Original Article

The Influence of the Mechanical Ventilation Weaning Protocol in Patients With Acute Kidney Injury Undergoing Adult Cardiac Surgery

Mohsen Ziyaeifard[1], MD; Hojatallah Assadzade[1], MS; Gholamreza Makhmalbaf[2], MD; Ziya Totonchi[1], MD; Seyedeh Zahra Faritus[1*], MD

ABSTRACT

Background: Mechanical ventilation is an important risk factor for acute kidney injury (AKI) in cardiac surgery patients. The Weaning protocol can speed weaning after open-heart surgery and might reduce the AKI risk in these patients. We explore the influence of the weaning protocol on the intubation time in cardiac surgery patients who developed AKI.

Methods: In a randomized clinical trial, 100 patients with AKI after open-heart surgery were enrolled. After surgery, the patients were randomized to the weaning protocol group (the intervention group) and the conventional weaning group (the control group). Arterial blood gas, hemodynamic variables, the serum blood urea nitrogen level, the creatinine level, and the intubation time were recorded and compared between the 2 groups.

Results: The weaning protocol group displayed a statistically significant shorter intubation time than the conventional weaning group (8.89±1.74 h vs 9.93±1.56 h; P=0.002). The postoperative serum urea level (r=0.240, P<0.016) and creatinine level (r=0.245, P<0.014) were positively correlated with the intubation time and the weaning protocol compared with conventional weaning. The weaning protocol decreased the urea and creatinine levels in cardiac surgery patients (P<0.04).

Conclusions: The use of the weaning protocol in cardiac surgery patients with AKI conferred shorter intubation times and lower blood urea nitrogen and creatinine levels than the use of conventional weaning. ***(Iranian Heart Journal 2021; 22(4): 6-14)***

KEYWORDS: Randomized controlled trial, Mechanical ventilation, Weaning protocol, Acute kidney injury

[1] Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, IR Iran.
[2] Faculty of medicine, Birjand University of Medical Sciences, IR Iran.

*** Corresponding Author:** Seyedeh Zahra Faritus, MD; Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, IR Iran.
Email: s.faritous@yahoo.com **Tel:** +982123922165

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Heart surgery is one of the most common surgeries in the world. In developed countries, 860 per 1 million people have undergone heart surgery.[1] Open-heart surgery is a frequently performed cardiac surgery to treat patients with heart valve failure and coronary artery complications.[2,3] Coronary artery bypass grafting surgery (CABG) is the most commonly performed open-heart surgery in adults.[4]

Acute kidney injury (AKI) after open-heart surgery is an important possible complication and is often associated with increased mortality and morbidity.[5] Despite many attempts to reduce the development of AKI,[6] the incidence of AKI after open-cardiac surgery has been reported to range from 5% to 30%.[7] The development of AKI after cardiopulmonary bypass is multifactorial,[8] and it involves renal ischemia, reperfusion injury, oxidative stress, maladaptive inflammatory responses, and microemboli.[9] The time of weaning from mechanical ventilation is usually regarded as a crucial risk factor for AKI.[10] Lombardi et al[11] reported that out of 2783 patients who were mechanically ventilated, 803 (28.8%) had AKI according to serum creatinine concentration in the first 48 hours. Heringlake et al[12] showed that the duration of mechanical ventilation was an important risk factor for AKI in cardiac surgery patients. Positive pressure during mechanical ventilation leads to a decrease in the glomerular filtration rate and the renal blood flow through humoral and neurohumoral pathways.[13] Nonetheless, premature weaning may be harmful to patients with mechanical ventilation, and it could render the patient at risk for reintubation and airway trauma.[14,15] Therefore, weaning patients from mechanical ventilation safely is of great importance.[16] There is increasing evidence that the use of weaning protocols may reduce the duration of mechanical ventilation, the length of hospital stay, and the weaning time.[17,18] Determining the appropriate weaning time is often based on judgment and experience, and weaning protocols may be useful, especially in situations where the decision to discontinue mechanical ventilation is difficult.[19] Considering the many benefits of weaning protocols, the aim of the present study was to determine the effects of a weaning protocol on the duration of mechanical ventilation in cardiac surgery patients who developed AKI.

