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Evaluation of Fully Automated Ventilation after Off-Pump Coronary Artery Bypass Grafting

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Abstract

Objective: The study aimed to evaluate the effectiveness of a fully automated ventilator with a quick-wean option after off-pump coronary artery bypass grafting (OPCAB).

Materials and methods: We retrospectively reviewed 54 patients (13 women, mean age 71.4 ± 8.2 years) who were undergone OPCAB alone. Patients were divided into two groups; patients using fully automated ventilation with a quick-wean option after OPCAB (AV group, n=41), patients using conventional synchronized intermittent mandatory ventilation+pressure support mode (PV group, n=13), and the following data were analyzed and compared between two groups. We used the modified G5 fully automatic ventilator (INTELLiVENT-ASV mode with quick-wean option; Hamilton Medical, Rhazuns, Switzerland) as an automated ventilator.

Results: There was no significant difference in preoperative and operative characteristics. Ventilation time after OPCAB was significantly shorter in the AV group compared with the PV group (PV: AV=17.6 ± 1.7:16.3 ± 1.4 hours, p=0.026). There was no patient with re-intubation in both groups after respiratory weaning.

In the AV group, the Intensive Care Unit (ICU) stay was significantly shorter than in the PV group (PV: AV=5.2 ± 1.6:4.4 ± 1.0 days, p=0.040).

Conclusion: Fully automated ventilation with a quick-wean option may facilitate respiratory management after OPCAB.

Keywords: Fully automated ventilation; Ventilator weaning; Off-pump coronary artery bypass grafting

Introduction

Recently, a mechanical ventilation system is widely developed in the intensive care unit (ICU) to support patients with respiratory failure. Mechanical ventilation is the standard life support treatment of respiratory dysfunction by providing adequate oxygenation and carbon dioxide elimination.

INTELLiVENT-ASV is one of the automated algorithms based on the principle of the least work of breathing. The Adaptive Support Ventilation (ASV) automatically adjusts oxygenation. The ventilation setting includes Minute Volume (MV), Tidal Volume (VT), and Respiratory Rate (RR). The settings are adjusted automatically to reach a target end-tidal CO_2 ($EtCO_2$) in passive patients and a target RR inactive patients. Oxygenation settings include the inspiratory fraction of oxygen (FiO_2) and Positive End-Expiratory Pressure (PEEP) and are adjusted automatically to reach a target oxygen saturation by pulse oximetry (SpO_2). INTELLiVENT-ASV includes an additional function of the automated weaning protocol (Quick Wean). The algorithm of Quick Wean protocol decreases Pressure Support (PS) progressively, screens for the readiness-to-wean criteria, and automatically conducts a fully controlled Spontaneous Breathing Trial (SBT).

INTELLiVENT-ASV has been studied not only in ICU patients [1,2], but also after cardiac surgery [3,4]. In these situations, INTELLiVENT-ASV was safe and delivered low VT, peak inspiratory pressure, and FiO_2 compared with the controlled period in conventional ventilation. However, there are a few reports about patients using INTELLiVENT-ASV mode with a quick-wean option after Coronary Artery Bypass Grafting (CABG) [5]. The purpose of this study was to investigate the early results of INTELLiVENT-ASV mode after off-pump CABG (OPCAB) compared with conventional mode.

Materials and Methods

This retrospective study was approved by the institutional review board of Soka municipal hospital.

In a total of 146 consecutive patients undergoing CABG only from February 2013 to December 2019 in our institution. In CABG only, 66 patients were undergone OPCAB. The patients performed an emergency operation and the patients with hemodialysis were excluded. So, 54 patients (13 women, mean age 71.4 ± 8.2 years) were intended.

Induction and maintenance of operative anesthesia were similar for all patients and administered weight- related doses of fentanyl, midazolam, and pancuronium bromide.

After OPCAB, normal dosage Propofol was consisted of as sedative drug until weaning from the respirator in all patients. Avoiding over suppression in ICU, the sedation levels of all patients were controlled by The Richmond Agitation-Sedation Scale [6] from 0 to 2 points. For pain control, acetaminophen was used in all cases controlled by Behavioral pain scale [7] under 5 points. In our hospital, weaning from respirator wasn't on the day of operation for the standpoint of medical safety. The sedation is stopped AM 8:00 in the first postoperative day. After weaning from the respirator, the postoperative rehabilitation program was started from the weaning day.

Once standard discharge criteria will be attained, the patients will be transferred from ICU to the general ward. Patients with drains, central venous catheters, and the use of catecholamine cannot be transferred from ICU to the general ward in our hospital.

