Original Article

Comparison of two modes of ventilation after fast-track cardiac surgery: Adaptive support ventilation versus synchronized intermittent mandatory ventilation

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ABSTRACT

Objective: There is substantial debate regarding the appropriate protocol for ventilatory management in fast-track cardiac anesthesia (FTCA). This study was carried out to assess and compare the risks and benefits of respiratory weaning based on adaptive support ventilation (ASV) and synchronized intermittent mandatory ventilation (SIMV) after uncomplicated cardiac surgery.

Methodology: In a randomized clinical trial, after receiving approval of the Department Research Committee and informed consent from study subjects, 100 patients undergoing elective coronary artery bypass graft (CABG) surgery with cardiopulmonary bypass (CPB) were enrolled during a 4-month period at a university-based hospital. After surgery and admission to the intensive care unit (ICU), patients were randomized to ASV and SIMV groups. Arterial blood gas (ABG) and hemodynamic variables, respiratory and ventilator characteristics including lung compliance, rapid shallow breathing index (RSBI), tidal volume (TV), respiratory rate (RR), peak inspiratory pressure (P peak), mean airway pressure (p mean), Pao2/FIo2, duration of mechanical ventilation and tracheal intubation, and length of ICU stay were recorded and compared between the two groups. The data were analyzed in 82 patients after considering the exclusion criteria.

Results: There were no differences between ASV and SIMV groups in demographics and preoperative characteristics. The duration of tracheal intubation and the length of ICU stay were similar in both groups. There were no statistically and clinically relevant differences between the two groups in ABG, hemodynamic changes, and respiratory and ventilator characteristics during ICU stay.

Conclusion: Although ASV may facilitate postoperative respiratory management in FTCA, both ASV and SIMV provide similarly safe and practicable respiratory weaning in the cardiac ICU. The evaluation of potential advantages in patient outcomes and resource utilization of respiratory weaning based on ASV deserves further study.

KEY WORDS: Fast track cardiac anesthesia, Mechanical ventilation, Adaptive support ventilation.

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INTRODUCTION

Cardiac surgery has undergone great advancements over the last two decades. In fast-track cardiac anesthesia (FTCA) during open heart surgery, patients are usually extubated within 3–8 hours of admission to the intensive care unit (ICU).[1] This strategy has been reported to result in reductions

in the length of ICU stay, duration of hospitalization, and costs with no adverse effects on mortality and morbidity.[2] Use of FTCA requires selection of special protocols and drugs during the perioperative period including ventilation management after surgery.[3,4] Ventilation modes such as synchronized intermittent mandatory ventilation (SIMV) are usually used in cardiac ICUs for postoperative mechanical ventilation. However, there are newer modes of ventilation, such as adaptive support ventilation (ASV), in which automatic control of respiratory parameters allows smooth and reliable respiratory weaning.[5] ASV is a closed-loop pressure-controlled ventilation mode in which the ventilator determines the respiratory rate (RR) and tidal volume (VT) with the least breathing effort required. When the patient begins an inspiratory effort, the ventilator switches to pressure support (PS) ventilation. The level of support is constantly adjusted to the patient's respiratory activity to attain the adjusted minute ventilation with favorable breathing pattern without interference of a physician or nurse.

It has been hypothesized that adopting a protocol of respiratory weaning based on ASV can reduce the duration of tracheal intubation and resource utilization when FTCA is used.[5] However, in one study of non-fast-track coronary artery bypass graft (CABG) patients, time until tracheal extubation with ASV was similar to that with pressure-controlled/pressure-support ventilation.[6] Meanwhile, the small number of studies to date does not allow for an informed selection of the appropriate respiratory weaning protocol after FTCA. In addition, fast-tracking respiratory weaning with ASV accompanied by intermediate-acting neuromuscular blocking (NMB) drugs has received little attention.[7] This study was conducted to compare the hemodynamic, respiratory, and ventilator characteristics in weaning of patients with ASV or SIMV after using cisatracurium as a muscle relaxant. Meanwhile, we evaluated the intubation time and ICU stay in these two groups.