METHODS

In November 2013, Rajaie Cardiovascular Medical and Research center adopted a mechanical ventilation weaning protocol (WM 42–05). Consent was obtained from 124 patients, of whom 100 were enrolled in the study. The study is a randomized controlled trial, where 100 patients with AKI after open-heart surgery and upon admission to the intensive care unit (ICU) were allocated to either the weaning protocol group (the intervention group) or the conventional weaning group (the control group). Randomization was conducted using the simple randomization method. The CONSORT diagram for the trial is shown in Figure 1. The study protocol was approved by the Ethics Committee of Rajaie Cardiovascular Medical and Research Center and was registered in the Iranian Registry of Clinical Trials (IRCT 20190221042783N1). Written informed consent was obtained from all the patients. All patients who were scheduled for elective open-heart surgery between May 2017 and March 2017 were screened for eligibility. The inclusion criteria were composed of age 18–75 years, an increase in serum creatinine ≥ 0.3 mg/dL or urine output <0.5 mL/kg/h for ≥ 4 hours, and no previous open-heart

surgery. Patients who returned to the operating room were excluded.
After surgery, the patients were transferred to the ICU with the help of an anesthesia technician and handed over to the responsible nurse. All the patients were ventilated using synchronized intermittent mandatory ventilation (SIMV) with a tidal volume of 10 mL/kg of body weight, a respiratory rate of 10–12/min, and 100% oxygen (Model 683; Harvard Apparatus Co, South Natik, MA).
Standard postoperative care was performed by the attending team. The patients were assessed for extubation when they were able to manage a 30-minute spontaneous breathing trial and were hemodynamically stable. The primary endpoint of the study was the duration of intubation in the ICU. The data were expressed as the mean ± the standard deviation. Comparison between the 2 groups was made using the Student *t* test. Categorical data were analyzed using the χ^2 test. The serum blood urea nitrogen (BUN) level and the creatinine level in the 2 groups at various time points after surgery were compared using repeated-measures ANOVA. A *P*-value <0.05 was considered significant.

RESULTS

The number of patients screened, randomized, and analyzed is presented in the CONSORT diagram (Fig. 1). Consent was obtained from 124 patients, of whom 100 were enrolled in the study. Fifty patients were, therefore, allocated to the weaning protocol group (the intervention group) and 50 patients received conventional weaning (the control group). The demographic information and baseline characteristics of the patients are shown in Table 1. There were no significant differences between the 2 groups in terms of demographic information and baseline characteristics. Men and women, respectively, comprised 57.0% and 43.0% of the study population. The duration of surgery, the aortic clamping time, and the cardiopulmonary bypass time were similar (*P*>0.05) in the intervention and control groups.

Table 1. Baseline characteristics of the randomized groups

Variables		Intervention Group	Control Group	*P*-value
Age, y mean± SD		61±7	62±6	0.522*
BMI (kg/m^2), mean± SD		25±4	26±4	0.266*
Sex, n (%)	Male	29(58)	28(56)	0.840**
	Female	21(42)	22(44)	
Hypertension, n (%)		35(70)	38(76)	0.499**
Pulmonary disease, n (%)		36(72)	34(68)	0.633**
Kidney disease, n (%)		42(84)	34(68)	0.061**
Thyroid disease, n (%)		31(62)	32(64)	0.836**
Diabetes mellitus, n (%)		27(54)	32(64)	0.309**
Smoking, n (%)		11(22)	10(20)	0.806**
Operation time, h, mean± SD		5.1±0.8	4.9±.08	0.24*
Aortic clamping time, min, mean± SD		66.5±14	64±14	0.4*
CBP, min, mean± SD		121±19	115±18	0.15*

