

Effectiveness of preoxygenation with positive airway pressure in non-obese healthy patient: a comparison of the supine and 25° head up position

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Abstract

Background Though conventional preoxygenation provides extended safe apnoeic period during endotracheal intubation, it is associated with atelectasis of lungs immediately after induction. Therefore, alternatives such as positive airway pressure and head-up tilt during preoxygenation have been explored but uniform recommendations have not yet been made. In the present study we aimed to find out the effect of combination of 5 cmH₂O CPAP and 25° head up position during preoxygenation on non-hypoxic apnea period. **Methods** In this randomized controlled trial, 60 non-obese healthy adult patients were randomly divided into three groups; Group C receiving preoxygenation in conventional technique, Group S receiving preoxygenation in supine position with 5 cmH₂O CPAP and Group H receiving preoxygenation in 25° head-up position with 5 cmH₂O CPAP. After 3 min of preoxygenation, anesthesia was induced and trachea intubated. After confirming the tracheal intubation by direct visualization, all patients were administered vecuronium to maintain neuromuscular blockade and midazolam to prevent awareness. Post-induction, patients in all groups were left apneic in supine position with the tracheal tube exposed to atmosphere till the SpO₂ dropped to 92%. The primary outcome compared between the groups was the non-hypoxic apnoeic period (time to fall SpO₂ to 92%). **Results** The duration of non-hypoxic apnea period was longer ($p < 0.05$) in Group H patients (405.90 ± 106.69 s) as compared to the Group C (296.90 ± 99.01 s) and Group S (319.65 ± 71.54 s). Although the duration of non-hypoxic apnea was clinically longer in the Group S as compared to Group C the difference was not statistically significant. There were no remarkable adverse events observed in any group. **Conclusion** Preoxygenation in 25° head-up position with 5 cmH₂O CPAP significantly prolongs non-hypoxic apnea period in non-obese healthy adults compared to supine position, with or without 5 cmH₂O CPAP.

Background

Hypoxemia can occur during induction of anaesthesia when securing airway becomes difficult and is considered as one of the leading cause of anaesthetic mortality. It makes sense to maximize oxygen stores before induction to prolong the period before the onset of hypoxemia in the event of serious difficulty with airway management. So, preoxygenation is performed before induction of anaesthesia to increase lung store of oxygen which is achieved by having patient breath 100% oxygen from close fitting facemask.¹

Traditionally preoxygenation is performed for 3-5 min in supine position to provide non-hypoxic safe apnea period of around 10 min in patients without significant cardiovascular diseases and normal oxygen consumption.² However, conventional preoxygenation technique is not considered ideal. Preoxygenation in supine position provides shorter duration of non-hypoxic apnea period than in various degree of head-up position especially in obese and elderly patient. This is most likely due to reduction of FRC.³ Various degrees of head-up tilt ranging from 20 ° 45 ° have been considered for preoxygenation but with associated technical difficulties and risk of hypotension.⁴⁻⁹

Induction of general anaesthesia is associated with development of atelectasis in dependent area of lung.^{10,11} If patients have not achieved a saturation greater than 93% to 95% before tracheal intubation, they have a higher likelihood of desaturation during their apnoeic and tracheal intubation periods.¹²⁻¹⁵ If patients do not achieve this saturation level after 3 min of tidal-volume breathing with a high FIO₂ source, it is likely that they have pulmonary shunt; any further augmentation of FIO₂ will be unhelpful. Application of PEEP/CPAP during induction has been found to decrease intrapulmonary shunting and increase non-hypoxic apnea period.¹⁶ Various levels of PEEP/CPAP are applied during preoxygenation to increase the duration of non-hypoxic apnea period.¹⁷⁻¹⁹ Varying techniques of preoxygenation with application of PEEP/CPAP and various degrees of head-up tilt have been explored but standard recommendations have not yet been made. And literature comparing combined effect of PEEP/CPAP and head-up tilt compared with conventional technique is unavailable or sparse. In the present study we attempted to find out the effect of combination of 5 cm H₂O CPAP and 25 ° head-up tilt during preoxygenation on duration of non-hypoxic apnea period.

Methods

Ethical clearance was obtained for the study from the B P Koirala Institute of Health Science (BPKIHS) Institutional Ethical Review Board (IERB Ref. No. 1598/ 070/ 071). Clinical trial registration was done on [ClinicalTrials.gov](https://clinicaltrials.gov) retrospectively (Identifier: NCT03861949). The study duration was of one year from June 2014 to June 2015 and conducted at BPKIHS, Dharan. After obtaining written consent adult patients of ASA physical status I and II aged 18-60 years undergoing surgery under general anaesthesia were included. Patients with anticipated difficult mask ventilation/ intubation, individuals with significant cardiorespiratory or cerebrovascular disease, pregnant ladies, patient with history of epilepsy, body mass index >25 kg/m², hemoglobin <8 gm/dL were excluded from the study. In addition, patients who were non-ambulant for >24 h, having SpO₂ < 97% while breathing in room air, phobia to facemask were also excluded from the study.

