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The Carrico index is the parameter that guides the requirement of oxygen in the postoperative period in patients undergoing head and neck surgery under general anaesthesia: a cross-sectional study

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Abstract

Background & aims: Altered lung function and consequent decrease in oxygenation has been linked to the duration of anaesthesia. This necessitates oxygen monitoring and supplementation in the perioperative period. But, evidence is lacking regarding the parameter that guides best the oxygen supplementation in the postoperative period and the parameter that correlates best with the duration of anaesthesia.

Methods: Adult patients scheduled for head & neck surgery under general anaesthesia were recruited. Two radial arterial blood samples one at pre-induction and the other at one hour after extubation were obtained. Primary outcome measures were partial pressure of oxygen (PaO_2), saturation (SpO_2), arterial oxygen content (CaO_2) and Carrico index (PaO_2/FiO_2) and their relation with duration of anaesthesia.

Results: Data from 112 patients showed a hypoxaemia incidence of 11.6%. We observed a drop in the mean CaO_2 and haemoglobin concentration but a rise in the mean PaO_2 at recovery. The mean PaO_2/FiO_2 deteriorated by 225.65 ± 72.46 (95% CI 367.66, 83.64, p = 0.000) at recovery and there was a significant correlation (r = 0.2, p = 0.03) between duration of anaesthesia and decrease in PaO_2/FiO_2 at recovery with a regression coefficient of 0.27 (95% CI 0.02, 0.50).

Conclusions: The Carrico index was proven to be the best parameter which needs to be monitored perioperatively to detect the alteration in the gaseous exchange in patients undergoing general anaesthesia for head and neck surgery. There is a positive correlation between the decrease in the Carrico index and the duration of anaesthesia especially when it is prolonged beyond 150 minutes.

Keywords: duration, anaesthesia, hypoxaemia, Carrico index, head and neck, surgery

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Introduction

Hypoxaemia after general anaesthesia is a common phenomenon especially among patients undergoing thoraco-abdominal surgeries. Reported incidence ranges from 6.8% to 30% depending upon whether it is reported for intraoperative or postoperative period [1-5]. Hence, it is a common practice to supplement oxygen during the postoperative period to all patients subjected to general anaesthesia. Being non-invasive, pulse oximetry is usually used to monitor oxygenation in the perioperative period. However, it has its own limitations [6].

Duration of both surgery and anaesthesia has been studied extensively as a potential risk factor of post-operative pulmonary complications albeit offering inconclusive results [4, 7-9]. This could be attributed to the non-availability of a standard parameter that could accurately capture the association between the

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changes in oxygenation with the changing duration of either surgery or anaesthesia.

Hence, the present study was undertaken in patients undergoing head and neck surgery under general anaesthesia with an objective to find the oxygenation parameter that could best guide oxygen requirements and supplementation during the recovery period in addition to reflecting the anaesthesia duration related pulmonary alterations. This should help us to avoid the issues related to oxygen excess and save the valuable but limited resources such as oxygen from being mis-utilized.

Methods

We carried out a hospital based cross-sectional study in the operation theater of our institute located in India. Ethical approval for this study was provided by the institute Ethics Committee, All India Institute of Medical Sciences, Bhubaneswar, India. All patients aged 18 to 60 years with no comorbid illness (American Society of Anesthesiologists physical status class I) posted for head & neck surgeries under general endotracheal anaesthesia between July 2015 to June 2016 were recruited in the study after obtaining written informed consent. The study was registered in the Indian national registry (http://ctri.nic.in/Clinicaltrials/showallp.php?mid1=14371&EncHid=&userName=CTRI/2017/03/008126. Patients with uncontrolled coagulopathies, vascular diseases, known cardiovascular or respiratory disease and patients on mechanical ventilation prior to surgery, those undergoing thoracic, abdominal and laparoscopic surgeries were all excluded from the study. Two radial arterial blood samples for blood gas analysis (ABG) were obtained from each patient under local lignocaine injection. A first sample was taken in the pre-induction area in the supine position and breathing room air (baseline). Standard fasting guidelines were followed. Premedication with alprazolam and ranitidine was given. Heart rate (HR), blood pressure (BP), electrocardiography (ECG) and peripheral oxygen saturation (SpO_2) were recorded at baseline and throughout the perioperative period.

