Original Article

A randomised controlled trial comparing transnasal humidified rapid insufflation ventilatory exchange (THRIVE) pre-oxygenation with facemask pre-oxygenation in patients undergoing rapid sequence induction of anaesthesia*

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Summary

Pre-oxygenation is an essential part of rapid sequence induction of general anaesthesia for emergency surgery, in order to increase the oxygen reservoir in the lungs. We performed a randomised controlled trial of transnasal humidified rapid insufflation ventilatory exchange (THRIVE) pre-oxygenation or facemask pre-oxygenation in patients undergoing emergency surgery. Twenty patients were allocated to each group. No patient developed arterial oxygen saturation < 90% during attempted tracheal intubation. Arterial blood gases were sampled from an arterial catheter immediately after intubation. The mean (SD) PaO_2 was 43.7 (15.2) kPa in the THRIVE group vs. 41.9 (16.2) kPa in the facemask group ($p = 0.722$); $PaCO_2$ was 5.8 (1.1) kPa in the THRIVE group vs. 5.6 (1.0) kPa in the facemask group ($p = 0.631$); arterial pH was 7.36 (0.05) in the THRIVE group vs. 7.34 (0.06) in the facemask group ($p = 0.447$). No airway rescue manoeuvres were needed, and there were no differences in the number of laryngoscopy attempts between the groups. In spite of this, patients in the THRIVE group had a significantly longer apnoea time of 248 (71) s compared with 123 (55) s in the facemask group ($p < 0.001$). Transnasal humidified rapid insufflation ventilatory exchange is a practicable method for pre-oxygenating patients during rapid sequence induction of general anaesthesia for emergency surgery; we found that it maintained an equivalent blood gas profile to facemask pre-oxygenation, in spite of a significantly longer apnoea time.

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Introduction

Induction of general anaesthesia in patients undergoing emergency surgery can be challenging, because of the often suboptimal circumstances under which anaesthesia has to be delivered, as well as potential physiological derangements caused by their underlying

illness [1]. Pre-oxygenation is usually achieved using oxygen delivered via a facemask before induction of anaesthesia; this potentially extends the time available for securing the airway before hypoxaemia to 6 min [2–4]. In patients undergoing elective surgery, the lungs are normally ventilated with a bag/facemask technique after induction, and this can be repeated if attempts at intubating the trachea are prolonged [5].

However, if hypoxaemia occurs in patients undergoing rapid sequence induction of anaesthesia for emergency surgery, options for re-oxygenation are limited [6]. Facemask ventilation has traditionally been avoided in this circumstance because of a perceived risk of gastric insufflation of gas, leading to increased intragastric pressure and raised risk of pulmonary aspiration of stomach contents, although more recently careful use of facemask ventilation has been recommended [5–7].

Nasal cannulae have been recommended as an alternative method of delivering continuous oxygen during induction of anaesthesia [5]. Patient discomfort resulting from symptoms of mucosal drying, frontal pain and sinus headaches limit the maximum rate at which dry oxygen can be delivered to 15 $l.min^{-1}$ in awake patients [8]. The ability to deliver warmed and humidified oxygen through specially designed nasal cannulae has enabled oxygen to be comfortably delivered at rates of > 70 $l.min^{-1}$ [8]. We have shown that nasal delivery of humidified oxygen to paralysed and anaesthetised patients at these rates maintains oxygenation and achieves carbon dioxide clearance. Using the transnasal humidified rapid insufflation ventilatory exchange (THRIVE) technique, we were able to achieve a median apnoea time of 14 min [9]. We hypothesised that an extended apnoeic period could be particularly beneficial to patients undergoing rapid sequence induction of general anaesthesia for emergency surgery, and therefore designed a randomised, controlled comparison of pre-oxygenation using THRIVE and facemask pre-oxygenation in this group of patients.

Methods

The study received approval from the Hampstead NRES Research Ethics Committee, and was performed between March and October 2015.