All the patients were kept fasting for 8 h before surgery and were premedicated with 10mg oral diazepam. On arrival to the operating room, the patient was allocated to one of the three groups as per the randomization sequence which were generated computer-based and maintained in sealed envelopes. The sealed envelope was opened by one of the investigator. All the patients were preoxygenated for 3 min with tight-fitting face mask connected to a circle system with the fresh oxygen flow of 10 L/min. In the control group (Group C), the patient was kept in supine position and the adjustable pressure limit (APL) valve of circle system was kept fully open. In Group S, the patient was kept in supine position and a 5 cmH₂O CPAP was provided by adjusting APL valve; and in Group H, the patient was placed supine with the torso tilted 25° head-up from hip upward and, a 5 cmH₂O CPAP was provided by adjusting the APL valve. The 25° head up position was attained by adjusting the operating table and measured with the help of a goniometer.

The parameters monitored during the procedure included electrocardiogram lead II, noninvasive blood pressure, SpO₂, arterial blood gases and end-tidal carbon dioxide. Intravenous access was established in the non-dominant hand of the patient. All the patients were pre-hydrated with 10 mL/kg Ringer's lactate solution intravenously. In the same limb, the radial artery was cannulated under local anaesthetics after performing Allen's test and was kept locked with heparinized saline. Baseline values of heart rate, blood pressure, and SpO₂ were recorded, and the first sample of arterial blood (ABG1) was taken with the patient breathing room air.

The second sample of arterial blood was obtained after 3 min of preoxygenation (ABG 2). Heart rate, blood pressure and SpO₂ were recorded at this point. While continuing oxygenation, anesthesia was induced with intravenous (IV) fentanyl 1.5 µg/kg followed by IV propofol 2 mg/kg. Immediately after loss of consciousness (as assessed by verbal response), 1.5 mg/kg of succinylcholine was given IV and time noted. Tracheal intubation was performed by an experienced anesthesiologist using conventional laryngoscopy 60 s after the injection of succinylcholine. The endotracheal tube position was confirmed by visual observation of the tube passing between the vocal cords. The cuff of endotracheal tube was inflated and proximal end (machine end) of tube kept open in the room air. Any patient with Cormack and Lehane (CL) laryngoscopy grade III or IV, requiring more than one intubation attempts and intubation time of >15 s was excluded from study.

Midazolam 2 mg was administered IV soon after intubation to ensure amnesia during the apneic period following intubation. Vecuronium was administered IV to maintain neuromuscular blockade. The patient was left apneic until SpO₂ dropped to 92%. The time from loss of consciousness until fall of SpO₂ to 92% (safe apnea period) was recorded. At this point of time, heart rate, blood pressure, and SpO₂ were recorded, and the third sample of arterial blood (ABG 3) was taken for analysis.

To keep the study conditions uniform, patients were not ventilated manually or mechanically until the endpoint SpO₂ (92%) was reached. After the SpO₂ reached 92%, all the patients were ventilated with 100% oxygen until the arterial oxygen saturation returned to baseline values. The patients kept in the head up position were also returned to supine position. A 3 mg bolus of mephentermine was given IV if the mean blood pressure fell below 65 mmHg. Subsequently, anaesthesia was managed as per the routine institutional protocols. After the patients became fully conscious and oriented, they were asked if they could recall any intraoperative events. Any other adverse events observed during the study period were also noted.

Statistical methods

Sample size was calculated based on finding of a similar previous study done by Herriger A et al.¹⁷ The safe apnoea period in their experimental arm (CPAP) was 599 s and the control arm was 470 s with the common standard deviation of 150 s. Keeping these values and setting an alpha of 0.05 and power of 0.8, 19 patients were required in each group. Finally, we included 20 patients in each group.

The data collected was entered into MS excel software 2007 and exported it into SPSS (Statistical Package for Social Science-11.5) for statistical analysis. Differences in mean between groups were assessed using 1-way analysis of variance. Further, Post-hoc analysis with Bonferroni correction (adjusted significance level of 0.0167) was done if statistically significant was observed between groups. For categorical data chi-square test or Fisher's exact test was used. A statistically significant difference was considered as a P-value of <0.05.