CBP, Cardiopulmonary bypass time

*: the *t* test
**: the χ^2 test

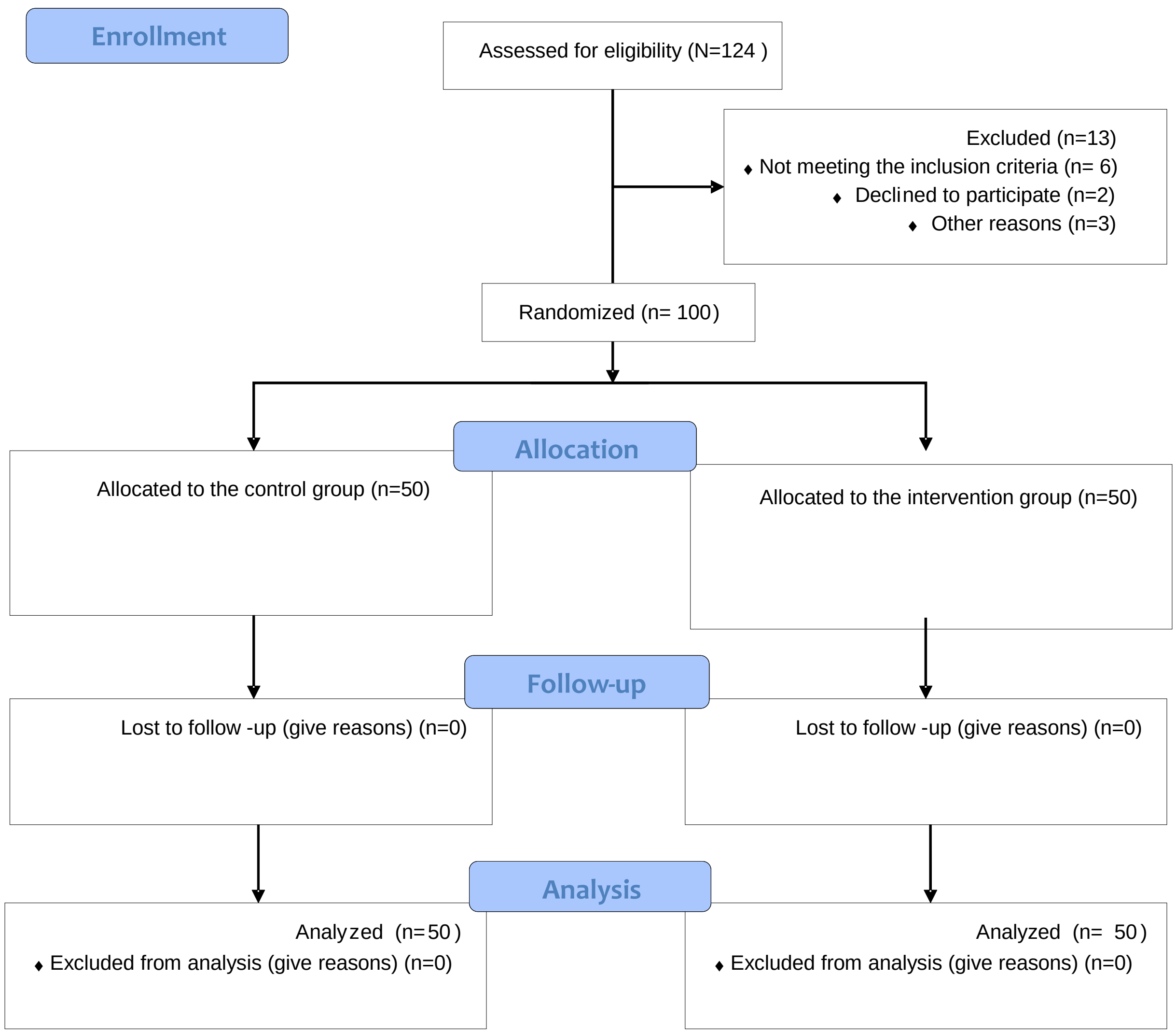

Figure 1. The image illustrates the CONSORT diagram.