Patients who required rapid sequence induction of general anaesthesia for emergency surgery, whose routine clinical care required arterial blood gas sampling, and who were competent to give consent were recruited. Patients were not included if they were < 16 years, unable to give informed consent because of a language barrier, or had severe respiratory disease. Consent was obtained from the patients on the ward or Emergency Department on the day of surgery, after their pre-operative anaesthetic evaluation. GraphPad StatMate (GraphPad Software Inc, San Diego, CA, USA) was used to generate a random number list with 1:1 allocation. The code was contained in a sealed envelope that was opened by the investigator after patient consent was obtained.

Patients in the THRIVE group were pre-oxygenated for three minutes using OptiFlow™ nasal high-flow cannulae (Fisher and Paykel Healthcare Ltd, Auckland, New Zealand). The oxygen flow rate was started at 30 $l.min^{-1}$, and was increased to 70 $l.min^{-1}$ over the course of the first minute of pre-oxygenation. This flow was maintained until placement of the tracheal tube.

Patients assigned to the facemask group were pre-oxygenated for three minutes via a facemask, using a circle system with an oxygen rate of 12 $l.min^{-1}$.

General anaesthesia was induced with a titrated dose of 1–2 $mg.kg^{-1}$ propofol and 1 $\mu g.kg^{-1}$ fentanyl, and was followed by 1 $mg.kg^{-1}$ rocuronium. Cricoid pressure was applied as the patient became drowsy. Facemask ventilation was not used after induction, but jaw-thrust was maintained throughout the period of apnoea. After allowing a minute for the rocuronium to take effect, laryngoscopy was performed. Patients in the THRIVE group continued to receive oxygen during laryngoscopy via the nasal cannulae, in contrast to the facemask group. Apnoea time was defined as the period from the end of propofol injection until the tracheal tube was secured.

After tracheal intubation, an arterial blood gas sample was collected. Information about patient characteristics, Cormack–Lehane laryngoscopy grade [10], modified Mallampati score [11], indication for surgery, seniority of the anaesthetist, P-POSSUM physiology and operative severity scores [12] were recorded. The number of attempts at laryngoscopy and use of any rescue manoeuvres were recorded.

Our primary outcome measure was PaO_2 after tracheal intubation. To determine sample size for the study, we used data showing that 3 min of high-flow nasal pre-oxygenation achieve a mean (SD) PaO_2 of 54 (10.7) kPa, and 3 min of facemask pre-oxygenation achieve 40 (10.6) kPa [13]. We assumed a difference between the two groups of 12 kPa and SD of 12 kPa. This yielded a sample size of 17 per group, with $\alpha = 0.05$ and $1 - \beta = 0.8$. We used unpaired Students t-test, Chi-square or Kruskal–Wallis tests as appropriate. Statistical analysis was performed using MedCalc® (MedCalc Software, Ostend, Belgium); a p value < 0.05 was considered statistically significant.

Results

Between March and October of 2015, 65 patients were invited to participate in this trial and 40 were included, with 20 in each group (Fig. 1). There was a significant difference in the P-POSSUM physiology scores between the two groups (p = 0.03; Table 1).

All patients in the facemask group achieved fractional expired oxygen (F_EO_2) of ≥ 90%. No patient developed arterial oxygen saturation < 90%, and no airway rescue manoeuvres were needed. The mean (SD) PaO_2 was 43.7 (15.2) kPa in the THRIVE group vs. 41.9 (16.2) kPa in the facemask group (p = 0.722);

Table 1 Characteristics of 40 patients receiving transnasal humidified rapid insufflation ventilatory exchange (THRIVE) or facemask pre-oxygenation. Values are mean (SD), number (proportion) or median (IQR [range]).

	THRIVE n = 20	Facemask n = 20
Age; years	46.4 (16.8)	51.8 (21)
Sex; male	11 (55%)	9 (45%)
BMI; $kg.m^{-2}$	26 (24.5–31.5 [22–46])	25 (23–29.25 [21–48])
ASA physical status		
1	7 (35%)	4 (20%)
2	5 (25%)	2 (10%)
3	7 (35%)	10 (50%)
4	1 (5%)	4 (20%)
Cormack-Lehane grade		
1	8 (40%)	11 (55%)
2	9 (45%)	8 (40%)
3	3 (15%)	1 (5%)
Modified Mallampati score		
1	2 (10%)	1 (5%)
2	11 (55%)	15 (75%)
3	7 (35%)	4 (20%)
P-POSSUM physiology score	17.5 (14–23 [13–28])	22.5 (18.75–22.25 [17–46])
P-POSSUM operative severity score	17.5 (14–23 [13–32])	22.5 (18.75–25.25 [13–46])
Grade of intubator; trainee	14 (70%)	11 (55%)
Number of attempts at laryngoscopy		
1	14 (70%)	17 (85%)
2	4 (20%)	2 (10%)
3	2 (10%)	1 (5%)