Figure 1: Consort diagram for patient recruitment

Results

A CONSORT Diagram is shown in Fig. 1. Demographic parameters, American Society of Anesthesiologists Physiological Status (ASA PS), history of smoking and hemoglobin level were comparable among the three study groups (Table 1).

Table 1: Patient characteristics

Duration of safe apnea period

Duration of safe apnea period was statistically and clinically significant in Group H (405.9 ± 106.69 s) compared to Group S and Group C. Although the duration of safe anpnea period was clinically longer in Group S (319.65 ± 71.54 s) compared to Group C (296.9 ± 99.01 s), it was statically insignificant (Table 2).

Table 2: Comparison of duration of safe apnea period

Arterial blood gases

The pH, PaO₂ and PaCO₂ at the start of preoxygenation, after preoxygenation and at desaturation (SpO₂= 92%) were comparable among the three groups (Table 3). The PaCO₂ level was slightly higher in Group H at desaturation compared to Group S and Group C but was statistically insignificant.

Table 3: Comparison of arterial blood gas values at different time points

No adverse hemodynamic instability was observed during the study period except transient ventricular premature beats in two patients, one in Group C and one in Group H, which did not require any treatment.

Discussion

The main finding of our study is that combining CPAP and 25 ° head up tilt prolongs apnoea time remarkably. There was almost two minutes non-hypoxic apnea advantage with combination of 25 ° head up tilt and application of a 5 cmH₂O CPAP when compared to conventional three min tidal volume preoxygenation in supine position. However, addition of 5 cmH₂O CPAP to conventional three min tidal

volume preoxygenation in supine position only marginally increased (less than half min) the non-hypoxic apnea period.

Previous studies that have compared the effects of headup (ranging from 20 ° to 60 °) on the duration of non-hypoxic apnea in comparison with conventional preoxygenation have drawn conclusions similar to ours.^{5,7-9} In studies performed by Dixon BJ et al.⁵ and Altermatt FR et al.⁹ have reported relatively shorter desaturation time compared to ours which is as expected because of morbidly obese patients selected in their studies (BMI>35). Similarly, Baraka AS et al.⁴ found increase in time to desaturation after preoxygenation in 45 ° head-up position compared to supine in non-pregnant ladies. But interestingly, they found no benefit in case of pregnant ladies which they attribute to the impairment of diaphragmatic excursion by gravid uterus.

The duration of non-hypoxic apnea was significantly longer by almost one and half min with the 25 ° head-up position plus CPAP as compared to application of only CPAP in supine position in the present study. Venkateswaran R et al.⁸ in their study found no significant difference in the duration of non-hypoxic apnea period between CPAP and head-up tilt group. Variation in the study design and subjects probably explain the difference between their and our findings. It is quite expected to have additive effect when head-up position is combined with CPAP.

In our study application of CPAP during three min tidal volume preoxygenation resulted in prolongation of non-hypoxic apnea period by approximately 23 s compared to conventional preoxygenation technique. Though this duration looks statistically insignificant it is clinically significant in airway management scenario. Similar results were found in studies done by Venkateswaran R et al.⁸ and Cressey DM et al.¹⁹ There are many studies that compared the effects of application of PEEP of 6–10 cmH₂O with conventional preoxygenation.^{17,18} In those studies the authors have found statistically significant increase in duration of non-hypoxic apnea period with application of PEEP compared to conventional technique. This can be explained by one notable difference of methodology compared to ours is that patients in PEEP group received PEEP with intermittent positive pressure ventilation with the mask following induction and paralysis. Along with that the PEEP applied was greater than in our study. However, in our study we didn't apply IPPV or PEEP after induction of anaesthesia. As we know the objective of preoxygenation is to prevent patients against hypoxia in difficult intubate and/ or ventilate scenario following induction of anaesthesia. Therefore, in our study we intended to find out effect of application of CPAP during preoxygenation to prolong the duration of non-hypoxic apnea period and its possible application in emergency situation and obese patients. This difference in methodology may explain why our results were different from those of other such studies.^{17,18}

Application of higher level of continuous positive airway pressure (CPAP)/ PEEP can be associated with adverse hemodynamic effects along with discomfort during preoxygenation. Hence, we decided to use only 5 cm H₂O CPAP which was well tolerated by all the patients and we did not encounter any significant hemodynamic disturbances.

It is expected that anesthetic induction maintaining the 25 ° head-up tilt can exacerbate the hypotensive effects. So, to counteract those effects we lowered the head-up patients to supine position immediately following desaturation in addition to preloading with fluid. Event of hypotension following induction was not observed in any of our patients. Theoretically preoxygenation in head-up position is believed to increase risk of aspiration if regurgitation occurs, though the risk of regurgitation as such is lower with the head-up position.⁷ Intubation in head-up may be technically difficult because of unconventional position, but in our study we did not encounter any difficulty since we use footstep to facilitate intubation.

