

Can integrative weaning index be a routine predictor for weaning success?

Ghada F. El-Baradei, Nagat S. El-Shmaa, Salwa A. Ganna¹

Abstract

Objective: To assess the effectiveness of integrative weaning index (IWI) as a predictor of weaning success. **Materials and Methods:** This is a prospective randomized controlled observer-blinded study and carried out on 120 patients of both sexes; patients who received mechanical ventilation for more than 24 h and met defined criteria for a weaning trial, underwent a 2-h spontaneous breathing trial with either IWI plus routine criteria of weaning (Group I $n = 60$) or routine criteria of weaning alone (control group) (Group C $n = 60$), in Group C the IWI was measured retrospective as it is not used in weaning decision. Those tolerated the trial would be immediately extubated. The primary outcome measure was the ability to maintain spontaneous, unassisted breathing for more than 48 h after extubation. Secondary outcome measures were the duration of mechanical ventilation, length of Intensive Care Unit (ICU) stay, and length of hospital stay. **Results:** The mean duration (hours) of mechanical ventilation and length of ICU stay (days) were significantly shorter in the Group I where the IWI was used (83.6 ± 34.3 vs. 97.49 ± 47.2 h, $P = 0.002$ and 5.5 ± 1.6 vs. 7.12 ± 2.3 days, $P = 0.03$, respectively). Weaning success rate was significantly higher in the Group I (53 vs. 34, $P = 0.0001$) while weaning failure rate was significantly lower in the Group I C (7 vs. 26, $P = 0.0001$). **Conclusion:** IWI is a strong predictor of both successful and failed weaning.

Keywords: Adult, integrative weaning index, ventilator weaning, weaning parameters, weaning protocol

Access this article online

Website: www.ijccm.org

DOI: 10.4103/0972-5229.171352

Quick Response Code:



Introduction

Invasive mechanical ventilation is life-saving for patients with acute respiratory failure, but it is also associated with multiples risks. Therefore, once the adequate recovery occurs, efforts focus on weaning the patient from the ventilator as rapid as possible. Using clinical judgment to identify the proper timing of weaning decision is not always succeeding. For the past three decades, use of one or more bedside weaning predictors is part of the standard care to decide if a patient is ready to breathe spontaneously as the first step to weaning.^[1] Specifically, it has been considered unsafe to discontinue mechanical ventilation if the vital

capacity or tidal volume (TV) is reduced, the negative inspiratory force is inadequate, or the respiratory rate (RR) is too rapid, or if a pattern of a fast and shallow breathing is present during a brief trial of spontaneous breathing. Although these weaning predictors have been extensively studied; their direct effects on outcome has never been studied.^[2] Unfortunately, few predictors associated with clinically significant changes in the probability of weaning success or failure. From 1991 to

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

From:

Departments of Anesthesia and Intensive Care Unit, Faculty of Medicine and Chest, Faculty of Medicine, Tanta University Hospital, Tanta, Egypt

Correspondence:

Dr. Nagat S. EL-Shmaa, Department of Anesthesia and Intensive Care Unit, Tanta University Hospital, Tanta, Egypt. E-mail: nagat_elshmaa@yahoo.com

For reprints contact: reprints@medknow.com

How to cite this article: El-Baradei GF, El-Shmaa NS, Ganna SA. Can integrative weaning index be a routine predictor for weaning success?. *Indian J Crit Care Med* 2015;19:703-7.

2009, respiratory shortening breathing index (RSBI) with a sensitivity of 95% was introduced as the best index and in 2009 Nemer *et al.*,^[3] report a new integrative weaning index (IWI) calculated as the product of static compliance (Cst), arterial oxygen saturation, and the f/TV (IWI = $Cst \times SaO_2 \times RR/TV$ should be >25). The significant physiologic weaning parameters included in IWI may make it a better predictor than traditional ones.^[4]

Materials and Methods

This is a prospective randomized controlled observer-blinded study carried out on 120 adult patients of both sexes during the period from January 2014 to April 2015 after approval by the Hospital Ethical Committee.

Inclusion criteria

Patients required mechanical ventilation for ≥ 24 h and considered ready for weaning.

Exclusion criteria

Age ≤ 18 years, inability to obtain informed consent, expected survival <48 h, intracranial hypertension, neuromuscular disease, pregnancy, hemodynamically unstable patients, or on high-dose vasopressor or inotropes.

Criteria of readiness for weaning included all the following: Reversal of the condition required ventilator support; oxygen saturation of >90% with a fraction of inspired oxygen (FiO_2) <50%, $PaO_2/FiO_2 \geq 200$, carbon dioxide tension in arterial blood ($PaCO_2$) <45 mmHg, PH ≥ 7.3 using (AVL-988), RR <30 br/min, TV >5 ml/kg, minute ventilation < 15 L/min and RR/TV <105 br/min/L with a positive end-expiratory pressure level <8 cm H₂O (Ventilation was performed with ["inspiration" LS Ventilator series e-Vent]), stable neurological status (awake and responsive), require bronchial toilet less than twice in the 8 h preceding the assessment, no need for vasoactive drugs; receiving only minimal or no sedation, serum electrolyte within normal, body temperature between 36°C and 38°C and hemoglobin >7 g/dl.