Respiratory support after OPCAB has been provided by a G5 ventilator (Hamilton Medical, Switzerland) with INTELLiVENT-ASV software using one SpO_2 sensor since July 2017. INTELLiVENT-ASV mode has automatically adjusted all parameters, target $EtCO_2$ with 35-45 mmHg, and SpO_2>95%. Also, we used the Quick Wean option with the automatic conduction of SBT. SBT lasted 30 min, and was automatically interrupted in case of SpO_2<90%, RR>30 /min, $EtCO_2$>45 mmHg and VT<5.0 ml/kg of predicted body weight. In case of unsuccessful SBT, another SBT could be automatically performed 30 min later.

Before July 2017, respirator support after OPCAB was provided by Servo-I ventilator (MAQUET, Inc, Wayne, NE) using synchronized intermittent mandatory ventilation (SIMV)+PS with manual adjustment of all the setting. On ICU arrival, patients have connected the ventilator, and the treating anesthesiologist performed the initial setting of the ventilator. TV was set at 10 ml/kg, RR at 12 breaths per minute, PEEP at 5 cm H_2O, and FiO_2 ranged from 50% to 100%. The ventilator protocol for the postoperative period was managed for FiO_2 weaning (decreased by 10% if SpO_2>95% to reach 40%). After patients were deemed to be able to breathe spontaneously, PS ventilation was used during the weaning phase.

Fifty-four patients were divided into two groups; patients using fully automated ventilation with a G5 ventilator after OPCAB (AV group, n=41), patients using conventional SIMV+PS with Servo-I (PV group, n=13), and the following data were analyzed and compared between groups.

Diabetes mellitus was defined as the recent use of anti-diabetic drugs, fasting blood glucose>126 mg/dl, and/or hemoglobin A1c>6.5%. Chronic kidney disease was defined as estimated glomerular filtration rate<50 ml/min/1.73 m^2.

Continuous data are expressed as mean ± SD with ranges when appropriate. Parametric data were compared using a student t-test. A Chi-squared test to examine with a contingency table was used. Differences were considered significant at p<0.05.

Results

In Table 1, there were preoperative characteristics for all patients. There were no significant differences between both groups in age, sex, prevalence (hypertension, dyslipidemia, diabetes mellitus, chronic obstructive pulmonary disease, and chronic kidney disease), smoking within a month, hemoglobin value, and ejection fraction. Inoperative characteristics, there was no difference between the two groups (Table 2).

	PV group (n=13)	AV group (n=41)	p value
Age (year)	71.9 ± 9.8	71.2 ± 7.7	0.782
Sex (female)	2(15.4%)	11(26.8%)	0.41
BMI (kg/m^2)	22.7 ± 3.8	24.0 ± 3.4	0.256
Prevalence			
Hypertention	13(100%)	38(92.7%)	0.325
Dyslipidemia	11(84.6%)	36(87.8%)	0.771
DM	8(61.5%)	30(73.2%)	0.155
CKD	3(23.1%)	3(7.3%)	0.12
COPD	5(38.5%)	8(19.5%)	0.17
Smoking within a month	3(23.1%)	7(17.1%)	0.635
Hb (g/dl)	12.7 ± 1.7	13.4 ± 1.9	0.244
EF (%)	58.2 ± 8.7	57.5 ± 15.5	0.886

Abbreviations: BMI: Body Mass Index; Dm: Diabetes Mellitus; CKD: Chronic Kidney Disease; COPD: Chronic Obstructive Pulmonary Disease; Hb: Hemoglobin; EF: Ejection Fraction

Table 1: Demographic characteristics of all patients before interventions.

	PV group (n=13)	AV group (n=41)	p value
Bypass number	2.7 ± 1.1	3.1 ± 0.9	0.36
Operative time (min)	304.5 ± 81.5	336.1 ± 92.9	0.277
Use of IABP	1(7.7%)	3(7.3%)	0.965
Blood transfusion	5(38.5%)	21(51.2%)	0.432

Abbreviations: OPCAB: Off-Pump Coronary Artery Bypass Grafting; Iabp: Intra-Aortic Balloon Pumping

Table 2: Surgical intervention.

In Table 3, there was no patient with re-intubation after weaning ventilation between both groups.

	PV group (n=13)	AV group (n=41)	p value
Re-stenotomy	0(0.0%)	0(0.0%)	
Mediastinitis	1(7.7%)	1(2.4%)	0.392
Atrial fibrillation	2(15.4%)	9(22.0%)	0.616
Re-intubation	0(0.0%)	0(0.0%)	

Table 3: Postoperative complication.

In Table 4, the intubation time was significantly shorter in the AV group than the PV group (PV group:AV group=17.6 ± 1.7:16.3 ± 1.4

hours, p=0.026). Though there was no significant difference in hospital stay between both groups (PV group:AV group=21.9 ± 9.9:20.2 ± 5.6 days, p=0.446), ICU stay was significantly shorter in the AV group than the PV group (PV group:AV group=5.2 ± 1.6:4.4 ± 1.0 days, p=0.040).