METHODOLOGY

After approval of the Anesthesiology and Critical Care Research Center of Isfahan University of Medical Sciences, this clinical trial (Research number 390229) was conducted between August and November 2011 in Martyr Chamran Hospital in Isfahan, Iran. The population studied included patients undergoing elective CABG with cardiopulmonary bypass (CPB). The inclusion criteria were age 18–75 years, body mass index (BMI) <30, forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) > 70%, FEV_1/FVC>70%, cardiac ejection fraction (EF) >40%, and absence of conditions such as valvular heart diseases, chronic obstructive pulmonary disease (COPD), asthma, acute or chronic kidney diseases (Creatinine>2 mg/dl), seizure disorders, and stroke. The exclusion criteria were the need for mechanical ventilation for more than 24 hours due to non-respiratory reasons, reoperation due to hemorrhage after surgery and severe postoperative hemorrhage (chest tube drainage> 500 ml/h, >350 ml/h during 2 h, or > 1,000 ml in total),intra-aortic balloon pump during or after surgery, high dose inotropic drugs, or concurrent valvular surgery, and the presence of myocardial ischemia (sustained ST depression for more than 30 minutes), resistant hypoxia (Pao_2/FIo_2<200), or postoperative neurological deficits including cerebrovascular accident (CVA) symptoms or unconsciousness after surgery.

After obtaining informed consent, hundred eligible patients were enrolled in the study according to the convenience sampling method and inclusion criteria. The patients were premedicated half an hour before the operation by intramuscular injection of morphine (0.1mg/kg) and promethazine (0.4 mg/kg). Induction of general anesthesia was performed according to our standard institutional protocol by administration of intravenous (IV) fentanyl(10µg/kg), etomidate (0.2mg/kg), cisatracurium (0.15 mg/kg), and lidocaine(1.5mg/kg). Anesthesia was maintained by administration of intravenous morphine (0.1mg/kg) and inhalation of 100% oxygen with isoflurane (1–1.5 minimum alveolar concentration (MAC). During the CPB period, isoflurane was temporarily discontinued and propofol infusion (100–150 µg/kg/min) was administered.

In addition, moderate hypothermia (28–32°C), a membrane oxygenator, and apulsatile blood flow were used and a hematocritconcentration above 20% and a mean perfusion pressure of 50–90 mmHg were maintained. Surgical procedure consisted of median sternotomy and left internal mammary artery (LIMA) and saphenous vein grafts. Patients were rewarmed to a nasopharyngeal temperature of 37°C before weaning off CPB. During surgery, arterial blood gas (ABG) analysis was taken repeatedly, and at the end of surgery, patients were transferred to cardiac ICU. Muscle relaxation was not reversed in either group. Surgeons and anesthesiologists in the operating room were blinded to the study groups.

On arrival to ICU, the patients were randomized to ASV and SIMV groups according to computer-based random allocation. All patients were ventilated by a Rafael XTC (Hamilton Medical, Switzerland) ventilator. Patient management, including setting the ventilator mode (ASV or SIMV) and parameters, was performed by an attending anesthesiologist according to a standardized protocol, and data were collected by a resident. Other strategies utilized included fluid resuscitation with normal saline and starch solutions, blood transfusion to maintain hemoglobin concentration (>9.0 g/dl), and continuous infusion of dopamine, epinephrine, and nitroglycerin to maintain mean arterial pressure at 70–90 mmHg. Sedation and analgesics were given by a nurse according to our institutional protocol. Morphine was given in a bolus of 2 or 3 mg intravenously when the patient complained or exhibited autonomic signs (e.g., sweating, tachycardia, and hypertension). Midazolam was given for sedation in boluses of 1 or 2 mg to a Ramsey score of sedation greater than 3 (i.e., responsive to commands).[8] The total amounts of morphine and midazolam given were recorded. Pethidine (25 mg IV) was administered to treat shivering.

Patients in the ASV group were supported by mechanical ventilation with ASV mode and ventilator parameters including100% of the theoretical value based on predicted body weight, oxygen inspiratory fraction (FIo_2) of 60%, positive end expiratory pressure (PEEP) of 3-5cm H_2O, and maximum airway pressure of 35 cm H_2O. Flow trigger sensitivity was set at 3 L/s. According to ABG analysis 30 minutes after connection to the ventilator or 30 minutes after any modification of the ventilator settings, if $Paco_2$ was <35 mmHg or > 45 mmHg, minute ventilation was decreased or increased, respectively, by 10%. FIo_2 was adjusted to maintain arterial oxygen saturation (Sao_2) of >95%. After commencement of spontaneous breathing, ASV setting was reduced by 50% of minute ventilation. When spontaneous breathing achieved an acceptable tidal volume (VT > 5 ml/kg), ventilator mode was changed to continuous positive airway pressure (CPAP) and apnea security at 20s. After 30 minutes, if the extubation criteria were met, tracheal extubation was performed.

