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Original Research Article

Cardiorespiratory changes during robotic pelvic surgeries- A prospective observational Study

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ABSTRACT

Introduction: Robot assisted pelvic surgeries are associated with cardiorespiratory changes due to conjunction of carboperitoneum and steep Trendelenburg position for prolonged durations.
Aim: To determine the changes in cardiovascular and respiratory systems in patients undergoing elective robot assisted pelvic surgeries under general anesthesia.
Materials and Methods: A prospective observational study was conducted in 35 patients scheduled for elective robot assisted pelvic surgeries. Patients belonging to ASA class I and II were included and their intraoperative hemodynamic and respiratory parameters were noted post induction (baseline), at pneumoperitoneum, at and every 15 minutes after steep Trendelenburg positioning, at resuming supine position, at deflation of pneumoperitoneum and post-deflation. Primary outcome was mean arterial pressure. Secondary outcomes were systolic and diastolic blood pressures, heart rate, central venous pressure, airway pressures (peak, plateau and mean), pulmonary compliance, minute ventilation, end tidal carbondioxide levels and blood gas values.
Results: On assuming steep Trendelenburg position, there was significant increase in systolic, mean and diastolic blood pressures. There was significant increase in peak, plateau and mean airway pressures and significant decrease in pulmonary compliance which led to increase in end tidal carbondioxide levels and minute ventilation. On resuming supine position and deflation of pneumoperitoneum, there was significant decrease in mean arterial pressure. Although the pulmonary compliance improved, it continued to be significantly lower than the post-induction baseline value.
Conclusion: Robot-assisted pelvic surgeries are associated with significant changes in hemodynamic and respiratory parameters of patients.

1. Introduction

Robot assisted surgery has served as an advancement in the field of minimally invasive surgery. It is known to improve surgical precision by teleporting surgeon to the patient and providing three-dimensional surgical experience to the surgeon as compared with two-dimensional handling of conventional laparoscopic surgeries.[1,2] Numerous studies have documented the impact of carbopneumoperitoneum on hemodynamic variables.[3,4] However, concurrent usage of carbopneumoperitoneum and steep Trendelenburg position (TP) (40°-45°) for a prolonged duration can have profound cardiorespiratory consequences. Several studies have been conducted in other laparoscopic surgeries involving TP with head tilt of 15-30°, but there are few studies conducted on steep TP with pneumoperitoneum.[5–14] Thus, we did this prospective observational study in adult patients who were scheduled for elective robotic pelvic surgeries to determine the change in cardiorespiratory function parameters during pneumoperitoneum and steep TP.

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2. Materials and Methods

This prospective observational study was conducted for a period of 18 months (October 2019- March 2020) after obtaining approval from hospital Ethics Committee (IEC/VMMC/SJH/Thesis/October/2018-19) and written informed consent from all patients. The study follows STROBE guidelines for observational studies. According to results of study done by Lestar et al to determine hemodynamic perturbations during robot assisted laparoscopic radical prostatectomy in 45^0Trendelenburg position (TP), there was increase in mean arterial blood pressure (MAP) by 20%.[5] Taking these reference values, minimum required sample size with 80% power of study and 5% level of significance was 32 patients. Total sample size was taken as 35 assuming few drop outs. Primary outcome was MAP. Secondary outcomes were other hemodynamic parameters such as systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), central venous pressure (CVP) and respiratory parameters such as end tidal carbondioxide ($EtCO_2$), pulmonary compliance, minute ventilation (MV), peak airway pressure (P_{peak}), plateau airway pressure (P_{plat}), mean airway pressure (P_{mean}) and arterial partial pressures of oxygen (P_aO_2), carbondioxide (P_aCO_2) and blood pH.

