ORIGINAL RESEARCH

Comparative study of respiratory dynamics using Pressure control volume guaranteed mode to conventional modes in elective robotic pelvic surgeries under general anesthesia

[1]Dr. Apoorva Naik, [2]Dr. Ankita Chaudhary, [3]Dr. Shruthi A, [4]Dr. Murugesan C

[1]Consultant Anaesthesiologist, Ground floor Ot Complex, District Hospital attached to Karwar Institute of Medical Sciences, Karwar, India
[2]Senior Registrar, Department of Anaesthesia, Narayana Hrudayalaya, Hosur road, Anekal, Bangalore, India
[3]Senior Registrar, Department of Anaesthesia and Critical Care, Vasavi Hospital, 1st stage Kumaraswamy Layout, Bengaluru, India
[4]Senior Consultant and Head of the Department of Anaesthesia, Mazumdar Shaw Medical Centre, Naryana Hrudayalaya, Hosur Road, Anekal, Bangalore, India

Corresponding author
Dr. Murugesan C
Senior Consultant and Head of the Department of Anaesthesia, Mazumdar Shaw Medical Centre, Naryana Hrudayalaya, Hosur Road, Anekal, Bangalore, India
Email: anaik868@yahoo.com

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ABSTRACT
Background: With modern anaesthesia workstation, newer modes of ventilation like pressure controlled volume guaranteed mode (PCV VG) which combines the advantages of (VCV) volume control mode & (PCV) pressure control mode are being explored. Present study was aimed to compare respiratory dynamics using Pressure control volume guaranteed mode to conventional modes in elective robotic pelvic surgeries under general anesthesia.**Material and Methods:**Present study was single-center, prospective, randomized, open label study, conducted in adult patients(>18 years), belonging to ASA I and II of either sex undergoing elective robotic pelvic surgery under general anaesthesia, Patients were ventilated by VCV, PCV or PCV VG modes based on randomization.**Results:**Peak airway pressures in PCV & PCV VG modes remained comparable after 30minutesofpneumo-insufflationtilltheendofonehourofpneumo-insufflationindicating both PCV & PCV VG modes were equivocal at maintaining low peakairwaypressureunderpneumo-insufflationandlithotomywith Trendelenburg position.Dynamic compliance was high in PCV VG mode when compared to the conventionalmodes with statistically significant p values throughout the study period. A fall indynamic compliance was noted in all 3 modes in comparison to the baseline valuesduringpositioning and pneumo-insufflation.PCV VG mode delivered a higher tidal volume throughout the study period whencompared to conventional modes. This indicates that a better tidal volume with lowerpeak airway pressure was achievable with PCV VG when compared to conventionalmodes in our study settings.**Conclusion:**PCV VG mode which incorporates the innovation of delivering the preset tidal volume in a pressure regulated fashion can be advantageous over the conventional modes of ventilation under general anaesthesia in terms of ease of use, better tidal volume delivery, maintaining lower peak airway pressure & better intraoperative hemodynamics.
Keywords: robotic surgeries, PCV VG, tidal volume, pneumoinsufflation

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INTRODUCTION

Over the past 20 years, technological advances coupled with changes in the practice patterns regarding the route of surgery have led to an increase in the incidence of robotic surgeries[1]. With the recent advancements in surgical procedures, there is a greater emphasis on minimally invasive techniques with the goal of improving patient outcome and satisfaction while decreasing the surgical morbidity and mortality.[1]

The birth of robotic surgery took place in an era where there was an increasing demand for greater surgical precision with surgical safety and the surgeons were increasingly adopting minimal invasive surgical (MIS) technologies to enhance their outcomes. Robotic assisted laparoscopic surgery was developed to overcome some of the limiting aspects of conventional laparoscopy. Advantages of the robotic platform include better ergonomics, wider range of motion and 3-dimensional stereo vision [6,7]. Likewise are the challenges associated with robotic anaesthesia. The robotic assisted laparoscopic pelvic surgeries require steep Trendelenburg position and pneumo-insufflation. The positional changes along with pneumo-insufflation cause dramatic physiologicalderangements.[8]