Besides, in the study done by Lee BJ et al.,²⁰ they found 25 ° head-up to be associated with better positioning of the head for optimal intubation and better access to the airway by gravitational retraction of the breast tissue in female patients.

In our study ABG was analyzed at different time points as SpO₂ can't be relied on completely to find accurate saturation of patient's Hb. In ABG analysis the minimum pH observed was 7.20 and the maximum PaCO₂ noted was 77.7 mmHg at the time of desaturation. Both of these values were clinically acceptable and immediately corrected after resume of ventilation with oxygen. In our study no anesthetic agents were delivered after intubation till desaturation which might predispose patients to the risk of awareness. Due to unavailability of target controlled infusion devices and Bispectral Index (BIS) for monitoring depth of anesthesia to prevent awareness, we decided to administer 2mg midazolam intravenously to all our patients. There was no report of any intraoperative awareness, in postoperative period or 24-hour follow-up.

There were no major adverse events in any of the patients studied except in two patients who developed occasional VPC for which no intervention was needed. In our study the value of PaCO₂ was higher at time of desaturation in head-up with CPAP group (64.18±7.87) compared to CPAP only (59.96±7.47) and control group (60.90±6.04) though it did not reach to the level of statistical significance. The finding is similar with the findings of the study done by Venkateswaran R et al.⁸ where they have found statistically significant increase in PaCO₂ in head-up group compared to control group. Longer duration of non-hypoxic apnea duration in head-up group is the most probable reason for this CO₂ retention.

The main limitation of our study is that the investigator observing the outcome could not be blinded. Although, standardized anesthetic induction technique was followed and observer-independent criteria for defining the duration of non-hypoxic apnea were used to limit possibility of bias.

Conclusion

Preoxygenation in 25° head-up position with 5 cmH₂O CPAP provides significantly longer duration of non-hypoxic apnea period compared to application of CPAP alone or conventional preoxygenation in non-obese healthy patient. Application of CPAP also prolongs the duration but not to the level of statistical significance.

Abbreviation

ASA: American Society of Anesthesiologists, ABG: Arterial blood gas,

Declarations

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Availability of data and material

The datasets analyzed during the current study are enclosed.

Ethics approval and consent to participate

This study was approved by the Ethics Committee at the BPKIHS Institutional Ethical Review Board (IERB Ref. No. 1598/ 070/ 071) and was registered in clinical trial in the [ClinicalTrials.gov](https://clinicaltrials.gov) (Identifier: NCT03861949) retrospectively. Written informed consent was obtained from all the patients.

Authors' contributions

AS, SK and BKB designed the study. AS and BKB performed the investigation and analyzed the data. YD was responsible for the study design, writing of the manuscript, analysis and interpretation of the data. All authors have read and approved the final manuscript.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1: Patient characteristics

Parameter	Group C (n=20)	Group S (n=20)	Group H (n=20)
Age (years)	34±12.8	32.2±10.2	28.4±6.9
Gender (male/female)	8/12	9/11	8/12
BMI (kg/m ²)	21.4±2.1	21.6±2.2	21.1±1.8
History of smoking (Y/N)	4/16	4/16	3/17
ASA-PS (I/II)	14/6	16/4	18/2
Hemoglobin in (g/dL)	13.1±1.4	12.7±2.1	12.9±1.7

Values are presented as mean (\pm SD) or *n* (%). *ASA-PS*=American Society of Anesthesiologists Physiological Status, *BMI*=body mass index, *Y/N*=yes/no

Table 2: Comparison of duration of safe apnea period

Groups	Time (in sec)	<i>P</i> -value
Group C (n=20)	296.90±99.01	
Group S (n=20)	319.65±71.54	0.724*
Group H (n=20)	405.90±106.69	0.001**
		0.014#

Values are presented as mean (\pm SD), *Group S vs. Control group, **Group H vs. Control group,