Thirty-five adult patients of either gender who were 18-75 years of age, belonging to ASA class I and II and scheduled for elective robotic pelvic surgeries in steep TP (40^0- 45º) were included. Obese patients were excluded (BMI >30 kg/metres^2). Subjects were asked to stay fasting overnight and prescribed tablet alprazolam 0.25 mg night before and two hours prior to surgery. On day of surgery, patient was wheeled in operation theatre and monitors: non-invasive blood pressure (NIBP), electrocardiography (ECG), pulse oximeter (SpO_2) applied. Intravenous cannula was secured. General anaesthesia was induced with intravenous injections of fentanyl 2μg/kg, propofol 2mg/kg and vecuronium 0.1mg/kg. After three minutes of mask ventilation with 100% oxygen (O_2) and isoflurane (0.8-1.2 MAC), endotracheal intubation was performed with appropriately sized cuffed endotracheal tube which was then fixed. Nasogastric tube was inserted and fixed. General anaesthesia was maintained with oxygen, nitrous oxide and isoflurane. Muscle relaxation was achieved with intravenous top-ups of injection vecuronium bromide 0.02mg/kg. Ventilation was done using volume control mode with tidal volume of 6-7ml/kg. Draeger Primus® (Draeger© Drägerwerk AG & Co. KGaA, 2021) anaesthesia workstation was used. MV was altered by altering respiratory rate (RR) targeting EtCO2 less than 45 mmHg. Under all aseptic precautions, left radial artery and right internal jugular vein were cannulated and invasive monitoring started. Both hands were kept straight and close to the body in supine position. Cotton padding of all pressure points, shoulder support and eye padding were done. Patient was strapped so as to prevent any fall. After cleaning and draping, pneumoperitoneum was generated with carbondioxide at filling rate of 3-6 liters/minute maintaining intra-abdominal pressure between 12-15 mm Hg. Patient was put in steep Trendelenburg position(45). Paracetaml one gram intravenous was given and injection fentanyl 0.5 microgram/kg repeated hourly. Restricted intravenous fluids (one liter Ringers Lactate) Anti-emetic injection ondansetron 0.1mg/kg, intravenous was given 30 minutes prior to neuromuscular block was reversed with neostigmine (0.05mg/kg) and glycopyrrolate (0.01mg/kg). Trachea was extubated after patient met extubation criteria. Patient received routine postoperative care and monitoring.

Parameters recorded were HR, SBP, DBP, MAP, MV, pulmonary compliance, P_{peak}, P_{plat}, $P_{mean}$and $EtCO_2$. These were recorded at baseline (T_b- five minutes after intubation), after pneumoperitoneum (T_p), after Trendelenburg position (T_t), every fifteen minutes subsequently (T_1, T_2, T_3 and so on), after coming back to supine position (T_s), at desufflation (T_d), 15 minutes post desufflation (T_f) and 30 minutes post desufflation (T_h). ABG was done at T_b, every hour intraoperatively and at T_f.

Categorical variables were presented in number and percentage. Continuous variables were presented as mean ± SD and median. Normality of data was tested by Kolmogorov-Smirnov test. If normality was rejected, then non-parametric test was used. Quantitative variables were compared using Paired t test/Wilcoxon signed rank test (when data sets were not normally distributed) across follow up. A p value of <0.05 was considered statistically significant. Data was entered in MS EXCEL spreadsheet and analysis was done using Statistical Package for Social Sciences (SPSS) version 21.0.

3. Results

A prospective observational study was conducted after seeking clearance from the institutional ethics committee. Thirty-eight patients were enrolled in study of whom three got excluded after applying exclusion criteria. Remaining 35 patients who were scheduled for Robot assisted pelvic surgeries consented for the study. Their cardiorespiratory parameters were recorded. Demographic characteristics are depicted in Table 1. Surgeries performed included robot assisted laparoscopic radical cystectomy and robot assisted laparoscopic radical prostatectomy in 68.57% and 31.43% patients, respectively.