The following parameters were recorded before performing the spontaneous breathing trial (SBT). Demographic data, including age, diagnosis, admission Acute Physiology and Chronic Health Evaluation (APACHE) II score,^[5] duration of mechanical ventilation and date of Intensive Care Unit (ICU) admission to estimate length of ICU stay later on; hemodynamic data,

including heart rate and mean arterial blood pressure using (Nihon Kohden BSM-2301K), fluid balance in the 24 h preceding the start of the SBT.

After meeting inclusion criteria, informed consent was obtained from the patient nearest relative's decision maker. Patients were then randomly assigned, in a blinded fashion with the use of opaque sealed envelopes, to undergo a 2-h SBT depending on either IWI plus routine criteria of weaning (Group I $n = 60$) or routine criteria of weaning alone (Group C $n = 60$) in Group C the IWI was measured retrospective as it is not used in weaning decision. IWI = $Cst \times SaO_2 \times RR/TV$ should be >25.

During the 1st min on spontaneous mode, pressure support (PS) turned to zero and by doing arterial blood gas, the amounts of recorded SaO_2 was measured at fixed FiO_2 40% to avoid FiO_2 variation. The Cst of the respiratory system (rs) was measured after an inspiratory hold for 0.5–1 s and could be collected from the data on the screen. The amounts of TV expiratory and spontaneous breathing were recorded, and RSBI index was obtained by dividing RR by spontaneous TV (VT in liters) and IWI was calculated if >25 decision to start SBT in Group I while in Group C collected data only and IWI will be calculated retrospective.

2 h SBT started using PS ventilation (5 CmH₂O) ("inspiration" LS Ventilator series e-Vent). Evaluation of SBT and the decision of extubation were made by the physician in charge (who was completely blind to the study and index evaluated).

Tolerance of the trial was continuously evaluated. Features of poor tolerance included: RR >35 breaths/min for 5 min or longer, $SaO_2 < 90\%$, increase in heart rate >140 beats/min, an increase in systolic blood pressure >180 mmHg or decrease to <90 mmHg, and increased anxiety, diaphoresis or thoracoabdominal paradox. For patients not tolerating the breathing trial, full ventilatory support was reinstated, while patients who tolerated the trial underwent immediate extubation and received supplemental oxygen via a face mask.

Reintubation rate for failed extubation was defined as the need for reintubation within 48 h after extubation and was performed in the following conditions: Hypoxemia (oxygen saturation <90% for more than 5 min while receiving $FiO_2 > 0.5$), presence of respiratory acidosis (arterial pH <7.3 with $PaCO_2 > 50$ mmHg), inability to

protect the airway because of upper airway obstruction (stridor); and evidence of excessive respiratory work (RR \geq 35 breaths/min 5 min, diaphoresis or thoracoabdominal paradox). The reason for and time to reintubation (rounded off to the nearest hour) were noted. Decisions regarding reintubation were made by caregivers who were blinded to patient group.

The primary outcome measure was successful extubation, defined as the ability to maintain spontaneous, unassisted breathing for longer than 48 h after removal of the endotracheal tube. This definition includes both the number of patients tolerating the breathing trial and the number able to maintain spontaneous breathing after extubation. All patients were followed until hospital discharge or death. Secondary outcome measures were the duration of mechanical ventilation, the length of ICU stay, and length of hospital stay.

Statistical analysis

Sample size calculation was performed before patient recruitment. Based on the previous reports; a sample size of 120 was estimated to obtain an 80% power, and a two-tailed significance level of 0.05 was used to detect a 1-day difference between groups with respect to the duration of mechanical ventilation. The sample size calculation was made using *a priori* sample size calculator for a Student's *t*-test.

Descriptive and analytic statistics were performed on IBM compatible computer by using SPSS 11.5 (SPSS Inc., Chicago, IL) software package under windows XP operating system. Data were presented in the form of mean \pm standard deviation. Data between groups were analyzed using unpaired *t*-test. Chi-square test and analysis of variance were used to compare patient characteristics and Fischer test for association between categorical variables. The power of significance was considered significant if ($P < 0.05$).

Sensitivity (SE = true positive/true positive + false negative), specificity (SP = true negative/true negative + false positive), positive predictive value (PPV = true positive/true positive + false positive), negative predictive value (NPV = true negative/true negative + false negative), and diagnostic accuracy = (true positive + true negative)/(true positive + true negative + false positive + false negative).