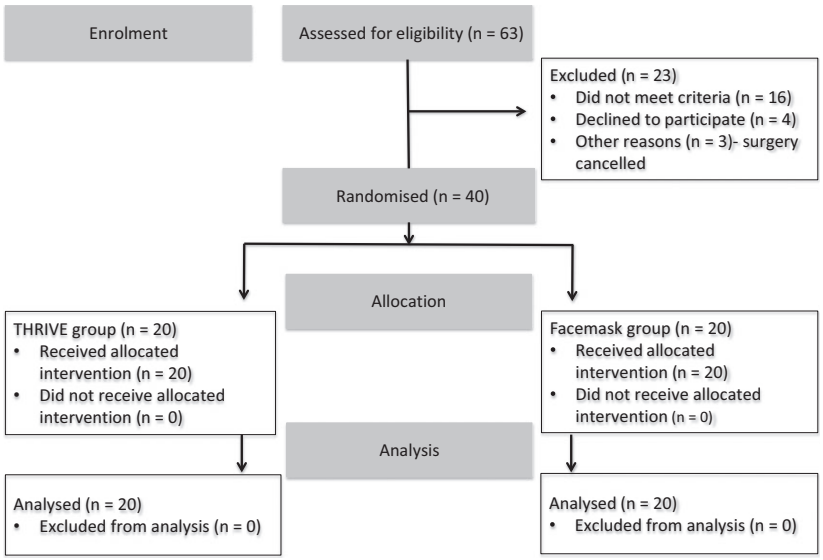

Figure 1 CONSORT diagram of recruitment. Transnasal humidified rapid insufflation ventilatory exchange, THRIVE.

the results for $PaCO_2$ were 5.8 (1.1) kPa and 5.6 (1.0) kPa ($p = 0.631$), and for arterial pH were 7.36 (0.05) and 7.34 (0.06) ($p = 0.447$), respectively (Fig. 2).

The apnoea time was 248 (71) s in the THRIVE group compared with 123 (55) s in the facemask group ($p < 0.001$; Fig. 2).

Discussion

The purpose of this preliminary randomised, controlled trial was to assess the feasibility of using THRIVE as a pre-oxygenation method in patients undergoing rapid sequence induction of general anaesthesia. We hypothesised that patients who had THRIVE pre-oxygenation would have a significantly better arterial PaO_2 than those who had facemask ventilation, based on previous data. However, there was no difference between the two groups in PaO_2, $PaCO_2$ or arterial pH.

In contrast, the mean apnoea time (and therefore intubation time) was 125 s longer in the THRIVE group. This was not due to apparent differences in