Systolic blood pressure (SBP) was significantly higher ($P < .0001$) at T_p (141.31 ± 12.36 mmHg) when compared with baseline (128.63 ± 11.15 mmHg). In the steep Trendelenburg position (TP), SBP continued to stay significantly higher ($P < 0.05$) than SBP at T_b at most of the measured time intervals. Post desufflation (T_d=123.46 ± 11.21 mmHg, T_f=121.86 ± 11.6 mmHg); SBP was significantly lower ($P<0.005$) as compared with baseline. At

T_h, SBP was significantly higher (137.4 ± 7.5 mmHg, P = .0002) as compared to baseline. Diastolic blood pressure (DBP) was significantly higher (P = .0003) at T_p (77.46 ± 8.46 mmHg) compared with DBP measured at baseline (71.46 ± 10.77 mmHg). DBP continued to stay higher than baseline (T_b) during steep TP with significant values at most times. DBP after resuming supine position (T_s) and after desufflation (T_d, T_h) was lower than DBP at T_b, although not significant. At T_h, DBP (75.97 ± 5.55 mmHg) was significantly higher (P = .0009) as compared with baseline. Mean arterial pressure (MAP) was significantly higher at T_p (98.43 ± 8.9 mmHg, P <.0001) and most of the time intervals in steep TP when compared with baseline (90.49 ± 7.69 mmHg). MAP was significantly lower at T_d (87.57 ± 8.7 mmHg, P = 0.034) and T_f (87.23 ± 9.1 mmHg, P = .045) than at T_b. However, MAP at T_h (96.14 ± 5.9 mmHg, P = .0001) was significantly higher as compared to baseline. Changes in SBP, DBP and MAP are depicted in Table 2.

There was a significant rise in heart rate (HR) at T_p when compared with baseline HR (P <.05). HR was higher than baseline throughout the intraoperative time elapsed under steep TP with significance at most of the measuring times. HR was significantly higher than baseline at T_s, T_d, T_f and T_h. CVP was significantly higher at T_p than at T_b. CVP continued to stay significantly above the baseline value throughout the steep TP. At desufflation (T_d and T_f), CVP was comparable with baseline value. At T_h, CVP was significantly lower as compared with baseline. Above measured hemodynamic parameters and p values after comparing with baseline are depicted in Table 3.

P_{peak}, P_{plat} and P_{mean} were significantly higher as compared with baseline from pneumoperitoneum (T_p) and continued to stay significantly higher after institution of steep TP and even after resuming supine position and desufflation (T_s, T_d). The airway pressures continued to stay higher at T_f and T_h. Changes in these airway pressures are depicted in Table 4.

Significant decline of pulmonary compliance compared from baseline (60.49 ± 5.7 ml/cm H_2O) was observed at T_p (37.63 ± 3.89 ml/cm H_2O, P <.0001) and during steep TP. Although pulmonary compliance started increasing at supine positioning and after desufflation, it was significantly lower than baseline value. $EtCO_2$ values after pneumoperitoneum (T_p, T_t, all intraoperative intervals in steep TP, T_d, T_s, T_f and T_h) were significantly higher when compared from baseline. It was maintained below 45 mmHg by increasing respiratory rate and thereby minute ventilation (MV). Hence, increase in MV followed to compensate for rising $EtCO_2$. MV was significantly higher than baseline value (4457.34 ± 792.87 ml) at all measuring time points starting from T_p (4917.43 ± 856.72 ml) up to T_f. Above measured respiratory parameters and p values after comparison with baseline are depicted inTable 5.

Mean value of partial pressure of CO_2 ($PaCO_2$, mmHg) of study subjects were significantly higher at first, second and third hours as compared with the baseline value. Mean value of partial pressure of oxygen (PaO_2, mmHg) was significantly lower as compared to baseline at all the subsequent hours. Mean value of pH at baseline, after 1 hour, after 2 hours and after 3 hours of study subjects was 7.35 ± 0.06, 7.33 ± 0.07, 7.3 ± 0.07 and 7.32 ± 0.03 respectively. At all the follow up time intervals, pH was significantly lower as compared to baseline. The blood gas analysis values are depicted in Table 6.

