# A prospective, randomised controlled trial comparing the efficacy of pre-oxygenation in the 20° head-up *vs* supine position*

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## Summary

We investigated whether positioning patients undergoing general anaesthesia for cholecystectomy in a 20° head-up position, as opposed to supine, improved the efficacy of 3 min of standard pre-oxygenation *via* a circle breathing system. Following pre-oxygenation, patients received a standard induction of anaesthesia and the apnoea time (from administration of rocuronium to the arterial oxygen saturation to fall to 95%) was recorded. Mean (95% CI) apnoea time was 386 (343–429) s in the 20° head-up position ($n = 17$) *vs* 283 (243–322) s in the supine position ($n = 18$; $p = 0.002$). Pre-oxygenation is significantly more efficacious and by inference more efficient in the 20° head-up position than in the supine position.

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Pre-oxygenation, the routine administration of 100% oxygen to the conscious individual before general anaesthesia, has become an integral part of safe conduct at induction of general anaesthesia. Apnoea following administration of an induction agent or neuromuscular blocking drugs can lead to a fall in arterial oxygen saturation ($S_pO_2$) to 80% within 1 min in healthy subjects breathing air before induction [1, 2]. Pre-oxygenation in adults increases total body oxygen stores from an estimated 1.2 l before oxygenation to 3.2 l at 1 min and 4.8 l at 3 min [3, 4]. This increase in oxygen reserve delays the onset of arterial oxygen desaturation during apnoea [5, 6], with a concomitant avoidance of the risk of tissue hypoxia and its sequelae.

The efficacy of pre-oxygenation is improved by placing the patient in the 45° head-up position as opposed to being supine [6]. However, repositioning the patient after induction is necessary to avoid exacerbation of arterial hypotension and to allow securing of the airway. This manoeuvre may facilitate passive regurgitation of gastric contents and pulmonary aspiration. Attempting to increase the functional residual capacity in the supine position using continuous positive airway pressure in obese individuals failed to demonstrate similar improvements in oxygenation [7]. We decided to determine the impact of placing the patient 20° head-up during pre-oxygenation and induction, which has the potential to provide a sufficient improvement in oxygenation over the supine position while allowing for airway manoeuvres and intubation without needing an alteration in position.

## Methods

After Local Research Ethics Committee approval, 40 females undergoing cholecystectomy gave written informed consent to be recruited to the study. Individuals with a previous known allergy to drugs used in the standardised anaesthetic regimen, a history of epilepsy, significant cardiorespiratory disease or difficult intubation, or those requiring a rapid sequence induction or who declared a phobia to facemasks were excluded.

 

Participants were randomly allocated *via* a predetermined computer generated sequence to receive pre-oxygenation in the 20° head-up or supine position for 3 min *via* a circle system prefilled with oxygen. A clear facepiece was held in position by the anaesthetist to achieve an airtight seal. Carbon dioxide and oxygen concentrations were measured using a calibrated Datex-Ohmeda Capnomac Ultima (Madison, WI). Patients failing to reach an end-expired oxygen fraction ($F_{E'}O_2$) of at least 0.85 were excluded from analysis. Standard monitoring was applied and 10 $ml.kg^{-1}$ Hartmann's solution was given through a 14-G intravenous cannula. Anaesthesia was induced using propofol *via* a target controlled infusion device (SIMS Graseby 3500, Graseby Ltd, Watford, UK) at a target serum concentration of 6 $\mu g.ml^{-1}$ accompanied by 1.5 $\mu g.kg^{-1}$ fentanyl. Rocuronium (0.6 $mg.kg^{-1}$) was given on loss of eyelash reflex. Tracheal intubation was performed 90 s after administration of rocuronium [8, 9]. Correct placement of the tracheal tube was confirmed by seeing the tube passing into the larynx plus observation of chest wall movement, auscultation at the left axilla and use of capnography during one 400-ml tidal volume breath (confirmed *via* a Blease 8500 ventilator; Blease, Chesham, England) delivered by hand ventilation after intubation. The grade of laryngoscopy was recorded according to the Cormack and Lehane classification [10]. The patient was disconnected from the breathing system and anaesthesia was maintained with propofol continuing at a target of 6 $\mu g.ml^{-1}$. Noninvasive blood pressure was recorded at 1-min intervals and 0.5-mg boluses of metaraminol were given i.v. if mean arterial blood pressure fell to below 70% of the pre-induction level. The duration of apnoea was recorded as from the time of administration of rocuronium to the time that $S_pO_2$ fell to 95%, at which point the patient was reconnected to the breathing system and ventilation was commenced with 100% inspired oxygen.

Based on the study by Baraka *et al.* [6], a sample size of 20 patients in each group was predicted to have 90% power to detect a difference in means of 100 s assuming a common SD of 9.5 s, using a two-group *t*-test with a 0.05 significance level. Statistical analysis was performed using SPSS Version 12.1 for WINDOWS.

## Results

Five patients (three allocated to the 20° head-up position and two allocated to the supine position) were excluded for failing to reach an $F_{E'}O_2$ of 0.85. No patient required intervention for arterial hypotension. Descriptive data are provided in Table 1. There were no differences in the time to achieve an $F_{E'}O_2$ of 0.85, in the $F_{E'}O_2$ at the end of pre-oxygenation, or in the grade of laryngoscopy (Table 2). Patients positioned 20° head-up had a longer mean (95% CI) apnoea time than those in the supine position (386 (343–429) s *vs* 283 (243–322) s, respectively; difference between the means 103 (42–163) s; p = 0.002) (Fig. 1).