Extubation was prescribed according to the following criteria: patient was responsive and cooperative and had an appropriate ABG (PH >7.30, $Paco_2$ ≤ 50 mm Hg, Sao_2 of>95% on a FIo_2 of <40%), a spontaneous respiratory rate of 10–20 breaths/ min, chest tube drainage ≤ 100 ml/h, stable cardiac rhythm, and a steady hemodynamic state (systolic blood pressure > 90mmHg). Sedation with IV midazolam was permitted until 30 minutes before extubation.

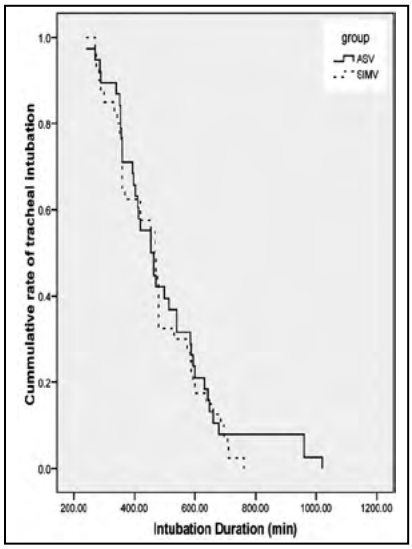

Fig.1: Duration of tracheal intubation expressed as a Kaplan–Meier curve in the adaptive support ventilation (ASV) and synchronized intermittent mandatory ventilation (SIMV) groups.

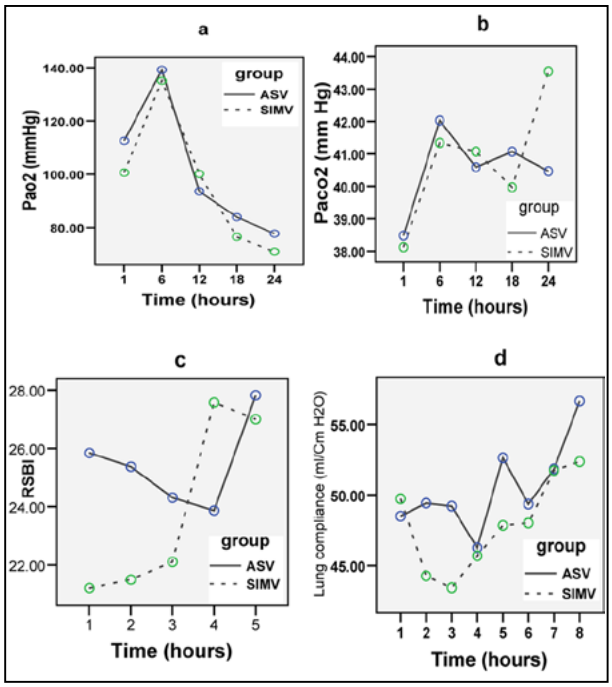

Fig.2: Trend of changes in a) Pao_2, b) $Paco_2$, c) RSBI (Rapid shallow breathing index), and d) lung compliance during ICU stay in the two study groups. In all panels (except for RSBI in the first three hours), repeated measures analyses showed no significant difference between ASV and SIMV groups.

Patients in the SIMV group were mechanically ventilated with a set tidal volume VT of 10ml/kg, $FIo_2$of 60%, respiratory rate (RR) of 10 breath/min, pressure support (PS) of 10 cm H_2O, and a PEEP of 3–5cm H_2O. After commencement of spontaneous breathing with an acceptable VT the RR in the ventilator was reduced by two breaths/minues every 30 minutes until it reached two breaths/min. Then, ventilation mode was converted to CPAP and the trachea was extubated based on the criteria defined for the ASV group.

In addition to ABG analysis, further respiratory characteristics including lung compliance, $Paco_2$, rapid shallow breathing index (RSBI),V_T, RR, peak inspiratory pressure (P peak), alveolar-arterial (A-a) difference of arterial partial oxygen pressure, ratio of arterial partial oxygen pressure to inspiratory oxygen concentration ($Pao_2/F_Io_{2)}$, lung compliance, and the duration of mechanical ventilation and tracheal intubation were recorded.

To calculate sample size, it was estimated that with 40 patients per group, a reduction of 20% of time until extubation could be found between the two groups with a statistical power of 80% and a cut off point for significance of 0.05. Data were statistically analyzed by SPSS for Windows (version 16.0, SPSS Inc., Chicago, IL) and appropriate statistical tests including Q square, Student's *t*-test, and variance analysis by repeated observations.