Table 1: Demographic profile of the patients

Variable	
Age (years)	
Mean ± SD	66.51 ± 5.36
Median (IQR)	67(62.5-70)
Sex (M/F) n (%)	7/28 (20/80)
BMI (kg/m^2)	
Mean± SD	23.74 ± 1.91
Median (IQR)	23.5(22.45-25)
ASA (I/II) n(%)	0/35(0/100)
Surgery	
RALP/RALC	11/24 (68.57/31.43)

BMI: Body Mass Index, ASA: American Society of Anesthesiologists, RALP: Robot Assisted Laparoscopic Prostatectomy, RALC: Robot Assisted Laparoscopic Cystectomy

4. Discussion

The introduction of robotic procedures necessitates use of steep Trendelenburg position (TP) in conjunction with pneumoperitoneum leading to changes in cardiorespiratory homeostasis. Thirty-five patients who underwent robot assisted laparoscopic pelvic surgeries were included and their cardiorespiratory parameters were recorded and analysed.

Heart rate (HR) (in beats per minute) increased significantly immediately from 66.37 ± 7.93 at baseline to 70.94 ± 7.07 at pneumoperitoneum (P <.0001); which decreased back to 67.74 ± 8.49 after steep TP (comparable to baseline, P=0.102). Similar changes in HR were reported by Kalmar et al.[6] Increase in HR after creation of pneumoperitoneum in our study could attributed to use of carbondioxide (CO_2) whose systemic absorption results in sympathetic stimulation and tachycardia. Pawlik et al reported decrease in HR from baseline on creation of pneumoperitoneum and after steep TP followed by increase in HR on supine positioning.[7] Many studies have reported no significant variations in heart rate during robotic pelvic surgeries.[5,8] Darlong et al reported significant decrease of HR from pre-induction value and attributed it to the combined use of fentanyl, thiopentone and vecuronium in

Table 2: Intra-operative Blood Pressure Values

Time	SBP (mmHg)		DBP (mmHg)		MAP (mmHg)	
	Mean ± SD	P value	Mean ± SD	P value	Mean ± SD	P value
T_b	128.63 ± 11.15	-	71.46 ± 10.77	-	90.49 ± 7.69	-
T_p	141.31 ± 12.36	<.0001	77.46 ± 8.46	0.0003	98.43 ± 8.9	<.0001
T_t	134.51 ± 13.93	0.0009	75.4 ± 9.94	0.022	95.2 ± 10.78	0.007
T_1	136.43 ± 15.89	0.002	76.83 ± 9.01	0.007	96.66 ± 10.45	0.0008
T_2	134.37 ± 16.35	0.054	75.37 ± 9.65	0.019	94.83 ± 11.41	0.045
T_3	135.86 ± 15.43	0.006	75.29 ± 10.34	0.032	95.54 ± 10.76	0.016
T_4	134.69 ± 12.72	0.009	74.46 ± 9.41	0.079	95.54 ± 13.03	0.013
T_5	135.74 ± 13.73	0.002	75.14 ± 10.72	0.082	95.94 ± 11.21	0.005
T_6	135 ± 17.1	0.029	75.66 ± 9.76	0.024	95.11 ± 11.23	0.034
T_7	131.94 ± 12.76	0.064	75 ± 9.33	0.051	93.97 ± 10.11	0.112
T_8	132.11 ± 15.6	0.228	74.54 ± 10.29	0.104	93.77 ± 11.33	0.094
T_9	132.29 ± 13.84	0.08	73.37 ± 10.67	0.231	93.03 ± 11.16	0.191
T_{10}	127.34 ± 12.82	0.456	71.03 ± 9.94	0.918	89.66 ± 10.76	0.301
T_{11}	127.63 ± 13.89	0.712	70.34 ± 9.95	0.512	89.17 ± 10.35	0.139
T_s	125.09 ± 13.4	0.071	69.89 ± 9.34	0.499	88.34 ± 10.3	0.097
T_d	123.46 ± 11.21	0.004	69.51 ± 8.25	0.682	87.57 ± 8.7	0.034
T_f	121.86 ± 11.6	0.002	69.23 ± 7.64	0.549	87.23 ± 9.1	0.045
T_h	137.4 ± 7.5	0.0002	75.97 ± 5.55	0.0009	96.14 ± 5.9	0.0001