With modern anaesthesia workstation, newer modes of ventilation like pressure controlled volume guaranteed mode (PCV VG) which combines the advantages of (VCV) volume control mode & (PCV) pressure control mode are being explored.[12] Not many studies are available in the Indian scenario comparing the advantages of pressure control volume guaranteed mode (PCVVG) over the conventional modes of ventilation (PCV & VCV) and its effects on the lung mechanics in robotic assisted laparoscopic pelvic surgeries. Present study was aimed to compare respiratory dynamics using Pressure control volume guaranteed mode to conventional modes in elective robotic pelvic surgeries under general anesthesia.

MATERIAL AND METHODS

Present study was single-center, prospective, randomized, open label study, conducted in department of anaesthesiology, at Mazumdar Shaw Medical Centre, Narayana Health City, Bommasandra, Bangalore., India. Study duration was of 6 months (July 2019 to November 2019). Study approval was obtained from institutional ethical committee.

Inclusion criteria

- Adult patients (>18 years), belonging to ASA I and II of either sex undergoing elective robotic pelvic surgery under general anaesthesia, willing to participate in present study

Exclusion criteria

- BMI>40
- Neurological (seizure), metabolic, neuromuscular or genetic disorders, valvular & structural heart diseases
- Underlying lung infections in past 2 weeks
- Hepatic or renal insufficiency

Patients were enrolled in the study after registering in CTRI registry. Randomization was done by block randomization. Randomization code was generated using online software and allocation concealment was done using serially numbered opaque sealed envelope into three groups: group VCV, group PCV and group PCV VG.

A written informed consent was taken after explaining in detail about the procedure during pre-anaesthetic visit prior to including in the study. Demographic data of the patients like age, sex and history were obtained through an interview. The physical and medical examination was conducted. Those findings were recorded on predesigned proforma.

Anaesthetic techniques were standardized for all patients. Pre anaesthetic checkup was done one day prior to the surgery. Patients were evaluated for any systemic diseases and routine, relevant laboratory investigations were conducted and evaluated. As per institutional protocol, fasting guidelines for elective surgery was followed. i.e., 6 hours for solids & 2 hours for clear fluids prior to the surgery.

All cases were performed on pre-determined anaesthesia workstation, Mindray Wato EX 65 equipped in the robotic operating room along with da Vinci Si robotic system. Standard general anaesthesia technique with the use of standard monitoring viz., electrocardiography, non-invasive blood pressure, capnography, core body temperature & pulse-oximetry was instituted. Invasive arterial line insertion for arterial blood gas analysis post induction was carried out only as per the requirement for the surgery among the participants in the study. Baseline vitals were recorded for all patients.

After successful intravenous (IV) cannulation, intravenous induction was followed using 0.05mg/kg of midazolam, 2 mcg/kg of fentanyl & 2mg/kg of propofol with titration of dose according to the age of the patient. Patients were relaxed by administration of 0.1mg/kg of cis-atracurium. After induction & muscle relaxation, patients were electively ventilated for 3minutes and endo-tracheal intubation was performed. Arterial line was secured post induction based on the requirement for the surgical procedure among the participants in the study group. After induction & intubation, general anaesthesia was maintained with the use of inhalational agent, isoflurane at 1-2% end tidal anaesthetic concentration. To maintain the surgical plane of anaesthesia, intravenous infusion of fentanylat1mcg/kg/hr and cis-atracurium infusion at 2-3 mcg/kg/min was used for the first one hour followed by 1 mcg/kg/min until undocking of robotic arms.