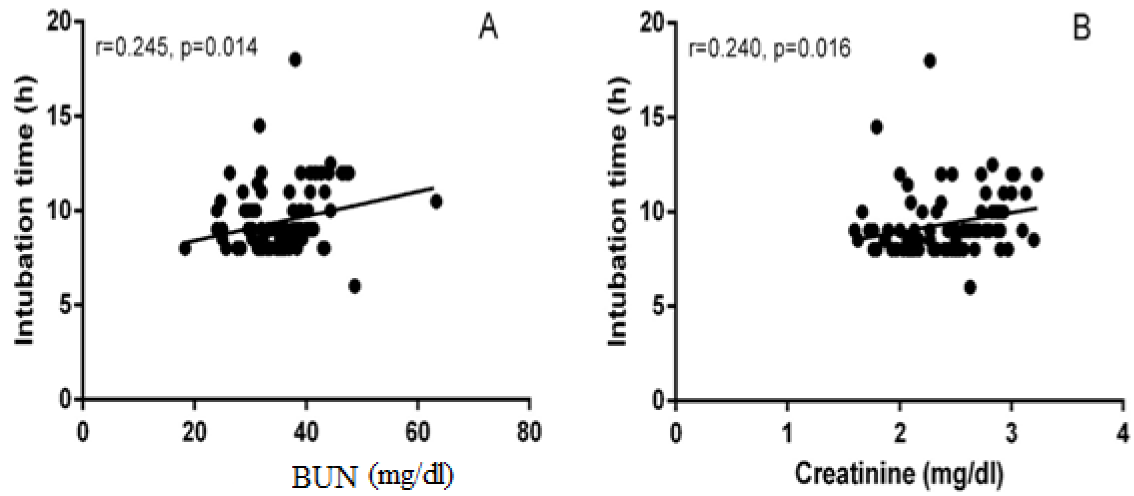

Figure 2. The images depict the relationships between the serum blood urea nitrogen (BUN) level and the intubation time and between the creatinine level and the intubation time.

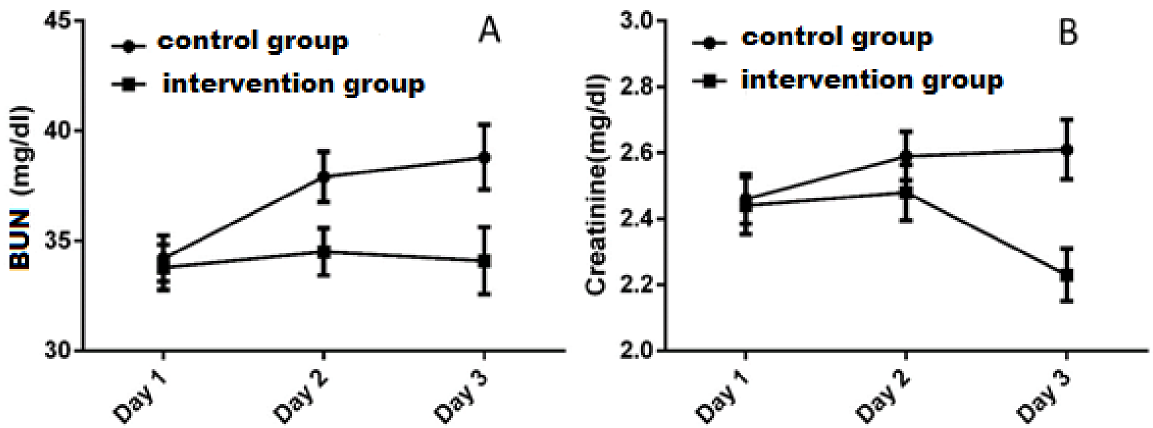

Figure 3. The images illustrate the serum blood urea nitrogen (BUN) level and the creatinine level in the intervention group and the control group at baseline and then at 48 and 72 hours after surgery.
Values are presented as mean±SD.

The Pearson correlation analysis was performed to assess the correlation between the serum BUN level and the intubation time and between the creatinine level and the intubation time. The serum BUN level was dependent on the intubation time (r=0.240, P<0.016), and there was a positive correlation between the serum creatinine level and the intubation time (r=0.245, P<0.014).

In the postoperative period, the decline in the levels of BUN and creatinine was significantly more pronounced in the weaning intervention group than in the control group (P<0.04) (Fig. 3).

The mean intubation time was 8.89±1.74 hours for the intervention group and 9.93±1.56 hours for the control group. The mean intubation time was significantly shorter in the intervention group than in the control group (*P*=0.002) (Fig. 4).

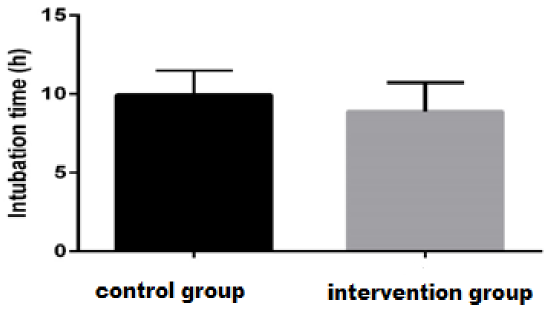

Figure 4. The image shows the intubation time in the intervention and control groups following surgery.