SBP: Systolic Blood Pressure, DBP: Diastolic Blood pressure, MAP: Mean Arterial Pressure

Table 3: Intra-operative heart rate and central venous pressure values

Time	HR (beats/min)		CVP (cm H_2 O)	
	Mean ± SD	P value	Mean ± SD	P value
T_b	66.37 ± 7.93	-	9.69 ± 1.2	-
T_p	70.94 ± 7.07	<.0001	12.4 ± 1.59	<.0001
T_t	67.74 ± 8.49	0.102	12.6 ± 1.5	<.0001
T_1	67.09 ± 9.01	0.376	19.26 ± 3.47	<.0001
T_2	66.14 ± 9.36	0.824	20.06 ± 2.58	<.0001
T_3	66.54 ± 9.59	0.881	20.34 ± 2.38	<.0001
T_4	67.2 ± 8.81	0.557	20.74 ± 2.08	<.0001
T_5	66.8 ± 9.19	0.72	20.6 ± 1.99	<.0001
T_6	67.91 ± 7.76	0.178	20.69 ± 1.92	<.0001
T_7	70.74 ± 7.27	0.0002	20.71 ± 1.92	<.0001
T_8	70.26 ± 7.75	0.004	20.2 ± 2.15	<.0001
T_9	69.89 ± 9.42	0.019	19.66 ± 2.2	<.0001
T_{10}	68.97 ± 10.22	0.108	19.11 ± 2.34	<.0001
T_{11}	69.29 ± 8.66	0.069	18.37 ± 2.71	<.0001
T_s	69.2 ± 7.65	0.099	14.69 ± 2.05	<.0001
T_d	68.66 ± 7.01	0.113	11.8 ± 1.39	<.0001
T_f	70.34 ± 6.3	0.017	9.91 ± 0.98	0.262
T_h	70.57 ± 5.86	0.005	8.89 ± 1.3	0.002

HR: Heart Rate, CVP: Central Venous Pressure

elderly patients.[9]

In our study, systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial pressure (MAP) increased immediately at pneumoperitoneum and remained significantly higher at most times in steep TP. This is in accordance with many previous studies.[5–11] Increase in BP can be explained by sympathetic stimulant effect of CO_2 and increased afterload consequent to aortic compression from raised intra-abdominal pressures. Additionally, steep TP can augment venous return thereby increasing preload. Also, in our study, there was significant decrease in MAP after resuming supine position. Restricted use of intraoperative intravenous fluids to facilitate surgical dissection during robot assisted surgeries can explain this finding. Similar fluctuations of BP were reported by Meininger et aland Kalmar et al.[6,10]

In our study, central venous pressure (CVP) showed a trend of consistent increase from baseline (9.69±1.2) to 12.4±1.59 at pneumoperitoneum (P<.0001) and 12.6±1.5 at steep TP (P<.0001). The consistent increase plateaued and