Patients were ventilated by VCV, PCV or PCV VG modes based on randomization. In all 3 modes, patients were ventilated with tidal volume of 6-8 ml/kg body weight, respiratory rate of 12-14 breaths per minute, I: E ratio 1:1.5, Fi02 0.5 & PEEP of 5 cm of water. The OT temperature was set at 20ºC and patients were kept warm using forced warm air device. All the pressure points were adequately padded with gel pads and the patients were strapped to the table and positioned in lithotomy with steep head low (steep Trendelenburg) 45– 60 degree position. Intra-abdominal pressure was maintained between 12-15 mm Hg during carbon dioxide pneumo-insufflation. After pneumo-peritoneum, respiratory rate or the peak inspiratory pressure was adjusted to achieve $EtCO_2$ between 33 – 37 mm of Hg based on

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modes of ventilation. After correction of fasting deficit, maintenance fluid was administered based on hemodynamic variations and as per surgical requirements. Hypotension (> 20% decrease in the preoperative mean blood pressure or mean arterial pressure ≤ 60 mmHg), bradycardia(heart rate of ≤ 50 beats per minute), and arterial desaturation, if any, was followed up in peri-operative period and managed accordingly.

Patients requiring more than 40 cm of water peak airway pressure to achieve desired tidal volume, the patients in whom the ventilator settings were not established even after 30 minutes of pneumo-insufflation, robotic surgery converted into open procedure, saturation maintaining below 95% & wide hemodynamic fluctuations intra-operatively were excluded from the study. The need for change over from conventional to advanced ventilatory modes after randomization if any, use of recruitment maneuvers if any during the intra-operative period were recorded & incidence of such conversion was statistically determined.

The respiratory parameters viz., tidal volume, respiratory rate, peak airway pressure, dynamic compliance, oxygen saturation, end tidal carbon dioxide, arterial blood gas analysis for arterial partial pressures of oxygen, carbon dioxide, arterial oxygen saturation, hemodynamic parameters viz., heart rate, systolic blood pressure, diastolic blood pressure &mean arterial pressure were recorded during the pre-determined (T0, T1, T2, T3, T4, T5) time periods.

- T0 is the time 5 minutes after intubation
- T1 is the time 10 minutes after induction & intubation in supine position.
- T2 is the time 15 minutes after positioning & pneumo-insufflation.
- T3 is the time 30 minutes after pneumo-insufflation
- T4 is the time 60 minutes after pneumo-insufflation
- T5 is the time 10 minutes after bringing to supine position &desufflation.

Any adverse event during the period of pneumo-insufflation viz., barotrauma, pulmonary oedema, atelectasis, subcutaneous emphysema, pneumothorax, pneumo-mediastinum, hypoxemia, gas embolism, pneumo-pericardium, airway oedema & cerebral oedema were recorded. At the end of surgery, residual neuromuscular blockade was reversed with neostigmine 0.05mg/kg, glyco-pyrrolate 0.01 mg/kg and tracheal extubation was performed once clinical signs of reversal, and a train of four (TOF) ratio of 0.9 was achieved. Patients received 0.1mg/kg i.v. ondansetron at the end of surgery to prevent postoperative nausea & vomiting. Postoperatively, pain was managed with IV paracetamol 1000 mg every 8^{th} hourly.

All the obtained data was statistically analyzed using SSPS software 21. Continuous variables were expressed by using mean and standard deviation. Categorical variables were expressed using percentage and frequency. Comparison of peak airway pressures between the three groups was done using ANOVA/Kruskal Wallis test with suitable post hoc tests. P value < 0.05 was considered statistically significant. Comparison of continuous variables between the groups was done using ANOVA.