In the theatre, after pre-oxygenation for 5 minutes with 100% O_2, all patients received a uniform balanced anaesthesia technique comprising of morphine (0.1 mg/kg), midazolam (0.05 mg/kg), and propofol 1-2 mg/kg. Once the adequacy of ventilation was checked, vecuronium bromide (0.1 mg/kg) was given and tracheal intubation performed with an appropriate sized tube 8.5 in males or 7.5 in females. They were put on mechanical ventilation with the following settings: volume control mode, FiO_2 0.5, oxygen in air combination, 8 ml/kg of tidal volume, respiratory rate of 12 to start with and titrated to maintain end tidal CO_2 of 30-35 mmHg, I:E of 1:2, positive end expiratory pressure of 5 cmH_2O, maximum pressure limit of 30 cmH_2O. Isoflurane was added to the gases at 1-1.5 minimum alveolar concentration and repeat doses of vecuronium were administered for maintenance. Measures to maintain normal intra-operative vitals were taken along with the infusion of the prescribed amount of intravenous fluids.

At the end of surgery, residual muscle paralysis was reversed with a combination of intravenous neostigmine (50 mcg/kg) and glycopyrrolate (0.2 mg/each mg of neostigmine). After one hour of extubation, a repeat sample of arterial blood was drawn under local anaesthesia from all patients. They received 40% O_2 via venturi mask in the recovery period. All ABG blood samples were analysed immediately utilizing a NOVA ABG analyzer machine and data were collected. Arterial samples and other relevant data were collected by two investigators (PBR, ST).

The duration of anaesthesia was defined as the time gap from anaesthesia induction to endotracheal extubation. Hypoxaemia was defined as $SpO_2 < 94\%$.

Statistical analysis

All parametric data such as age, haemoglobin, SpO_2, partial pressure of oxygen (PaO_2), Carrico index (PaO_2/FiO_2) and arterial blood oxygen content (CaO_2) are expressed as mean ± SD and the nonparametric data as median (interquartile range). Independent T-test and paired T-test were used for measuring the central tendency and comparisons between means of parametric data respectively. The Mann-Whitney and Wilcoxon signed rank test were used for non-parametric data comparison. Scatter plot analysis was done for all the studied oxygenation parameters with the duration of anaesthesia followed by the correlation and linear regression analysis for the significant correlation obtained. All tests were two-sided, and the level of significance was set at $p = \leq 0.05$. For all analyses, the SPSS for windows version 16.00 was used.

Results

Overall 120 patients were eligible for the study. Of these, we had to exclude 8 patients during data analysis as post op samples were missing for comparison. Study findings of 112 patients have been reported in this paper. Patient characteristics and the studied oxygenation parameters are depicted (Table 1). Incidence of post-operative hypoxaemia was 11.6% and 43% of cases had a below normal Carrico index at recovery ($PaO_2/FiO_2 < 300$).

We observed a rise in the mean PaO_2, but a drop in the mean CaO_2 by [0.74 ± 2.13 (95% CI 0.34, 1.14, p = 0.000)] and mean haemoglobin concentration by [0.69 ± 1.53 (95% CI 0.40, 0.98, p = 0.000)] at recovery as

Table 1. Demographics and other studied variables

Variables	Baseline	Recovery	p value*
Age (years) (mean ± SD)	45.17 ± 10.87		
Male: Female ratio	13:10		
Respiratory Rate (mean ± SD)	18.16 ± 1.40	17.58 ± 1.69	0.070
HR Median (IQR)	77.00 (70.25, 83.00)	76.5 (72.25, 81)	0.656
Blood Pressure, mmHg (mean ± SD)	96.80 ± 9.75	95.42 ± 7.28	0.126
Temp in °C (mean ± SD)	37.01 ± 2.21	37.26 ± 0.47	0.587
% SpO_2 (mean ± SD)	96.48 ± 2.54	96.91 ± 2.62	0.149
PaO_2 (mean ± SD)	120.69 ± 75.58	160.11 ± 100.93	0.000
Haemoglobin (g/dl) (mean ± SD)	12.99 ± 3.22	12.29 ± 2.50	0.000
CaO_2 vol% (mean ± SD)	17.15 ± 4.16	16.41 ± 3.01	0.000
PaO_2/FiO_2 (mean ± SD)	437.19 ± 59.33	211.54 ± 36.94	0.000
Duration of anaesthesia in minutes (mean ± SD)	194.36 ± 69.46		

n = 112; * p < 0.05 = significant; SD – standard deviation; IQR – interquartile range; HR – heart rate; Temp – temperature; SpO_2 – peripheral oxygen saturation; PaO_2 – partial pressure of oxygen; CaO_2 – arterial oxygen content; FiO_2 – inspired fraction of oxygen

compared to preoperative values. The recovery mean SpO_2 remained close to the baseline value without statistically significant alterations. The mean PaO_2/FiO_2 ratio was observed to be significantly deteriorating at recovery as compared to baseline (p = 0.000). The Bland-Altman plot (Figure 1) showed a mean drop of 225.65 ± 72.46 (95% CI 367.66, 83.64, p = 0.000) in PaO_2/FiO_2 at recovery as compared to the baseline.