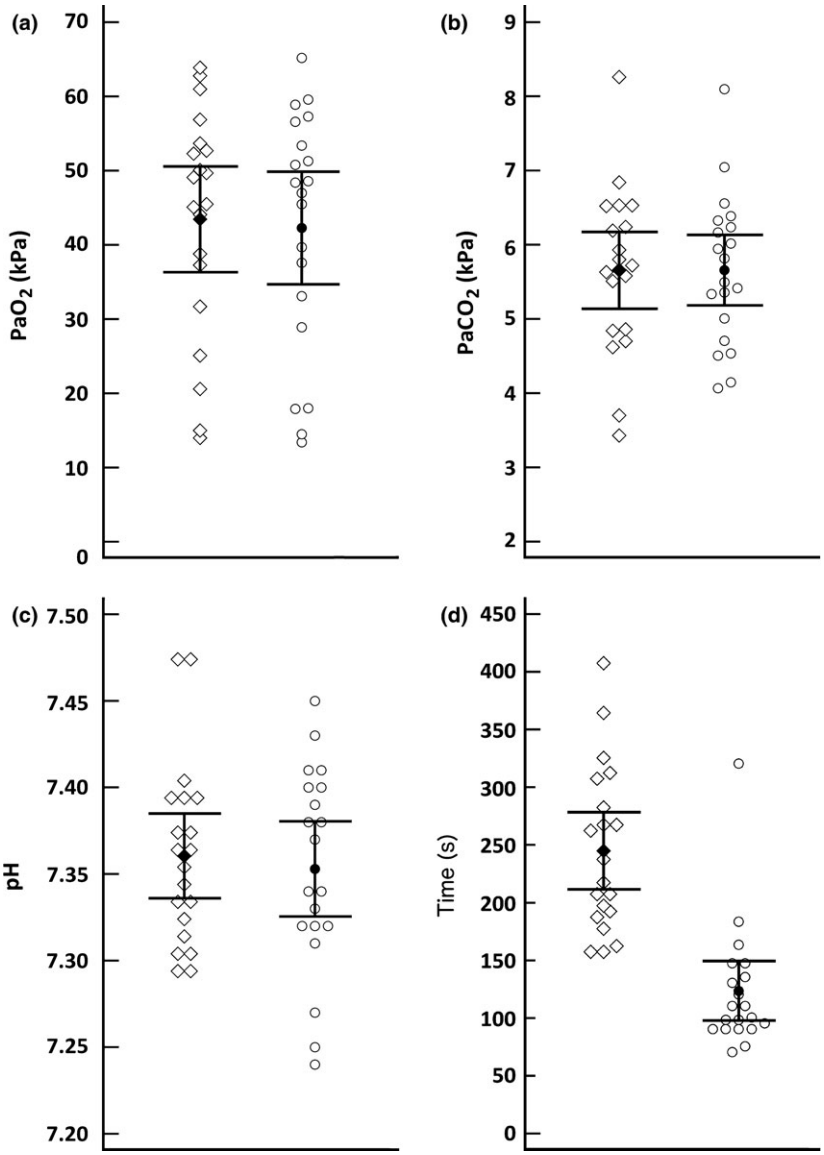

Figure 2 Comparison of (a) PaO_2, (b) $PaCO_2$, (c) arterial pH and (d) apnoea time between patients who had transnasal humidified rapid insufflation ventilatory exchange (THRIVE) pre-oxygenation (diamonds) or facemask pre-oxygenation (circles). Error bars denote 95% CI.

procedural difficulty. The laryngoscopic view was similar between the two groups, and there was no requirement for airway rescue manoeuvres. We speculate that, if the time taken to intubate had been the same in both groups, then the arterial blood gases and pH would have been more favourable in the THRIVE group.

We have previously shown that in patients with known or anticipated difficult airways, oxygenation using the THRIVE technique is associated with prolonged apnoea time before arterial oxygen desaturation [9]. This may relate to both effective supply of oxygen, as well as other incompletely elucidated mechanisms such as apnoeic ventilation. Administration of low flow oxygen via nasal cannulae has been shown to prolong the time until oxygen desaturation in apnoeic patients [14–16], and computer modelling suggests improved effects from high-flow oxygen [17]. Improved oxygen administration should not affect $PaCO_2$; however, based on the difference in apnoea time between groups, we would have expected $PaCO_2$ to be 0.7–0.9 kPa higher in the THRIVE group [9].

We suggest that the explanation for a difference in apnoea time between groups is as follows. The study could not be blinded, and the anaesthetist's knowledge that THRIVE can prolong safe apnoea time led to more controlled and careful laryngoscopy and intubation in this group. We accept this as a potential bias within the study, although the longer apnoea time in the THRIVE group would have tended to reduce any potential superiority of the technique with respect to arterial blood gases.

To our knowledge this is the first randomised, controlled trial of the use of THRIVE as a method of pre-oxygenation in patients having rapid sequence induction of general anaesthesia. Our results do not indicate the superiority of either method, but we have shown that THRIVE is practicable, and likely to be safe. Formal time-to-desaturation trials are needed to characterise and quantify the range and limitations of apnoea time extension in different patient populations.

Competing interests

AP and RN have received research, consultancy and travel support from Fisher and Paykel Healthcare Ltd. The equipment used for the study was provided by Fisher and Paykel Healthcare Ltd. No external funding or other competing interests declared.

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