RESULTS

The study group comprised of adult patients >18 years. In present study, mean age, gender, ASA grade, type of surgical procedures & anthropometrical measurements (weight, height & BMI) were comparable in all3 groups & difference was not statistically significant. (p > 0.05)

Table 1: General characteristics

	Group			Total	P value
	PCV	PCVVG	VCV		
Age					
≤ 35	3	1	2	6	0.859
36 -55	12	13	11	36	
≥ 56	10	11	12	33	
Sex					
Male	7	8	4	19	0.4
Female	18	17	21	56	
ASA Grade					
1	12	7	8	27	0.297
2	13	18	17	48	
Surgery					
Gynaecological Surgery	16	17	20	53	
Lower Abdominal Surgery	3	1	1	5	
Urological Surgery	6	7	4	17	
Anthropometry					
Weight (kg)	60.6 ± 12.443	61.51 ± 9.49	60.48 ± 11.709		0.94
Height (cm)	161.84 ± 8.295	160.36 ± 7.21	160.72 ± 7.374		0.776

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BMI	22.91 ± 3.056	23.84 ± 2.897	23.24 ± 3.256		0.557

At time points T0 & T1 : Post induction & intubation before the pneumo-insufflation, peak airway pressures were comparable among the 3 groups with no statistically significant difference between the groups.(p value>0.05) After pneumo-insufflation, peak airway pressures increased with reference to their baseline values individually in all 3 groups. Highest increase in peak airway pressure from the baseline value was noted in the VCV group (VCV: P peak from 19.4±2.76 at T0 to 34.08±2.61 at T2).

At T2 time interval i.e., 15 minutes after pneumo-insufflation there was statistically significant difference in peak airway pressure between the 3 groups. At T2, VCV mode recorded the highest peak airway pressure (34.08±2.61) followed by PCV(30.04±2.89)& PCV VG recording the lowest peak airway pressure (28.28 ± 2.151). The inter group p values were statistically significant. (At T2, p values– VCV vs. PCV VG<0.01, VCV vs. PCV<0.01, PCV VG vs. PCV =0.01) Thus, implying that rise in peak airway pressure after pneumo-insufflation was least with PCV VG mode & highest with VCV mode with statistically significant intergroup p values emphasizing the superiority of PCV VG mode over conventional modes soon after pneumo-insufflation.

At T4:Peak airway pressure remained higher than baseline values individually in all 3 groups. But, peak airway pressure was comparable between PCVVG & PCV with no statistical significance. (p value: PCV VG vs. PCV:at T3, p =0.096; at T4, p =0.35) Peak airway pressure remained highest in VCV mode in comparison to the other 2 modes at T3 & T4 with statistically significant intergroup p values. (At T3, P value: VCV vs. PCV VG < 0.01, VCV vs. PCV <0.01) (AtT4, P value: VCV vs. PCVVG <0.01,VCV vs. PCV <0.01)

It was observed that peak airway pressure was higher in VCV mode after 30 minutes of pneumo-insufflation while peak airway pressure was maintained on lower side in pressure regulated modes PCV & PCV VG. PCV VG & PCV were equivocal in maintaining a lower peak airway pressure after 30 minutes of pneumo-insufflation. VCV remained inferior to PCV & PCV VG in maintaining peak airway pressure after 30minutesofpneumo-insufflation.

After desufflation at T5: Peak airway pressure remained comparable between the 3 groups with no statistical significance between the3 groups (p>0.05).

Table 2: Peak airway pressure (P peak) between the groups

Peak Pressure (cm of H2O)	PCV	PCVVG	VCV	P Value ANOVA	PCV Vs PCVVG	VCV Vs PCV	VCV Vs PCVVG
T0	18.36 ± 2.94	18.08 ± 1.869	19.4 ± 2.769	0.167	0.701	0.157	0.074
T1	18.52 ± 2.80	19.12± 2.682	19.36± 3.121	0.569	0.463	0.305	0.769
T2	30.04± 2.894	28.28± 2.151	34.08± 2.613	<0.01	0.018	<0.01	<0.01
T3	30.4 ± 2.915	29.24 ± 2.296	35.44 ± 2.002	<0.01	0.096	<0.01	<0.01
T4	30.08± 2.532	29.44± 2.485	35.04± 2.274	<0.01	0.356	<0.01	<0.01
T5	20.64± 2.481	20.76± 3.345	22.2 ± 2.858	0.117	0.885	0.063	0.085

At baseline T0 & T1 intervals, dynamic compliance was highest for PCVVG (46.48±7.241), followed by PCV (41.12±7.58) least for VCV (37±4.062). Difference in baseline values of dynamic compliance was statistically significant between the 3groups. (p<0.01).