A correlation was observed (r = 0.2, p = 0.03) between the duration of anaesthesia and delta PaO_2/FiO_2 (the difference between baseline PaO_2/FiO_2 and recovery PaO_2/FiO_2) with a regression coefficient of 0.27 (95% CI 0.02, 0.50) (Figure 2). Additionally, this study resulted in a significant decrease in the PaO_2/FiO_2 from preoperative levels as the duration of anaesthesia was prolonged beyond 150 minutes (2.5 hours) (Table 2).

Discussion

This study focuses on the peroperative alteration in different oxygen parameters and their correlation with the duration of anaesthesia in head and neck surgery under general anaesthesia. We did not observe any significant alteration in oxygen saturation but a drop in the mean haemoglobin and CaO_2 in the recovery. To our surprise, we evidenced a significant rise in PaO_2 at recovery rather than a fall. But, there was a sig-

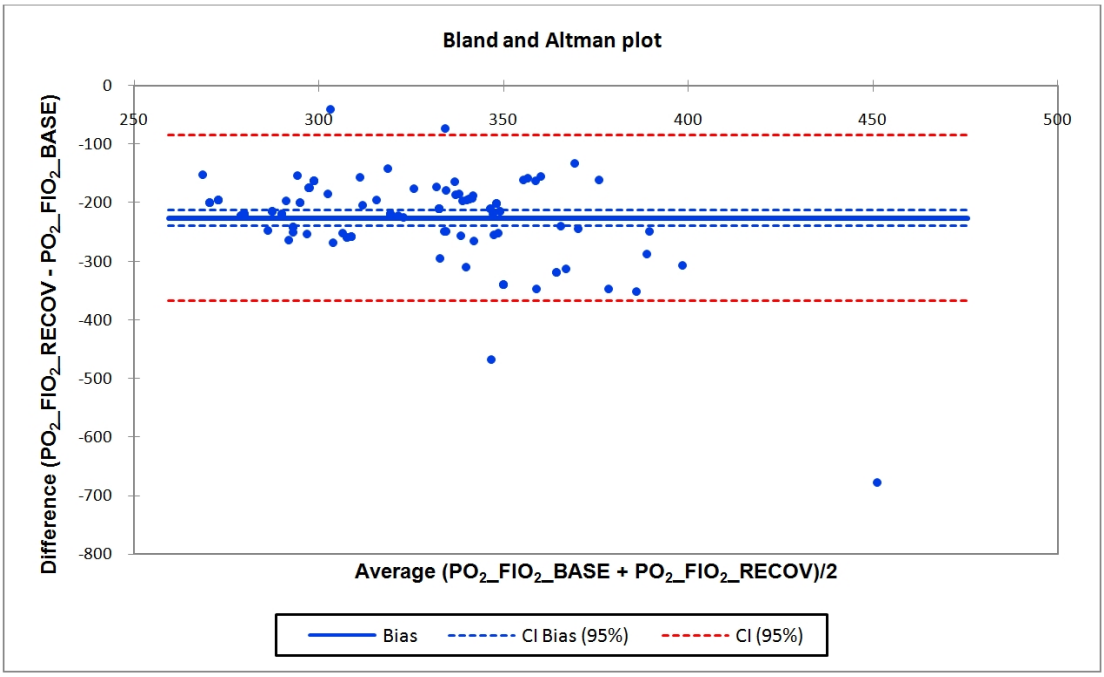

Fig. 1. Bland-Altman plot for average and delta PaO_2/FiO_2 (recovery – baseline)