#Group H vs. CPAP group

Table 3: Comparison of arterial blood gas values at different time points

	Group C (n=20)	Group S (n=20)	Group H (n=20)	P-value
<i>Baseline</i>				
pH	7.40±0.01	7.40±0.02	7.39±0.02	0.369
PaO ₂ (mmHg)	85.97±13.92	88.37±11.92	91.90±10.71	0.313
PaCO ₂ (mmHg)	46.91±6.15	44.60±7.71	44.92±5.80	0.493
<i>After preoxygenation</i>				
pH	7.40±0.02	7.39±0.02	7.38±0.03	0.259
PaO ₂ (mmHg)	274.85±44.90	289.95±49.26	286.75±62.02	0.635
PaCO ₂ (mmHg)	44.86±5.59	44.61±6.85	47.29±7.65	0.387
<i>At desaturation (SPO2 92%)</i>				
pH	7.28±0.03	7.28±0.02	7.27±0.03	0.159
PaO ₂ (mmHg)	62.17±5.55	64.40±6.58	65.92±9.47	0.279
PaCO ₂ (mmHg)	60.90±6.04	59.96±7.47	64.18±7.87	0.157

Values are presented as mean (±SD)

Figures

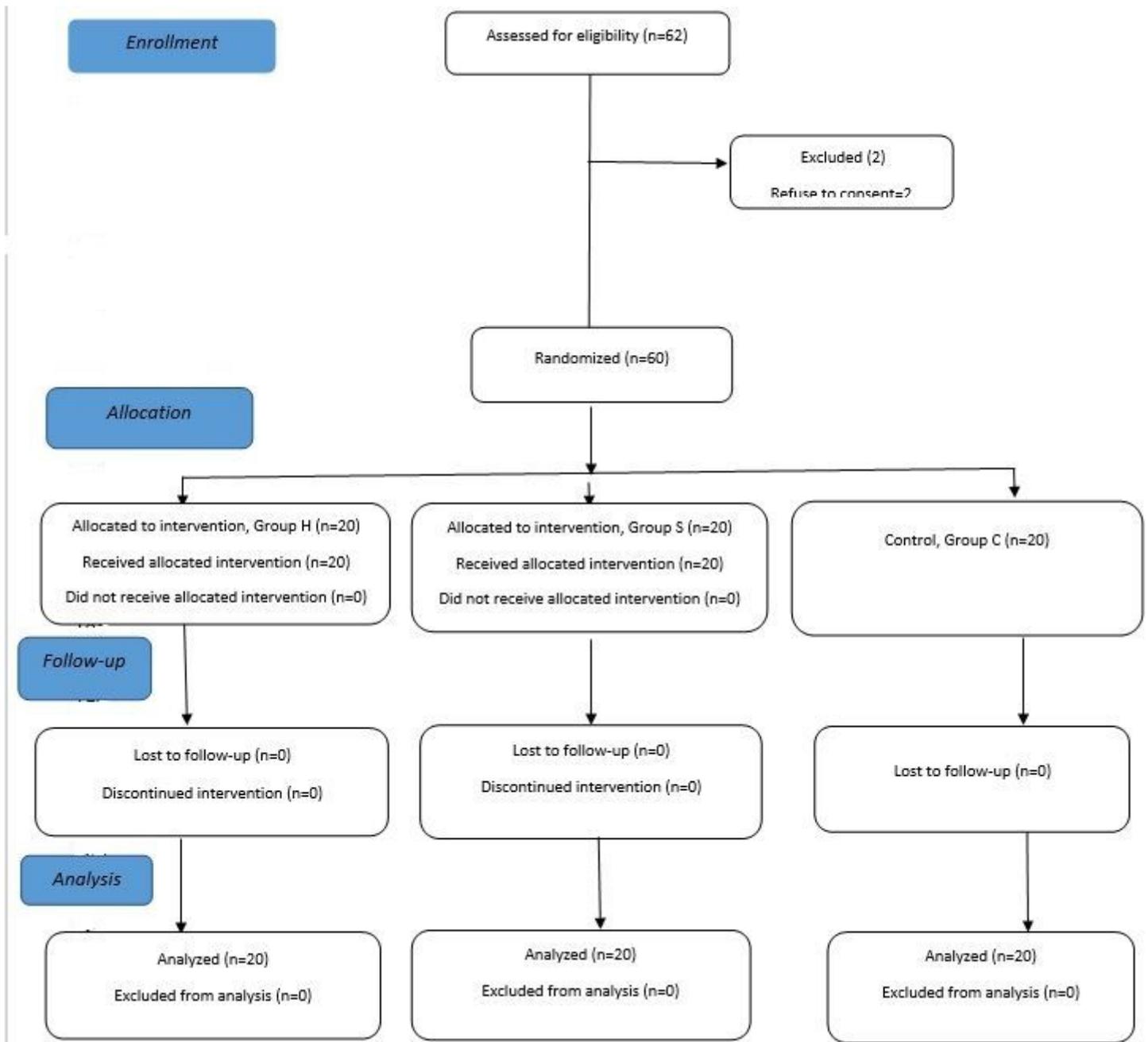


Figure 1

Consort diagram for patient recruitment

Supplementary Files

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