On pneumo-insufflation:(T2,T3,T4) there was decrease in compliance from baseline values individually in all 3 groups immediately after pneumoinsufflation (T2 time interval onwards)and same trend was noticed from T2 to T4i.e. 60 minutes after pneumo-insufflation.

During the period of pneumo insufflation, dynamic compliance remained comparable between PCVVG & PCV with no statistical significance from T2 to T4 time intervals.

PCVVG & PCV were equivocal in maintaining dynamic compliance during the period of pneumo-insufflation. VCV recorded lowest dynamic compliance among the 3 groups during the period of pneumo-in sufflation from T2 to T4 time intervals with statistically significant intergroup p value. This observation implied that VCV was inferior to the other 2 modes PCV & PCVVG in maintaining dynamic compliance during the period of pneumo-insufflation. Post desufflation at T5, dynamic compliance remained high in PCV VG group followed by PCV group & lowest in VCV group with statistically significant intergroup p values. (p <0.01)

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Table 3: Dynamic compliance between groups

Cdyn (ml/cm Of H2O)	PCV	PCVVG	VCV	P Value ANOVA	PCV Vs PCVVG	VCV Vs PCV	VCV Vs PCVVG
T0	41.12 ± 7.585	46.48 ± 7.241	37 ± 4.062	<0.01	0.005	0.028	<0.01
T1	40.96 ± 9.185	46.16 ± 7.116	37.04 ± 4.373	<0.01	0.012	0.05	<0.01
T2	19.2 ± 4.637	19.12 ± 2.991	13.08 ± 1.631	<0.01	0.932	<0.01	<0.01
T3	18.64 ± 4.424	19.08 ± 3.148	12.8 ± 1.691	<0.01	0.637	<0.01	<0.01
T4	18.92 ± 4.183	18.96 ± 3.102	13 ± 3.367	<0.01	0.969	<0.01	<0.01
T5	33.96 ± 6.419	41.04 ± 5.849	26.2 ± 3.428	<0.01	<0.01	<0.01	<0.01

At baseline, T0 & T1 time intervals, mean end tidal carbon dioxide was comparable between the 3 groups. There was no statistical significance noted between the 3 groups. ($p>0.05$ at T0 & T1) On pneumo-insufflation and positioning, at T2, end tidal carbon dioxide remained comparable between the 3groups with no statistical significance ($P>0.05$). At T3, EtCO2 was highest in VCV mode followed by PCV mode and lowest in PCVVG mode with statistically significant intergroup p value between VCV vs. PCVVG. At T4, EtCO2 was highest in VCV mode followed by PCV mode and lowest in PCVVG mode with statistically significant intergroup p value between VCV vs. PCV VG ($p = 0.006$)

Overall, under pneumo-peritoneum PCVVG maintained a lower EtCO2 in comparison to conventional modes. AtT5 postdesufflation,EtCO2 was highest with VCV mode followed by PCV mode and lowest with PCV VG mode with statistically significant pvalue. Thus, EtCO2 was better maintained in pressure regulated modes (PCV & PCVVG) after T3 time interval than volume controlled mode.