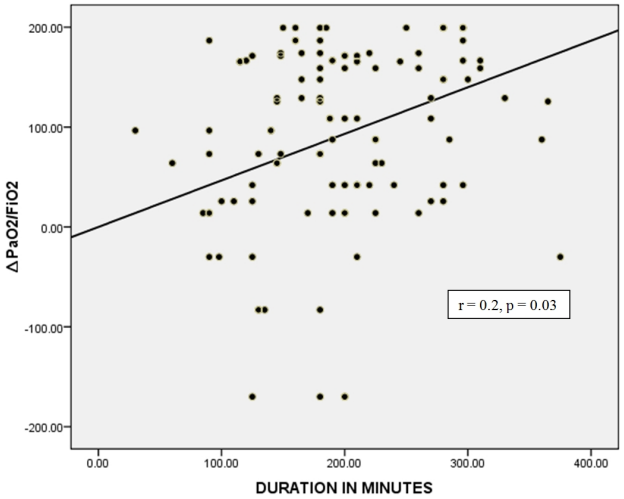

Fig. 2. This is a scatter plot depicting the correlation between delta PaO_2/FiO_2 i.e. difference between baseline and recovery values and duration of anaesthesia in minutes

nificant drop in PaO_2/FiO_2 at recovery which correlates well with the duration of anaesthesia especially when it is prolonged beyond 150 minutes.

Our findings are consistent with several previous reports. Martin JB et al. reported most of the atelectasis occurs immediately after induction and intubation [9]. We witnessed a similar alteration in lung function reflected by an alteration in oxygenation parameters peroperatively.

Dunham CM et al. studied patients undergoing general anaesthesia for different types of surgery and reported an incidence of 8-25.6% of hypoxaemia which is in concordance with our study results of 11.6%. But, as the O_2 requirement and the supplementation differ at different time points for a patient undergoing surgery, they had to consider different cut off saturation levels (< 94% on room air, < 98% on oxygen, and $\geq$ 5% fall from baseline for postoperative hypoxaemia) to define hypoxaemia [4].

As the FiO_2 at recovery (40%) was twice that of baseline (room air), a similar saturation level at different FiO_2 levels strongly indicates a deterioration in lung function peroperatively. A similar study by Bablekos et al. in patients undergoing laparoscopic versus open cholecystectomy also resulted in no difference in oxygen saturation between the groups [10].

We observed a rise in PaO_2 at recovery but a fall in CaO_2 and PaO_2/FiO_2. This is possible because PaO_2 contributes less to the arterial oxygen content equation than haemoglobin and SpO_2 [11]. There was a mean drop of 0.74 ml% in CaO_2 at recovery from baseline which was statistically significant as well. Bablekos et al. had a similar observation as a reduction of O_2 content from 17.55 ± 1.90 to 15.69 ± 1.88 in laparoscopic and from 16.99 ± 2.37 to 14.62 ± 2.23 (mean ± SD) in the open cholecystectomy groups but that was not statistically significant; probably a result of analyzing a limited sample size of 28 participants [10].

In a similar way, a rise in PaO_2 but a fall in PaO_2/FiO_2 is probably explained by the fact that O_2 supplementation might increase the partial pressures but as the lung function deteriorates, the ratio decreases. Staehr et al. did a randomized trial in thirty-five patients of ovarian cancer undergoing elective laparotomy to establish the impact of different levels of FiO_2 on pulmonary function. They found the median PaO_2/FiO_2 was 69 kPa [53-71] in the 30% FiO_2 group and 60 kPa [47-69] in the 80% FiO_2 group (P = 0.25) immediately after intubation. At the end of anaesthesia, they observed a similar drop in the Carrico index to 58 kPa [40-70] in the 30% and 57 kPa [46-67] in the 80% FiO_2 group (P = 0.10) [12].

Again, as the duration of anaesthesia lengthens, the lung function is expected to deteriorate in direct proportion as evidenced by multiple investigators. Duration of surgery and exposure to anaesthesia for 2.5-4 hours had an increased risk of pulmonary complications and a poor postoperative outcome [13-17].

Anaesthesia duration of $\geq$ 180 minutes has been found to be an independent risk factor (OR 4.3, 95% CI 1.7 to 10.8) in predicting postoperative pulmonary complications [13, 17]. In contrast, a multi-center prospective study in Europe (PERISCOPE), designed to find predictive factors in non-thoracic or non-obstetric surgery for postoperative complications did not result in anaesthesia duration as a risk factor. The number of patients studied were only eleven which probably explains the results [18]. Our study results stand clear of the fact that we are not predicting postoperative pulmonary complications rather that we have observed an immediate drop in the Carrico index in proportion to the duration of anaesthesia (> 150

Table 2. Delta PaO_2/Fio_2 (difference between baseline and recovery) and duration of anaesthesia

Duration in minutes	No. of observations	Delta PaO_2/FiO_2 mmHg (mean ± SD)	p value*
$\leq$ 150 mins	34	61.88 ± 90.54	0.02
> 150 mins	78	103.16 ± 86.75	

n = 112; * p < 0.05 = significant

minutes) same as that of McAlister FA et al. [14]. The results of our study could establish the PaO_2/FiO_2 as the parameter to be monitored as the duration of surgery and anaesthesia is prolonged and deterioration in lung function is expected.