	PV group (n=13)	AV group (n=41)	p value
Intubation time (hour)	17.6 ± 1.7	16.3 ± 1.4	0.026
ICU stay (day)	5.2 ± 1.6	4.4 ± 1.0	0.04
Hospital stay (day)	21.9 ± 9.9	20.2 ± 5.6	0.446
Hospital death	0(0%)	0(0%)	
ICU: Intensive Care Unit			

Table 4: Clinical outcome.

Discussion

The present study showed that there was no patient with re-intubation after weaning ventilation in both groups. The intubation time was significantly shorter in the AV group than the PV group. Moreover, ICU stay was significantly reduced in the AV group compared with the PV group. We showed that INTELLiVENT-ASV mode was safe and effective in patients undergoing OPCAB in this study.

In INTELLiVENT-ASV, TVs below 10 ml/kg predicted body weight was provided automatically. Oxygenation parameters ($EtCO_2$, SpO_2) were also automatically managed, allowing automated weaning of FiO_2 and avoiding hypoxia with the automated system. So, the number of manual interventions reduced compared with protocolized ventilation managed respiratory therapists, anesthesiologists, and critical care physicians [2-4].

In INTELLiVENT-ASV, one of the effects presented by past studies is providing protective mechanical ventilation. In INTELLiVENT-ASV, providing protective ventilation can be explained by the automated continuous monitoring of the patient respiratory status with more frequent automated adjustments of ventilator setting compared with conventional modes [8]. Fot et al. demonstrated automated mode reduced the number and duration of deviations from safety ventilation zone [5]. Lellocuche et al. showed fully automated system can be safely used in patients undergone on-pump cardiac surgery by providing protective mechanical ventilation [3]. Another one of the effects of INTELLiVENT-ASV mode is avoiding lung trauma. The recent studies showed that the duration of unacceptable ventilation was also significantly longer in conventional ventilation than INTELLiVENT-ASV [3,9]. Additionally, the past studies presented excessive oxygen supply led to the associated atelectasis and lung trauma [10-12]. Several studies demonstrated that INTELLiVENT-ASV mode decreased FiO_2 without a significantly reduced PaO_2 compared with other modes included manually adjusted modes [5,8]. In this present study, we didn't measure the incidence and duration of unacceptable respiratory support, and the load on medical stuff. However, we showed fully automated ventilation with a quick-wean option reduced postoperative intubation time and ICU stay. These results might be led by appropriate ventilation of INTELLiVENT-ASV mode.

Several past studies presented that the use of protective ventilation during the perioperative period can decrease the number of complications after surgery in high-risk patients [13,14]. Celli et al. reported that the average length of intubation was significantly shorter in the ASV group than in the SIMV with pressure support group after orthotopic liver transplantation [15]. There are some studies reported on the efficiency and safety of ASV mode for the patients undergone cardiac surgery 5[16-22]. Sulzer et al. presented that the duration of tracheal intubation was shorter in group ASV than in group control after on-pump CABG [16]. Gruber et al. showed that the median duration of intubation was significantly shorter in the ASV group than in the pressure-regulated volume-controlled ventilation group after on-pump CABG [17]. ASV was reported to reduce ventilation time in patients who have undergone on-pump cardiac valvular surgery compared with controls [19]. Additionally, the duration of mechanical ventilation after OPCAB was significantly shorter in the automated ventilation group in our study (Table 4) for the first time. Though the past study reported that the duration of postoperative ventilation did not differ between automated weaning and protocolized weaning group after OPCAB 5), one of the causes was thought to the limited number of observations. ASV could reduce ventilation time after OPCAB.

In the recent meta-analysis, the automated weaning mode can decrease the duration of mechanical ventilation in the medical patients, but not surgical ICU [23]. Only a few studies show the automated modes influenced the length of ICU stay in therapeutic patients [24]. Petter et al. presented that there was no significant difference in the length of ICU after cardiac surgery [20]. In this present study, we showed that ICU stay was significantly shorter in the AV group than the PV group though there was no significant difference in hospital stay between both groups. This difference might be associated with different comparison groups, different modes of different ventilators, and different weaning protocols. Because we standardized all characteristics (patients, operation, the automated mode, the protocol weaning etc.), the present study could show that the reduction of ICU stay length. Though the reason for the short ICU stay is unclear, the several effects of ASV might get involved. The decease of postoperative lung complications would reduce the treatment length and the short ventilation time could lead to the fast start of cardiac rehabilitation.

This present study has several limitations. Firstly, our study was a retrospective design. Secondly, the present study was a single-center experience and was limited by the relatively small number of patients included. And, the groups compared were performed in different periods. Therefore, further prospective studies with a large group are expected.

Conclusion

Fully automated ventilation with a quick-wean option after OPCAB reduced postoperative intubation time and ICU stay. Fully automated ventilation with a quick-wean option may facilitate respiratory management after OPCAB.

Disclosure Statement

There is no conflict of interest for this article.

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