Table 4: End tidal carbon dioxide

EtCO2 (mmHg)	PCV	PCVVG	VCV	P Value ANOVA	PCV Vs PCVVG	VCV Vs PCV	VCV Vs PCVVG
T0	33.4± 1	32.68 ± 1.314	33.24± 1.363	0.104	0.043	0.649	0.114
T1	32.84± 1.546	32.96 ± 1.645	32.92± 1.288	0.959	0.778	0.851	0.925
T2	34.84± 0.85	34.44 ± 1.356	34.84± 1.344	0.405	0.245	1	0.245
T3	34.88± 1.269	34.16 ± 1.313	35.24± 1.234	0.012	0.049	0.32	0.004
T4	34.64± 1.221	34.28 ± 1.308	35.21± 0.833	0.021	0.269	0.086	0.006
T5	33.6± 0.866	33.4 ± 1.155	34.24± 1.2	0.021	0.516	0.04	0.008

At baseline, T0 & T1 time intervals VCV mode generated a lower tidal volume when compared to PCV & PCVVG with statistically significant p values. (At T0, VCV-405.6 ± 21.56, PCV –439.6 ± 28, PCVVG – 445.9±22.5) Tidal volume was comparable between PCV & PCVVG with no statistical significance between the 2 groups ($p>0.05$).

On pneumo-insufflation:(T2,T3,T4), after pneumo-insufflation, there was fall from baseline values individually in all 3groups. At T2 & T3, PCV VG mode recorded highest tidal volume followed by PCV mode and the least being VCV mode, with statistically significant p values.

At T4, PCV & PCV VG were comparable with respect to the tidal volume generated while volume control mode had least tidal volume generated with statistically significant p values.

Post desufflation, at T5, VCV had least tidal volume followed by PCV whereas PCVVG had highest tidal volume with significant inter group p value of <0.01.

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Table 5: Tidal volume

Tidal Volume (ml)	PCV	PCVVG	VCV	P Value ANOVA	PCV Vs PCVVG	VCV Vs PCV	VCV Vs PCVVG
T0	439.6 ± 28.295	445.9 ± 22.53	405.6 ± 21.57	<0.01	0.361	<0.01	<0.01
T1	431.08 ± 29.489	438.48 ± 23.682	392.2 ± 19.636	<0.01	0.291	<0.01	<0.01
T2	393.92 ± 33.062	409.16 ± 16.436	366.4 ± 20.992	<0.01	0.031	<0.01	<0.01
T3	388.28 ± 32.671	409.4 ± 17.1	356.4 ± 17.231	<0.01	0.002	<0.01	<0.01
T4	386.88 ± 32.707	407.32 ± 19.237	346 ± 73.951	<0.01	0.136	0.004	<0.01
T5	414.96 ± 30.831	432.28 ± 20.995	375.4 ± 15.473	<0.01	0.011	<0.01	<0.01

Arterial partial pressure of oxygen was comparable between the 3 groups from T0-T5 time intervals without statistically significant p value.($p > 0.05$)

Table 6: PaO2

PaO2	PCV	PCVVG	VCV	P Value ANOVA	PCV Vs PCVVG	VCV Vs PCV	VCV Vs PCVVG
T0	251.3 ±53.141	259.67 ± 44.593	292.78 ± 59.491	0.221	0.733	0.1	0.195
T3	167±29.922	176.67±36.878	168.11 ± 46.601	0.838	0.586	0.95	0.638
T5	210.2 ± 54.924	209.11 ± 35.332	199.33 ± 41.572	0.851	0.959	0.605	0.65

Arterial partial pressure of carbon dioxide was comparable between all 3 groups at T0, T3 & T5 intervals with no statistical significant p values among the groups.

Table 7: PaCO2

PaCO2	PCV	PCVVG	VCV	P Value	PCV Vs PCVVG	VCV Vs PCV	VCV Vs PCVVG
T0	34.1 ± 3.573	36.22 ± 1.481	38 ± 7.517	0.232	0.349	0.091	0.443
T3	40.1 ± 4.358	39.67 ± 5.895	43.78 ± 4.522	0.171	0.85	0.118	0.09
T5	38.8 ± 3.327	40.11 ± 2.667	41.11 ± 2.934	0.261	0.351	0.106	0.486

Arterial oxygen saturation was comparable among all 3 groups. It remained uniform at 100 in all 3 groups at T0 and T5 time intervals whereas at T3, VCV had a mean of 99.89 as opposed to 100 in PCV & PCVVG although this difference was not statistically significant.($p=0.341$).