Table 4: Intra-operative Airway Pressure Values

Time	P_{peak}(cm H_2 O)		P_{plat}(cm H_2 O)		P_{mean}(cm H_2 O)	
	Mean ± SD	**P value**	**Mean ± SD**	**P value**	**Mean ± SD**	**P value**
T_b	22.29 ± 3.45	-	20.63 ± 3.58	-	7.23 ± 2.43	-
T_p	24.94 ± 2.78	<.0001	23.43 ± 3.38	<.0001	7.71 ± 2.15	0.006
T_t	26.03 ± 3.23	<.0001	24.71 ± 2.87	<.0001	8 ± 2.14	0.0009
T_1	26.66 ± 3.75	<.0001	24.8 ± 2.86	<.0001	8.51 ± 1.92	<.0001
T_2	27.74 ± 3.62	<.0001	25.43 ± 3.23	<.0001	9.14 ± 1.91	<.0001
T_3	28.11 ± 3.25	<.0001	25.63 ± 3.1	<.0001	9.51 ± 2.05	<.0001
T_4	28.31 ± 3.86	<.0001	26.14 ± 3.16	<.0001	10 ± 2.04	<.0001
T_5	28.71 ± 3.85	<.0001	26.34 ± 3.41	<.0001	10.43 ± 1.91	<.0001
T_6	28.77 ± 3.82	<.0001	26.23 ± 3.4	<.0001	10.26 ± 1.95	<.0001
T_7	28.6 ± 3.76	<.0001	26 ± 3.64	<.0001	10.14 ± 1.78	<.0001
T_8	28.89 ± 3.96	<.0001	25.66 ± 3.51	<.0001	9.86 ± 1.7	<.0001
T_9	28.46 ± 4.58	<.0001	25 ± 4.24	<.0001	9.51 ± 1.77	<.0001
T_{10}	27.97 ± 4.7	<.0001	24.29 ± 4.38	<.0001	9.17 ± 1.64	0.0001
T_{11}	27.4 ± 4.2	<.0001	23.6 ± 3.72	<.0001	8.77 ± 1.54	0.0007
T_s	27.09 ± 4.16	<.0001	23.17 ± 3.66	<.0001	8.31 ± 1.55	0.005
T_d	26.8 ± 3.95	<.0001	22.37 ± 3.4	0.001	8.03 ± 1.36	0.026
T_f	25.2 ± 3.9	<.0001	21.74 ± 3.3	0.03	7.6 ± 1.4	0.225
T_{15}	23.69 ± 3.63	0.019	20.94 ± 3.19	0.509	7.37 ± 1.37	0.591

P_{peak}: Peak Airway Pressure, P_{plat}: Plateau Airway Pressure, P_{mean}: Mean Airway Pressure

Table 5: Intraoperative Lung Compliance, $EtCO_2$ and MV values

Time	Compliance (ml/ cm H_2 O)		$EtCO_2$ mm Hg		MV (ml)	
	Mean ± SD	**P value**	**Mean ± SD**	**P value**	**Mean ± SD**	**P value**
T_b	60.49 ± 5.7	-	27.26 ± 2.57	-	4457.34 ± 792.87	-
T_p	37.63 ± 3.89	<.0001	31.69 ± 2.77	<.0001	4917.43 ± 856.72	<.0001
T_t	37.74 ± 3.98	<.0001	32.4 ± 2.67	<.0001	5038.06 ± 849.32	<.0001
T_1	37.77 ± 4.1	<.0001	32.11 ± 2.81	<.0001	5525.8 ± 839.19	<.0001
T_2	38.01 ± 4.12	<.0001	32.97 ± 2.22	<.0001	5772.06 ± 936.53	<.0001
T_3	38.3 ± 4.05	<.0001	33.49 ± 2.27	<.0001	6033.14 ± 946.06	<.0001
T_4	38.63 ± 3.91	<.0001	33.26 ± 2.24	<.0001	6083.29 ± 993.95	<.0001
T_5	38.68 ± 3.81	<.0001	33.6 ± 2.24	<.0001	6185.4 ± 962.26	<.0001
T_6	39.15 ± 3.49	<.0001	33.14 ± 2.26	<.0001	6224.57 ± 894.68	<.0001
T_7	39.68 ± 3.51	<.0001	33.09 ± 2.61	<.0001	6037.94 ± 893.58	<.0001
T_8	40.31 ± 3.37	<.0001	33.51 ± 2.5	<.0001	5880.74 ± 820.52	<.0001
T_9	41.82 ± 3.47	<.0001	33.29 ± 3.02	<.0001	5753.06 ± 760.47	<.0001
T_{10}	42.65 ± 3.6	<.0001	33 ± 2.51	<.0001	5574.31 ± 708.43	<.0001
T_{11}	43.08 ± 3.7	<.0001	32.83 ± 3.1	<.0001	5494.63 ± 774.46	<.0001
T_s	43.86 ± 3.96	<.0001	32.71 ± 3.49	<.0001	5335.8 ± 886.94	<.0001
T_d	44.68 ± 4.23	<.0001	32.8 ± 3.04	<.0001	5095.43 ± 795.83	<.0001
T_f	45.51 ± 4.1	<.0001	32.94 ± 3	<.0001	4924.29 ± 849.5	0.002
T_h	46.52 ± 3.86	<.0001	32.69 ± 2.64	<.0001	4800.86 ± 873.05	0.026