Results

Group (I and C) were similar as regard to gender, age, APACHE II score, and diagnosis at admission. The

duration (hours) of mechanical ventilation and length of ICU stay (days) were significantly shorter in Group I where the IWI was used (83.6 ± 34.3 vs. 97.49 ± 47.2 h, $P = 0.002$ and 5.5 ± 1.6 vs. 7.12 ± 2.3 days, $P = 0.03$, respectively). There was no difference as regard to length of hospital stay (days) and in-hospital mortality rate. Weaning success rate was significantly higher in the Group I as compared with Group C (49 vs. 32, $P = 0.001$) while weaning failure rate was significantly lower in Group I as compared with Group C (11 vs. 28, $P = 0.001$). Failure of SBT and failure of extubation were lower in Group I as compared to Group C (2 vs 19 and 5 vs. 7, $P = 0.03$, respectively). IWI had high sensitivity (0.97), specificity (0.78), positive and NPVs (0.92 and 0.93, respectively), positive and negative likelihood ratios (12.4 and 0.07, respectively), and accuracy (0.92) [Tables 1-3].

Discussion

Long-term intubation and mechanical ventilation increased risk of mortality and morbidity due to fatal complications, as ventilator-associated pneumonia, tracheal stenosis, prolong ICU stay, and increases health care costs.^[6] Therefore, efforts for early identification of the proper time of weaning patients from mechanical ventilation are indicated to minimize exposure to these complications. Another goal of the proper timing of weaning is the avoidance of premature weaning, which expose patient to severe respiratory, cardiovascular, and psychological stress. The clinical decision is not enough to predict weaning outcome accurately as judgment may be incomplete and require more accurate predictors for successful weaning, in addition to clinical signs.^[7]

More than 50 different weaning predictors have been studied.^[8] These studies have been observational, with predictors measured and then correlated with weaning outcome.^[9-11]

The major findings of the current study are that the use of the IWI shortens the total duration of mechanical ventilation and the length of ICU stay, weaning success rate was significantly higher in the Group I as compared with controlled Group C while weaning failure rate was significantly lower in the Group I as compared with Group C, and failure of SBT and failure of extubation were lower in Group I as compared to Group C.

Furthermore, when IWI measured in a retrospective manner in control group, we found 32 patients of total 34 with succeeded weaning had IWI > 25 . On the other hand, all patients with failed weaning in control group

Table 1: Baseline characteristics of the patients under study

Parameter (mean±SD)	Control group (group C)	IWI group (group I)	P
Age (years)	40.9±13.5	42.6±11.2	0.42
Sex (male:female)	34:26	29:31	-
Diagnosis	12 head trauma 7 brain tumor 5 morbid obese 14 polytrauma 13 major abdominal surgery 9 respiratory failure	14 head trauma 6 brain tumor 6 morbid obese 17 polytrauma 11 major abdominal surgery 8 respiratory failure	
APACHE score	17.6±4.2	18.3±9.7	0.4
Duration (h) of mechanical ventilation	97.49±47.2	83.6±34.3	0.002*
Length of ICU stay (days)	7.12±2.3	5.5±1.6	0.03*
Length of hospital stay (days)	25.4±3.8	23.8±2.3	0.11
Mortality rate, %	(14/60) 23.3	(16/60) 26.7	0.68

*Denotes statistical significant $P < 0.05$. SD: Standard deviation; ICU: Intensive Care Unit; IWI: Integrative weaning index; APACHE: Acute Physiology and Chronic Health Evaluation

Table 2: Comparison between the two groups in terms of success or failure of spontaneous breathing trial

Number of patients	Control group (group C)	IWI group (group I)	P
Weaning success	34	53	0.0001*
Weaning failure	26	7	
Failure of SBT	19	2	0.02*
Reintubation rate (failed extubation)	7	5	

*Statistical significant $P < 0.05$. IWI: Integrative weaning index; SBT: Spontaneous breathing trial

Table 3: Sensitivity and specificity of IWI $n = 120$

Parameters number of patients	Positive IWI	Negative IWI
Weaning success	85 (True +ve)	2 (False -ve)
Weaning failure	7 (False +ve)	26 (True -ve)

Sensitivity	Specificity	Prevalence	True +ve (PPV)	True -ve (NPV)
0.97	0.78	0.72	0.92	0.93

Accuracy	LR+	LR-	Probability of false +ve	Probability of false -ve
0.92	12.4	0.07	0.076	0.071

LR+: Likelihood rate of positive; LR-: Likelihood rate of negative; PPV: Positive predictive value; NPV: Negative predictive value

had IWI < 25 . This makes IWI had high sensitivity (0.97), specificity (0.78), positive and NPVs (0.92 and 0.93 respectively), positive and negative likelihood ratios (12.4 and 0.07, respectively) and accuracy (0.92).