There were no differences between the 2 groups concerning arterial blood gas (ABG) and hemodynamic variables (Table 2).

DISCUSSION

The main findings of this study are as follows:

- In the intervention group, compared with the control group, the intubation time decreased.
- The Pearson correlation analysis revealed that the intubation time correlated positively with the levels of creatinine and BUN.
- There were no differences in ABG and hemodynamic variables between the 2 groups.
- There were lower levels of BUN and creatinine in the intervention group than in the control group.

AKI is an important clinical problem after open cardiac surgery and is associated with mortality.[20] Recent studies have suggested several mechanisms for impaired renal function, including ischemia, reperfusion injury, inflammation, oxidative stress, anemia, atheroembolic events, hyperglycemia, and neurohumoral activation.[12,21,22] The duration of postoperative positive pressure ventilation is an additional parameter that predicts AKI in cardiac surgery patients. Heringlake et al[12] showed that the rate of AKI was 17% in patients extubated within 4 hours postoperatively compared with 62.3% in patients ventilated for more than 16 hours. Brito et al[23] performed a prospective study during a 3-year period on 186 patients who underwent CABG and observed that longer duration on mechanical ventilation was a risk factor of AKI. In the present study, the postoperative levels of serum BUN and creatinine were positively associated with the intubation time and patients with a longer intubation time also had elevated levels of BUN and creatinine. Therefore, reducing the time of mechanical ventilation could reduce or even prevent deleterious side effects such as kidney injury.

Table 2. Arterial blood gas and hemodynamic changes in the 2 study groups

Variables	Intervention Group (mean±SD)	Control Group (mean±SD)	*P*-value
pH	7.40±.030	7.41±.024	0.108
pO2, mm Hg	90.45±6.60	89.33±4.74	0.32
pCO2, mm Hg	39.37±4.49	39.63±3.74	0.75
HCO3, meQ/L	22.20±1.22	22.17±1.29	0.9
SATO2, %	94.89±0.52	94.91±0.46	0.88
BE	-3.38±0.86	-3.11±0.79	0.101
K, mEq/L	4.37±0.22	4.36±.0.22	0.86
Na, mEq/L	137.07±2.25	136.24±2.38	0.07
Respiratory rate, per minute	9.31±0.87	9.61±0.88	0.09
PEEP, cmH2O	4.23±0.80	3.97±0.66	0.08
Heart rate, beats per minute	88.96±7.48	88.98±12.57	0.62
Systolic blood pressure, mm Hg	123±12	122±10	0.73
Diastolic blood pressure, mm Hg	71.89±10	73.79±11	0.33

The results in the intervention group showed that the weaning protocol led to a lower weaning time and duration of mechanical ventilation as compared with the control group, which is in line with several studies.[24-26] In contrast, Krishnan et al[27] found no differences in the duration of mechanical ventilation, the ICU length of stay, or the ICU and hospital mortality between the intervention group and the usual care group. Zhu et al[28] randomized 68 subjects from a multidisciplinary ICU to an adaptive support ventilation group and a control group after cardiac valvular surgery. They found a reduction in the ventilation time in the adaptive support ventilation group (205 min vs 342 min; *P*=0.013). We demonstrated that adherence to an optimized postoperative protocol significantly shortened the intubation time. Thus, patients at risk of AKI after open-heart surgery might benefit from this approach. We applied a weaning protocol developed by a multidisciplinary team and succeeded in lessening the intubation time from a mean of 9.93 hours in the control group to 8.89 hours in the intervention group.

CONCLUSIONS

Because our study was a single-center experience, caution should be applied in the use of this protocol for a larger patient population. In summary, our study demonstrated that the weaning protocol shortened the intubation time in cardiac surgery patients who developed AKI. Additionally, the results of the present study suggested that longer mechanical ventilation duration might increase the risk of AKI in cardiac surgery patients. ABG and hemodynamic variables were not affected by the weaning methods within the groups.

Conflict of Interest

The authors declare no competing interests.

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