$EtCO_2$: End tidal Carbondioxide, MV: Minute Ventilation

Table 6: Intraoperative ABG values

Time	pH		$PaCO_2$ (mmHg)		PaO_2 (mmHg)	
	Mean ± SD	**P value**	**Mean ± SD**	**P value**	**Mean ± SD**	**P value**
T_b	7.35 ± 0.06	-	29.42 ± 3.9	-	116.63 ± 22.9	-
At 1 hour	7.33 ± 0.07	0.0002	44.89 ± 7.26	<.0001	108.14 ± 16.95	<0.0001
At 2 hours	7.3 ± 0.07	<.0001	50.89 ± 6.56	<.0001	99.94 ± 15.9	<0.0001
At 3 hours	7.32 ± 0.03	0.0008	49.49 ± 7.5	<.0001	102.74 ± 14.04	0.0001

ABG: Arterial Blood Gas, $PaCO_2$: Partial pressure (arterial) of carbondioxide, PaO_2: Partial pressure (arterial) of oxygen started decreasing to become comparable to baseline after desufflation. Other studies have also reported significant rise in CVP after creation of pneumoperitoneum and steep TP.[5–9,11,12] Pneumoperitoneum induced autotransfusion of blood from splanchnic circulation into central compartment, augmentation of venous return by steep TP and transmission of increased intra-arterial pressure to the thorax could be the factors responsible for this rise in CVP. Darlong et al who also found similar rise in CVP reported that transcapillary fluid filtration into the interstitial space in dependent areas of the body could be responsible for the upper body edema that may occur in patients after robot assisted pelvic surgeries despite restriction of intravenous fluids thereby making CVP a less reliable guiding factor for fluid therapy. Kalmar et al, reported increase in CVP after TP that persisted intraoperatively followed by decrease in CVP on resuming the supine position.[6] The observed increase in CVP was attributed to increased hydrostatic pressure at the level of external auditory meatus caused by steep TP. Raised CVP and chemosis may reflect presence of lung interstitial edema and cerebral edema. These may lead to the requirement of post-operative ventilation. In our study none of the patients required post-operative ventilation.

In our study, pulmonary compliance (mL/cm H_2O) decreased significantly immediately from 60.49 ± 5.7 at baseline to 37.63 ± 3.89 at pneumoperitoneum (P <.0001); after which it remained low at 37.74 ± 3.98 (P <.0001) after steep TP and at all the following time intervals. Similar to our study, decreased pulmonary compliance after pneumoperitoneum and steep TP was reported by Lestar et al and Kalmar et al.[5,6] Increase intra-abdominal pressure leads to cephalad shift of diaphragm, and it also gets transmitted to thorax resulting in reduced pulmonary compliance.[6] After reinstitution of the supine position, the compliance was lower than the baseline value. This could be explained by basal atelectasis caused by cephalad movement of diaphgram due to pneumoperitoneum and steep TP, residual cephalad displacement of diaphragm upon supine positioning.[6]

Peak airway pressure (cm H_2O) showed a consistent increase from baseline (22.29 ± 3.45) to 24.94 ± 2.78 at pneumoperitoneum (P<.0001) and 26.03 ± 3.23 at steep TP (P<.0001). Airway plateau pressure (cm H_2O) showed a consistent increase from baseline (20.63 ± 3.58) to 23.43 ± 3.38 at pneumoperitoneum (P<.0001) and 24.71 ± 2.87 at steep TP (P<.0001). Airway mean pressure (cm H_2O) also showed a consistent increase from baseline (7.23 ± 2.43) to 7.71 ± 2.15 at pneumoperitoneum (P=0.006) and 8 ± 2.14 at steep TP (P=0.0009). Thereafter, these parameters were significantly higher above the baseline at all time intervals in steep TP. Our findings were similar to Lestar et al and Kalmar et al who observed that peak and plateau airway pressures increased at pneumoperitoneum and further increased after steep TP.[5,6]

