Preoxygenation in children using expired oxygraphy

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Summary
We performed preoxygenation on 25 patients, aged 1–12 yr. End-tidal oxygen sampling was used to find the duration of preoxygenation required to reach an end-tidal oxygen fraction of 0.9. All children reached this end-point within 80 s, which was markedly more rapid than that observed in adult subjects. The clinical applications of this form of monitoring in children are discussed. (Br. J. Anaesth. 1996;77:333–334)

Key words

Preoxygenation of the lungs is an important component of rapid sequence induction of anaesthesia and in many instances is part of routine anaesthetic practice. It reduces the risk of hypoxia during apnoea after induction of anaesthesia by providing a reservoir of oxygen in the patient’s functional residual capacity (FRC). Although there have been many studies on the period required for preoxygenation, none has measured alveolar gas concentration in the paediatric population. Recent work has established respiratory oxygraphy as a reliable and non-invasive measure of end-tidal oxygen fraction ($F_{T}O_2$). The purpose of this study was to determine the duration of preoxygenation required in paediatric patients to achieve an $F_{T}O_2$ of 0.9.

Patients and methods
After obtaining Ethics Committee approval, informed parental consent and patient assent, where appropriate, we studied 25 patients, aged 1–12 yr, ASA I–III, before induction of general anaesthesia. Premedication comprised midazolam 0.2 mg kg$^{-1}$ intranasally at the discretion of the anaesthetist. Exclusion criteria included intracardiac shunting, active respiratory disease (including upper respiratory tract infection within 2 weeks), acute abdominal disease, known difficult airway or craniofacial abnormality such that an anaesthetic mask could not be applied to the face. Mean age was 4.1 (range 1–12) yr and mean weight was 20.9 (SD 14.2) kg.

A circle absorber system was flushed with 100% oxygen and a flow rate of 6 litre min$^{-1}$ was used for the study. A clear anaesthetic face mask (Vital Signs, Totowa, USA) of appropriate size was used. Subjects were laid supine and the mask was applied to produce a gas tight seal. If old enough to understand, subjects were instructed to breathe normally. In-spired and expired gases were sampled from immediately adjacent to the mask by a Rascal II monitor (Ohmeda, Salt Lake City, USA) calibrated according to the manufacturer’s instructions. This device uses the Raman light scattering principle to measure anaesthetic and respiratory gases with a response time of less than 350 ms (10–90% rise time). $F_{T}O_2$ was recorded every 10 s and preoxygenation proceeded until $F_{T}O_2$ reached 0.9.

Results
Mean (95% confidence limits) $F_{T}O_2$ values were calculated for each 10-s period from the start of preoxygenation and used to construct a graph of oxygen wash-in against time (fig. 1). It was found that 22 (88%) of the subjects reached an $F_{T}O_2$ of 0.9 within 60 s and all reached this end-point within 80 s.

Discussion
There have been many studies of desaturation during induced apnoea after preoxygenation. Two studies of time for oxygen saturation to decrease to 90% in children showed that desaturation can occur rapidly, especially in small children, and that preoxygenation was useful in preventing this. However, using time to desaturate is a poor method of defining the time required for adequate preoxygenation. Desaturation

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is affected not only by variations in oxygen wash-in to the lungs, but also by variables such as cardiac index and oxygen consumption. It is also a delayed and retrospective measurement. Measurement of oxygen saturation during the preoxygenation process is of little value as saturation may be 99–100% while breathing room air.

End-tidal oxygraphy enables the anaesthetist to see on a breath-by-breath basis the success of the preoxygenation process. Studies in adults have shown that oxygen wash-in follows an exponential pattern and it has been proposed that the end-point for adequate preoxygenation should be an $\text{FeO}_2$ of 0.9. The remaining 0.1 fraction consists mainly of carbon dioxide and nitrogen. Compared with pulse oximetry, an advantage of using respiratory oxygraphy lies in the fact that it is a real-time measurement and reveals variations in oxygen wash-in between patients. It is also a sensitive detector of poor mask fit in that air entrainment is recognized immediately and can be rectified.

We have shown that preoxygenation to an $\text{FeO}_2$ of 0.9 was possible within 80 s in all patients. This finding is in contrast with studies in 40 healthy adults and 200 adult elective surgical patients in whom 20% and 23%, respectively, of subjects had not reached an $\text{FeO}_2$ of 0.9 within 180 s. More rapid oxygen wash-in would be expected in children. Tidal volume, deadspace and FRC values in children are similar to those of adults when related to body size, but children have a higher ventilatory frequency. Closing volumes are not reached during the course of normal expiration in children, unlike in the case of older adults.

Children may be less compliant than adults with a prolonged period of preoxygenation. Expired oxygraphy enables the anaesthetist to monitor alveolar gas concentrations precisely so that induction of anaesthesia can occur as soon as $\text{FeO}_2$ reaches the desired level. There is a theoretical benefit in continuing preoxygenation after an $\text{FeO}_2$ of 0.9 has been reached as poorly perfused organs may take longer to equilibrate with the alveolar oxygen fraction.

In summary, we have shown that all children attained an $\text{FeO}_2$ of 0.9 with 80 s of preoxygenation. We have also demonstrated the value of expired oxygraphy in the assessment of optimal preoxygenation on an individual patient basis. When suitable monitors are unavailable we suggest that a sensible duration of preoxygenation in healthy children should be not less than 60 s, paying attention to technique to produce a good mask seal and prevent air entrainment.

References