In addition, Sim and Splinter [39] reported that fentanyl 3µg kg⁻¹ in combination with thiopentone 5 mg kg⁻¹ could also completely attenuate the haemodynamic responses to laryngoscopic orotracheal intubation in children aged 2–12 yr. Our previous study [10] confirmed that both fibreoptic and laryngoscopic orotracheal intubation might result in the same pressor and tachycardiac responses in children. Based on the results of this study and other previous studies, we presume that the effective dose of fentanyl blunting the circulatory responses to FOI may be 3µg kg⁻¹ in healthy children and fentanyl should be administered 5 min before the induction of anaesthesia with propofol. These problems deserve further study.

In conclusion, the present study demonstrated that under general anaesthesia, FOI might cause a more significant pressor response in children than in adults. Fentanyl 2 µg kg⁻¹ in combination with propofol 2.5 mg kg⁻¹ in children and 2 mg kg⁻¹ in adults administered i.v. 2 min before intubation was insufficient to effectively blunt the circulatory responses to FOI.

References