End tidal carbondioxide ($EtCO_2$) (mmHg) increased significantly immediately from 27.26 ± 2.57 at baseline to 31.69 ± 2.77 at pneumoperitoneum (P <.0001); which increased to 32.4 ± 2.67 (P <.0001) after steep TP. Thereafter, at all measuring time points, $EtCO_2$ was significantly higher as compared to baseline (p value<.05). ABG analysis showed that partial pressures of oxygen showed a consistent decrease and CO_2 showed a consistent increase over time and pH showed a significant fall, values of pH fluctuated between mean of 7.3-7.35. Similar to Kalmar et al, in the present study, the $PaCO_2$ and $EtCO_2$ difference increased with the duration of surgery.[6] This implies that EtCO2 may not be an accurate reflection of $PaCO_2$ at all time points during surgery. Since hypercarbia may cause choroidal dilatation increasing the intraocular pressure resulting in ocular complications such as postoperative visual loss, and also cerebral vasodilatation with consequent increase in intracranial pressure, the utility of solitary $EtCO_2$ monitoring without $PaCO_2$ in prolonged surgeries performed in steep TP with carboperitoneum requires further validation.[6] Lestar et al, observed that $EtCO_2$ was comparable at pneumoperitoneum and increased during the Trendelenburg position and after the conclusion of surgery.[5]

Minute ventilation(mL/min) increased significantly from baseline (4457.34 ± 792.87) to 4917.43 ± 856.72 at pneumoperitoneum (P<.0001) and 5038.06 ± 849.32 at steep TP (P<.0001). In our study volume control mode was used and tidal volume was kept 6-8 ml/kg and was not varied much. Further changes in minute ventilation were made by increasing respiratory rate to maintain $EtCO_2$ below 45 mmHg. Kalmar et al also reported that median value of minute ventilation showed increase from pre-Trendelenburg position to TP and post-Trendelenburg position (P<0.05).[6] Lestar et al, reported that volume-controlled ventilation ensured a stable tidal volume.[6] Peak and mean inspiratory pressures were increased by pneumoperitoneum, 46% and 28% (P < 0.001), and further increased after TP 20% and 11%, respectively (not significant) as was seen in our study.

The present study was conducted on patients belonging to ASA class 1 and 2, and results of this study cannot be extrapolated to patients falling in ASA class 3 and 4. Many patients undergoing laparoscopic radical pelvic surgeries may fall in ASA class 3 or 4, whose cardiovascular and respiratory systems can be more vulnerable to the effects of prolonged pneumoperitoneum and steep TP.

It can be concluded from the present study that laparoscopic radical urosurgeries performed in steep TP with pneumoperitoneum can cause significant cardiorespiratory changes. Hemodynamic changes included tachycardia, rise in systolic, diastolic and mean arterial pressures, rise in central venous pressure. Pulmonary compliance was reduced and airway pressures increased that affected pulmonary gas exchange with consequent decrease arterial partial pressure of oxygen, arterial oxygen saturation. There was tendency towards hypercapnia and hypercarbia which was managed by increasing the minute ventilation. These changes are of concern in patients with pre-existing diseases of cardio-respiratory systems such as hypertension, ischemic heart disease, chronic obstructive pulmonary disease etc. Pre-operative assessment of cardiopulmonary reserve and optimization of any cardiovascular and respiratory ailment is suggested for patients undergoing laparoscopic radical urosurgeries.

5. Conflict of Interest

The authors declare that there are no conflicts of interest in this paper.

6. Source of Funding

None.

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