**Table 1** Descriptive data of patients pre-oxygenated in the 20° head-up or supine position. Values are mean (SD).

| | **20° head-up ($n$ = 17)** | **Supine ($n$ = 18)** |
|---|---|---|
| Age; years | 51.8 (19.3) | 56.3 (13.4) |
| $S_pO_2$ breathing air; % | 97.0 (1.6) | 96.7 (1.4) |
| ASA physical status; 1/2 | 8/9 | 7/11 |
| Body mass index; $kg.m^{-2}$ | 26.3 (4.7) | 27.9 (4.9) |
| Smoker/non-smoker | 6/11 | 6/12 |
| Haemoglobin concentration; $g.dl^{-1}$ | 13.7 (1.0) | 13.5 (1.2) |

**Table 2** Time to achieve an end-expired fractional concentration of oxygen ($F_{E'}O_2$) of 0.85, $F_{E'}O_2$ at the end of pre-oxygenation, and grade of laryngoscopy in patients pre-oxygenated in the 20° head-up or supine position. Values are mean (SD). There were no significant differences between the groups.

| | **20° head-up ($n$ = 17)** | **Supine ($n$ = 18)** |
|---|---|---|
| Time to achieve $F_{E'}O_2$ of 0.85; s | 113 (33) | 109 (36) |
| $F_{E'}O_2$ at end of pre-oxygenation | 0.89 (0.03) | 0.90 (0.03) |
| Grade of laryngoscopy; 1/2 | 14/3 | 12/6 |

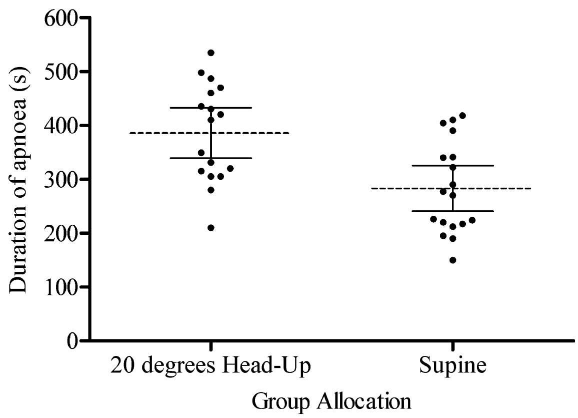


**Figure 1** Duration of apnoea time (from the time of administration of rocuronium to the time that $S_pO_2$ fell to 95%) in patients pre-oxygenated in the 20° head-up or supine position. The horizontal lines indicate mean and 95% CI; p = 0.002.

## Discussion

During standard pre-oxygenation (tidal breathing of 100% oxygen through a facepiece connected to an appropriate breathing system for a number of minutes) early gains in stored oxygen are predominantly the result of nitrogen washout from the lungs accompanied by wash-in of oxygen. This process is 80% complete at 1 min [11, 12] and takes approximately 7 min to reach 'total denitrogenation' following an exponential function [13]. The larger the functional residual capacity of the lungs, the greater the volume of oxygen stored. Notably, the functional residual capacity decreases with alteration of posture from the upright to the supine position [14] and with increasing age and obesity. Haemoglobin becomes fully saturated early in the oxygenation process, making observation of an $S_{p}O_2$ of 100% an unsuitable end-point for completion of pre-oxygenation. The gains in oxygen storage in the latter minutes of pre-oxygenation mainly result from increased quantities of dissolved oxygen within the plasma and body tissues. This explains the superior efficacy (the duration of apnoea before arterial oxygen desaturation occurs) of standard pre-oxygenation over alternative methods of pre-oxygenation aimed at improving efficiency (the time required to reach a chosen endpoint of pre-oxygenation) such as the use of a limited number of vital capacity breaths [15, 16]. Both efficiency and efficacy are improved by prefilling appropriate breathing system apparatus with oxygen and ensuring that an airtight seal is achieved around the facemask [17].

We decided to limit our selection of patients to females requiring general surgery for elective cholecystectomy in order to reduce confounding factors, and because standard anaesthesia for elective cholecystectomy (open or laparoscopic) requires general anaesthesia, neuromuscular blockade and tracheal intubation. Cricoid pressure is not applied during routine intubation because the small risk of disruption of the airway is greater than the very small risk of regurgitation of gastric contents. The 20° head-up position alone should theoretically further reduce the chance of passive regurgitation, although the risk of pulmonary aspiration would be enhanced should regurgitation occur. Dixon *et al.* [18] have recently demonstrated in extremely obese patients (mean body mass index 45–50 kg.m$^{-2}$) that a 25° head-up position during pre-oxygenation provides superior arterial oxygen tensions with an associated improvement in apnoea time compared with the supine position. We have shown that the benefits of oxygenation afforded by the 20° head-up position need not be solely reserved for the severely obese patient, but also apply to our relatively healthy population. An unanticipated difficult airway or intubation is not limited to the morbidly obese patient.

Our study was not blinded. We attempted to reduce any resulting bias through the employment of a standardised anaesthetic regimen in all subjects. Patients not achieving an $F_{E'}O_2$ above 0.85 were excluded from further analysis and there was no statistical difference between groups in this regard, with expired oxygenation concentrations favouring the supine group (Table 2). In addition, the duration of apnoea was defined by observer-independent criteria.

In conclusion, pre-oxygenation is clinically and statistically more efficacious and by inference more efficient in the 20° head-up position than in the supine position, without detriment to the grade of intubation.

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