RESULTS

In this study, one hundred patients undergoing CABG surgery with CPB were enrolled. After considering the exclusion criteria, data from 81 patients (41 in the ASV group and 40 in the SIMV group) were finally analyzed. Patient characteristics in the ASV group and the SIMV group are presented in Table-I. The two groups were not different with respect to demographic and baseline perioperative characteristics. Duration of surgery, CPB, and aortic cross-clamping were similar (p>0.05) in the ASV and SIMV groups (Table-I).

The total doses of midazolam and morphine (mg/kg body weight) used during the ICU stay were not different between groups. The average duration of tracheal intubation was comparable in the ASV and SIMV groups (498.7 ± 185.3 vs. 469.3 ± 141 min, respectively). In addition, the duration of ICU stay was similar in both groups (27 ± 3.4vs. 26.2 ± 2.4h, respectively) (p> 0.05) (Table-I).

Hemodynamic and ventilatory characteristics are summarized in Table-II. Performing the variance analysis test with repeated observations of the data showed that systolic, diastolic, and mean blood pressure changes from baseline to 6 hours in the ICU were not significantly different between the two groups (p> 0.05). Among ventilator characteristics, V_T, RR, P peak, (A-a) O_2 difference, lung compliance, and Pao_2/F_Io_2 showed similar trends of changes as determined by ANOVA test with repeated observations of the data(p> 0.05).V_T, RR, P peak, and lungs were checked every hour until the ventilator was totally weaned. Only RSBI in the first three hours was significantly different between the two groups (P< 0.01) (Fig.2).

Performing the variance analysis test with repeated observations on the ABG parameters also showed that all data were comparable between groups (p> 0.05) (Table-II and Fig.2).

Table-I: Perioperative clinical characteristics in the two study groups.

Variables	*ASV*	*SIMV*	*P value**
Number of patients	41	40	-
Age (years)	57.9±8.9†	59.8±12.7	0.4
Sex(M/F)	27/14	24/17	0.5**
BMI (kg/m^2)	26±2.9	26.3±4.4	0.7
Preoperative LVEF (%)	51.4 ± 9	49.6± 11	0.4
Operation duration (min)	267±50	257±56	0.4
CPB duration (min)	85±22.2	92.7±28.3	0.2
Cross-clamping duration (min)	51.8±16.4	58.6±21.6	0.14
Midazolam total dose (mg/kg body weight)	0.08±0.06	0.11 ± 0.09	0.08
Morphine total dose (mg/kg body weight)	0.13 ± 0.09	0.11 ± 0.08	0.14
Intubation duration (min)	498.7 ±185.3	469.3 ±141	0.8
Length of ICU stay (h)	27 ± 3.4	26.2 ± 2.4	0.4

†mean ± standard deviation,* t test unless otherwise specified, ** Q square
ASV: Adaptive support ventilation, SIMV: Synchronized intermittent mandatory ventilation,
CPB: Cardiopulmonary bypass, ICU: Intensive care unit

Table-II: Hemodynamic and ventilatory characteristics in the two study groups during ICU stay.

	ASV	*SIMV*	*P value**
Systolic blood pressure (mm Hg)	124 ± 18.8	122 ± 17†	0.7
Diastolic blood pressure (mm Hg)	74 ± 14.2	72 ± 13	0.7
Mean arterial pressure (mm Hg)	84 ± 13.4	82 ± 13.2	0.7
Heart rate	96±18.3	98±16.2	0.2
VT (ml)	598±153	561±114	0.9
RR	12.3±1.68	13.5±4.3	0.4
P Peak (Cm H_2O)	20.8±4.8	20.5±5.6	0.8
(A-a) O_2 Difference (mm Hg)	54.2±38.5	58.5±41.3	0.6
RSBI	26.5±10.3	23±11.2	0.2
Lung compliance (ml/cm H_2O)	48.5±10.9	51.2±17.5	0.4
PH	7.37±0.04	7.36±0.03	0.2
$Paco_2$(mm Hg)	40.9±4.4	40.8±5.5	0.8
Pao_2(mm Hg)	100±29	95±28	0.4
Hco_3 (meq/l)	23.2±2.3	22.9±3.2	0.6
Pao_2/FIo_2	201±48	198±62	0.9

† mean ± standard deviation,* t test or repeated measures analyses.
ASV: Adaptive support ventilation, SIMV: Synchronized intermittent mandatory ventilation,
VT: Tidal volume, RR: Respiratory rate, P Peak: Peak airway pressure, (A-a) O2 Difference: Alveolar-arterial difference of O_2 partial pressure, RSBI: Rapid shallow breathing index, Pao_2/FIO_2: ratio of arterial partial oxygen pressure to inspiratory oxygen concentration.