Oxygenation parameters analysed were obtained from subgroup of the study population with the arterial line inserted postinduction, as per the requirement for the surgery.

Table 8: SaO2

SaO2	T1	T3	T5	MeanatT3	Std. Deviation At T3	P Value
PCV	100	100	100	100	0	0.341
PCVVG	100	100	100	100	0	
VCV	100	99.89	100	99.89	0.333	

DISCUSSION

As such laparoscopic surgeries are designed to offer an equivalence to open surgery with less tissue trauma and speedier discharge.[3] However, some of the challenges to widespread adoption of the laparoscopic approach are the steep learning curve, longer operating times as well as counter-intuitive hand movements, two-dimensional visualization and limited instrument mobility [6,7]

The physiological effects of pneumo-peritoneum can cause cardiovascular instability with increased systemic vascular resistance & higher myocardial oxygen consumption. The respiratory system changes include increased ventilation perfusion mismatch,

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decrease in functional residual capacity, decreased compliance, higher peak airway pressure & pulmonary congestion.[8] Many ventilator strategies like recruitment maneuvers, inverse ratio ventilation and application of PEEP have been utilized for better ventilation in robotic and minimal access surgeries.[9] The advantages of pressure control mode over volume control mode have also been studied extensively.[10,11]

Pressure controlled volume guaranteed breaths are characterized by decelerating flow waveforms and this mode delivers breaths with the efficiency of pressure control mode yet compensating for the changes in lung compliance with consistent tidal volumes unlike pressure control mode where there is a need to repeatedly adjust the airway pressures to deliver desired tidal volume whereas volume control may require higher airway pressures to deliver constant flow rate and constant tidal volume.[12,13]

Robotic pelvic surgeries pose great challenges to anaesthesiologist because of steep Trendelenburg position for prolonged hours along with pneumo-insufflation which significantly decreases the functional residual capacity (FRC) of the patients' lungs under anaesthesia. Decrease in FRC, decreased compliance with increased peak airway pressures are the effects caused on respiratory system. Increase in heart rate & blood pressure occurs due to increased venous return in Trendelenburg position.[11]

Application of advanced ventilator mode, PCVVG which guarantees set tidal volume delivery in pressure regulated ventilation is theoretically thought to be advantageous over conventional modes in these surgeries requiring pneumoinsufflation with Trendelenburg position.[14,15]

Distribution of age was comparable among the 3 groups without statistically significant difference between the groups. Majority of the patients were in 3rd to 5thdecades of their life in our study. The age distribution was concordant with our reference articles involving laparoscopic procedures & robotic gynecological procedures.[16,17] But , our reference studies involving radical prostatectomies involved population in their 5th& 6th decade of life.[18,19]

The study conducted by Kothari A *et al.*,[20] in laparoscopic cholecystectomy among 3 groups observed that PCV VG & PCV were comparable with respect to peak airway pressure after pneumo insufflation whereas VCV mode recorded statistically significant higher peak airway pressures. Dion *et al.*,[21] also observed similar finding in their study conducted on laparoscopic assisted bariatric surgeries between the 3 modes. Our study showed similar finding after 30 minutes of pneumo-insufflation. Additional observation of our study was that of occurrence of statistically significant lower peak airway pressure for PCV VG group after 15 minutes of pneumo-insufflation. Thus, our study population showed a favourable response to PCVVG immediately on positioning & pneumo-insufflation when compared to conventional modes of ventilation. Trendelenburg position and decrease in FRC leading to minimal atelectasis resulting in non-homogenous lung fields in our patients within 15 minutes of repositioning and pneumo-insufflation would have lead to this observation. Due to positive pressure effect & PEEP compensating for atelectatic changes, PCV and PCV VG modes became comparable after 30minutesup to 60 minutes of pneumo-insufflation during the study.