Being noninvasive in nature, pulse oximetry is a standard of care, but with its own limitations [19]. Additionally, because of the characteristic haemoglobin oxygen dissociation curve, a small reduction in SpO_2 corresponds to much larger reductions in PaO_2 especially at the upper part. Hence, PaO_2 is a better and more sensitive indicator of trivial alterations than saturation itself [20]. But again, solely PaO_2 does not give the true picture of arterial oxygenation, alteration in lung mechanics and its quantification in patients who are already receiving O_2. Even though, CaO_2 is the parameter which reflects the O_2 content in the arterial blood; it takes into account both the PaO_2 and SpO_2 in addition to haemoglobin and amenable to alterations with and without O_2 supplementation, probably not reflecting the true picture.

Hence, as the present study results depict, the Carrico index may be the better alternative to record the alteration in lung function with general anaesthesia. Being a ratio between PaO_2 and FiO_2, it actually reflects the dynamic changes in partial pressure in proportion to the fraction of O_2 inspired. Additionally, we found it to be the only parameter correlating well with the duration of anaesthesia exposure as opposed to other parameters. Although, the index may be affected by numerous other factors, our study purpose was only to establish the relation between duration and oxygenation parameters. The study resulted in a significant correlation between changes in PaO_2/FiO_2 and duration of anaesthesia. SpO_2 has been considered as the parameter to decide for supplementation of oxygen in the recovery period in multiple studies. But, there are many factors which affect pulse oximetry; it is insensitive at both the extremes, delays the detection of hypoxaemia and there is no established cut off. Hence, it cannot be the only parameter which necessitates the need of oxygen supplementation in the postoperative period putting patients at a higher risk of hypoxia related damage which is often irreversible. Therefore, there was a need for an indicator which reflects altered respiratory mechanics after general anaesthesia and guides oxygen supplementation in the recovery. This study tried to find the most suitable and best correlating parameter together with the duration of anaesthesia for deciding the necessity of oxygen in the recovery period.

Although, the limitations of this study are the observational study design and limited sample size, some kind of studies should be observational only. Another limitation is not following the changes into the late postoperative period; but this was purposefully excluded from the methodology as postoperative changes have been already studied extensively by many authors.

Conclusions

This study tried to evaluate the old problem with new perspectives and efforts to answer questions such as "is duration really important in relation to postoperative hypoxia" and if yes, "which is the best parameter that correlates best so as to be able to monitor the decision for oxygen supplementation in the recovery room".

The study resulted in the Carrico index being the best parameter which requires monitoring perioperatively to detect the alteration in gaseous exchange in patients undergoing general anaesthesia for head and neck surgery. There is a positive correlation between the decrease in Carrico index and the duration of anaesthesia especially when it is prolonged beyond 150 minutes. A prospective trial with a large sample size to further verify these findings and to address the preventive measures will be of the utmost importance.

Conflict of interest

Nothing to declare

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References

1. Ehrenfeld JM, Funk LM, Van Schalkwyk J, Merry AF, Sandberg WS, Gawande A. The incidence of hypoxaemia during surgery: evidence from two institutions. Can J Anaesth 2010; 57: 888-897. doi: 10.1007/s12630-010-9366-5
2. Canet J, Ricos M, Vidal F. Early postoperative arterial oxygen desaturation: determining factors and response to oxygen therapy. Anesth Analg 1989; 69: 207-212. doi: 10.1213/00000539-198908000-00012
3. Daley MD, Norman PH, Colmenares ME, Sandler AN. Hypoxaemia in adults in the post-anaesthesia care unit. Can J Anaesth 1991; 38: 740-746. doi: 10.1007/BF03008452
4. Dunham CM, Hileman BM, Hutchinson AE, Chance EA, Huang GS. Perioperative hypoxemia is common with horizontal positioning during general anesthesia and is associated with major adverse outcomes: a retrospective study of consecutive patients. BMC Anesthesiol 2014; 14: 43. doi: 10.1186/1471-2253-14-43
5. Xará D, Santos A, Abelha F. Adverse respiratory events in a post-anesthesia care unit. Arch Bronconeumol 2015; 51: 69-75. doi: 10.1016/j.arbres.2014.04.016
6. Qaseem A, Snow V, Fitterman N, Hornbake ER, Lawrence VA, Smetana GW, et al.; Clinical Efficacy Assessment Subcommittee