DISCUSSION

In this randomized clinical trial focused on selecting an appropriate ventilation mode for respiratory weaning after FTCA, ASV was compared with SIMV. The muscle relaxant cisatracurium was administered to facilitate tracheal intubation. The major findings were that duration of tracheal intubation and ICU stay were similar in the ASV and SIMV groups. Other respiratory characteristics and hemodynamic variables were also comparable between groups.

Our review of the available literature determined that few studies have assessed the efficiency of ASV compared to other ventilator modes, such as SIMV, to evaluate its effectiveness in decreasing the duration of tracheal extubation after FTCA.[9,10] Automated modes such as ASV require fewer user interactions and give fewer alarms[11], and thus can be beneficial for healthcare providers. It has also been reported that ASV results in shorter ventilation times, reduces costs, and prevents human errors.[5,12] Cisatracuriumas an intermediate-acting NMB drug has been suggested as one of the best choices during cardiac surgery and is preferable whenever hemodynamic stability and drug metabolism is important.[7] According to our results, after using cisatracurium and without reversal of its NMB action, patients can be extubated in a reasonable period regardless of the mode of ventilation. It has been claimed, however, that prolonged intensive analgesia during ICU care may reduce postoperative myocardial ischemia.[13]

Based on this concept, in our institution, morphine and midazolam are used at lower threshold levels, which can lead to some delays in tracheal extubation.[14] This is in contrast to the results of one study performed by Sulzer et al on cardiothoracic surgery patients. In their study, propofol was given for sedation in boluses of 20 or 30 mg and tracheal intubation time with ASV was significantly shorter than that in the control group.[5] However, the patients in our study received midazolam and morphine, which have longer durations of action than propofol. Another important difference between our study and other previous studies, such as the Sulzer study, was that we did not change the ventilator mode to CPAP until at least 30 minutes after spontaneous breathing produced an acceptable tidal volume and then waited at least 30 minutes, to meet the extubation criteria for tracheal extubation. This difference may explain the longer duration of tracheal intubation and absence of such a difference in this duration between the two groups in our study.[15,16]

In a study by Danglemans et al., non-fast-track CABG patient lungs were ventilated with ASV or pressure-controlled/pressure support ventilation (control). In that study, time until tracheal extubation was similar in the two groups (16.4 vs. 16.3 hours, respectively). The authors stated that Pco_2

levels were lower in the ASV group than in control patients, which resulted in ASV patients reverting to assisted ventilation less often during respiratory weaning.[6] However, in our study, Pco_2 levels were similar in the two groups (Fig.2).

The longer duration of intubation in our trial, as compared with other FTCA studies, may have been due to other reasons. One possible factor is the fact that patients in our department are left intubated overnight and are not discharged from ICU earlier than the day after operation. Thus, there is no need for early tracheal extubation in our institution. In addition, ICU discharge in our institution is highly dependent on external factors, such as the availability of beds in the ward and surgeons' orders; therefore, the generalizability of our results about the length of ICU stays is limited.

Hemodynamic variables were also evaluated during respiratory weaning of patients in the ICU. We did not find any similar studies that considered these patient characteristics when comparing ASV with other ventilatory modes. Stable and safe hemodynamic variables including blood pressure and heart rate confirm that ASV is an appropriate weaning strategy in ICU patients with the FTCA protocol.

In addition to the lack of generalizability mentioned above, our study had a few other limitations. First, because most data collection was performed from ventilator monitors, this trial could not be practically performed in a completely blinded fashion. Second, in most cases, the decision to continue with tracheal extubation was made by the anesthesia team who were not continuously at the bedside, rather than ICU nurses. We suggest further studies in other centers with different postoperative protocols to evaluate the influence of ASV on duration of mechanical ventilation and intubation.

In conclusion, although ASV is a reliable and simple method, the duration of MV and intubation with ASV is equivalent to that with non-automated weaning when FTCA is used. Because of the beneficial effects of ASV for respiratory weaning of patients with FTCA, additional studies with more structured protocols and proper use of neuromuscular monitoring devices in the ICU should be performed to evaluate weaning strategies with ASV.

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