There were no other articles comparing all the3 modes together in a single study. Gad M *et al.*,[17] compared PCV VG vs. VCV in robotic pelvic surgery and concluded that PCVVG maintained lower peak airway pressures on pneumo insufflation. Their observation was similar to our observation. Other studies quoted in our review compared either PCV or PCV VG with VCV mode &found that pressure controlled modes maintained lower peak airway pressures over volume controlled mode as observed in our study.

Additional observation in our study was that although PCV VG mode maintained better dynamic compliance than PCV mode before pneumo-insufflation & after desufflation, during the period of pneumo-insufflation dynamic compliance remained comparable between PCV & PCV VG. Similar observation was noted by Kothari A*et al.,*[19] in their study.

The increase in EtCO2 is usually compensated by increasing the respiratory rate in electively ventilated patients especially in volume control mode. This observation denotes the fact that building up EtCO2 led to increase in respiratory rate during the period of pneumo- insufflation. Thus respiratory rate was higher in VCV group than PCV & PCV VG groups in our study. But, respiratory rate remained comparable in all 3 groups in our reference studies which were mainly based on laparoscopic surgeries. Gad *et al.*[25]followed equal ratio ventilation in volume control group during pneumo-insufflation in their study. Thus, variation in observation with respect to respiratory rate between our study population & our reference studies can be attributed to the varied intra-operative strategies used at maintaining acceptable EtCO2 during the period of pneumo-insufflation.

Tidal volume was comparable between PCV & PCV VG modes at T0 & T1 whereas VCV mode achieved lower tidal volume than pressure controlled modes during T0 & T1 time intervals. There was a drop in tidal volume achieved among all the 3 groups at T2 i.e. 15 minutes after pneumoinsufflation. PCVVG mode had highest tidal volume achieved followed by PCV mode and least being VCV mode at T2. Similar trend was observed at T3timeinterval i.e., 30 minutes after pneumo-insufflation as well.

Kothari A *et al.*,[19] observed that tidal volume delivered was comparable between the 3 groups at all time periods but this difference in observation can be attributed to the fact that their study was conducted in laparoscopic cholecystectomy. Our other reference studies analysed only peak airway pressure, dynamic compliance, hemodynamic sand oxygenation

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parameters.

Based on the hemodynamic parameters analysed we observed that the hemodynamic parameters remained stable in all 3 groups within the study period. Mean arterial pressure & oxygen saturation were well maintained with normal limits and were comparable between the 3 groups at all the time points of the study but heart rate was better maintained in PCV VG mode when compared to conventional modes after 30 minutes of pneumo-insufflation. This observation implies that although all 3 modes maintained stable hemodynamics, PCVVG had a better edge than the conventional modes in maintaining a more stable and lower heart rate during period of pneumo-insufflation. In our reference studies, hemodynamic parameters were stable between the compared modes without statistically significant difference. But, we observed in our study that PCVVG maintained a lower heart rate than the conventional modes.

There was no incidence of any adverse events associated with pneumo-insufflation viz., barotrauma, pulmonary oedema, atelectasis, subcutaneous emphysema, pneumothorax, pneumo-mediastinum, hypoxemia, gas embolism, pneumo-pericardium, airway oedema & cerebral oedema in our study population.

CONCLUSION

We conclude that with the advent of modern minimally invasive surgical practice involving robotic surgeries which require pneumo-insufflation & extreme surgical positions, PCV VG mode which incorporates the innovation of delivering the preset tidal volume in a pressure regulated fashion can be advantageous over the conventional modes of ventilation under general anaesthesia in terms of ease of use, better tidal volume delivery, maintaining lower peak airway pressure & better intraoperative hemodynamics when compared to the conventional modes (PCV, VCV) especially so in extreme surgical positions and pneumoinsufflation affecting the FRC & lung compliance as in robotic assisted laparoscopic pelvic surgeries. Future scope remains to explore the added advantages of PCV VG mode in robotic surgeries by means of multicentric trials.

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