of the American College of Physicians. Risk assessment for and strategies to reduce perioperative pulmonary complications for patients undergoing noncardiothoracic surgery: a guideline from the American College of Physicians. Ann Intern Med 2006; 144: 575-580. doi: 10.7326/0003-4819-144-8-200604180-00008

7. Smetana GW, Lawrence VA, Cornell JE; American College of Physicians. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med 2006; 144: 581-595. doi: 10.7326/0003-4819-144-8-200604180-00009
8. Nunn JF, Payne JP. Hypoxaemia after general anaesthesia. Lancet 1962; 2: 631-632. doi: 10.1016/S0140-6736(62)92541-2
9. Martin JB, Garbee D, Bonanno L. Effectiveness of positive end-expiratory pressure, decreased fraction of inspired oxygen and vital capacity recruitment maneuver in the prevention of pulmonary atelectasis in patients undergoing general anesthesia: a systematic review. JBI Database System Rev Implement Rep 2015; 13: 211-249. doi: 10.11124/jbisrir-2015-1410
10. Bablekos GD, Michaelides SA, Analitis A, Lymperi MH, Charalabopoulos KA. Comparative changes in tissue oxygenation between laparoscopic and open cholecystectomy. J Clin Med Res 2015; 7: 232-241. doi: 10.14740/jocmr2086w
11. Collins JA, Rudenski A, Gibson J, Howard L, O'Driscoll R. Relating oxygen partial pressure, saturation and content: the haemoglobin-oxygen dissociation curve. Breathe (Sheff) 2015; 11: 194-201. doi: 10.1183/20734735.001415
12. Staehr AK, Meyhoff CS, Henneberg SW, Christensen PL, Rasmussen LS. Influence of perioperative oxygen fraction on pulmonary function after abdominal surgery: a randomized controlled trial. BMC Res Notes 2012; 5: 383. doi: 10.1186/1756-0500-5-383
13. Scholes RL, Browning L, Sztendur EM, Denehy L. Duration of anaesthesia, type of surgery, respiratory co-morbidity, predicted VO_2max and smoking predict postoperative pulmonary complications after upper abdominal surgery: an observational study. Aust J Physiother 2009; 55: 191-198. doi: 10.1016/S0004-9514(09)70081-9
14. McAlister FA, Bertsch K, Man J, Bradley J, Jacka M. Incidence of and risk factors for pulmonary complications after nonthoracic surgery. Am J Respir Crit Care Med 2005; 171: 514-517. doi: 10.1164/rccm.200408-1069OC
15. Toori KU, Khan JS, Nomani AZ, Hussain SW, Hashmi S. A prospective study of factors predicting postoperative pulmonary complications (PPC) in patients undergoing non-cardiothoracic surgery under general anaesthesia in a developing country. Anaesth Pain Intensive Care 2012; 16: 252-256
16. Kelkar KV. Post-operative pulmonary complications after non-cardiothoracic surgery. Indian J Anaesth 2015; 59: 599-605. doi: 10.4103/0019-5049.165857
17. Saraçoglu A, Yavru A, Küçükgöncü S, Tüzüner F, Karadeniz M, Başaran B, et al. Predictive Factors Involved in Development of Postoperative Pulmonary Complications. Turk J Anaesthesiol Reanim 2014; 42: 313-319. doi: 10.5152/TJAR.2014.50133
18. Canet J, Hardman J, Sabaté S, Langeron O, Abreu MG, Gallart L, et al. PERISCOPE study: predicting post-operative pulmonary complications in Europe. Eur J Anaesthesiol 2011; 28: 459-461. doi: 10.1097/EJA.0b013e328344be2d
19. Chan ED, Chan MM, Chan MM. Pulse oximetry: understanding its basic principles facilitates appreciation of its limitations. Respir Med 2013; 107(6): 789-799. doi: 10.1016/j.rmed.2013.02.004
20. Sarkar M, Niranjan N, Banyal PK. Mechanisms of hypoxemia. Lung India 2017; 34: 47-60. doi: 10.4103/0970-2113.197116