There were limited data in the literature regarding whether the use of IWI affected the success rate of weaning from mechanical ventilation. In the study of Esteban *et al.*,^[9] on use of weaning predictors, it was concluded that among indexes that had been introduced, IWI was the best index for predicting weaning with a sensitivity of 0.97.

In the study of Nemer *et al.*,^[3] on use of IWI as a predictor of weaning, 18% of patients who tolerated the SBT were re-intubated. IWI predicted extubation failure in nine out of 10 patients who presented unsuccessful extubation. IWI presented the highest probability of weaning success when the test was positive (0.99) and the lowest probability of weaning success when the test was negative (0.14). According to our results, IWI had higher sensitivity, specificity, positive and NPVs, positive and negative likelihood ratios and accuracy.

Madani *et al.*,^[12] assessed validity of IWI for discontinuation from mechanical ventilation in Iranian ICUs, it was studied in six ICU patients with different characteristics, and sensitivity of 94.59, Specificity equal to 66.67, PPV of 97.22, NPV equal to 50, positive likelihood ratio of 2.84, negative likelihood ratio equal to 0.08 and accuracy of 92.5 were obtained; and could prove persistence of successful weaning in a 48-h period with an accuracy above 90%.

In our study, IWI had better predictive value for weaning patients from mechanical ventilation and by using IWI, intubation, and its complications can be reduced. One limitation of our study is the difficulty in measuring Cst of the respiratory system in the spontaneously breathing patient. Although Cst, rs can be measured during discontinuation from mechanical ventilation,^[13,14] it is not an easy to be performed during the weaning process, because the patient's inspiratory effort during the assisted breath could interfere with the inspiratory plateau pressure measurement. In our study, we minimized this limitation by observing the digital display of the pressure-time inspiratory plateau curve thus avoiding respiratory cycles that revealed clear inspiratory efforts of the patients. In our study, the IWI was measured with a fixed FiO₂ of 40% to avoid variations in SaO₂ due to FiO₂ variations. Further studies must be performed to test the IWI accuracy in a wide range of FiO₂ values. Another limitation of this study is combined SBT failure and extubation failure, an approach to be discouraged because the latter often results from distinct causes related to the capacity to protect the airway as stridor or upper airway edema not responding to medical treatment or weak cough reflex.

Conclusion

This study confirms the usefulness of IWI during the weaning process, being effective in predicting both successful and failed weaning outcome. Hence, we recommend its use as routine weaning predictor beside the clinical data in mechanically ventilated patients.

Acknowledgment

The authors would like to thank nurses at the Intensive Care Unit of Tanta University Hospital, Tanta, Egypt, for their assistance in conducting the study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Epstein SK. Weaning parameters. *Respir Care Clin N Am* 2000;6:253-301, v-vi.
2. Boles JM, Bion J, Connors A, Herridge M, Marsh B, Melot C, *et al.* Weaning from mechanical ventilation. *Eur Respir J* 2007;29:1033-56.
3. Nemer SN, Barbas CS, Caldeira JB, Cárias TC, Santos RG, Almeida LC, *et al.* A new integrative weaning index of discontinuation from mechanical ventilation. *Crit Care* 2009;13:R152.
4. Solsona JF, Díaz Y, Vázquez A, Pilar Gracia M, Zapatero A, Marrugat J. A pilot study of a new test to predict extubation failure. *Crit Care* 2009;13:R56.
5. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: A severity of disease classification system. *Crit Care Med* 1985;13:818-29.
6. Fagon JY, Chastre J, Hance AJ, Montravers P, Novara A, Gibert C. Nosocomial pneumonia in ventilated patients: A cohort study evaluating attributable mortality and hospital stay. *Am J Med* 1993;94:281-8.
7. Ely EW, Baker AM, Dunagan DP, Burke HL, Smith AC, Kelly PT, *et al.* Effect on the duration of mechanical ventilation of identifying patients capable of breathing spontaneously. *N Engl J Med* 1996;335:1864-9.
8. Meade M, Guyatt G, Cook D, Griffith L, Sinuff T, Kergel C, *et al.* Predicting success in weaning from mechanical ventilation. *Chest* 2001;120 6 Suppl: 400S-24S.
9. Esteban A, Frutos F, Tobin MJ, Alía I, Solsona JF, Valverdú I, *et al.* A comparison of four methods of weaning patients from mechanical ventilation. Spanish Lung Failure Collaborative Group. *N Engl J Med* 1995;332:345-50.
10. Brochard L, Rauss A, Benito S, Conti G, Mancebo J, Rekié N, *et al.* Comparison of three methods of gradual withdrawal from ventilatory support during weaning from mechanical ventilation. *Am J Respir Crit Care Med* 1994;150:896-903.
11. Krishnan JA, Moore D, Robeson C, Rand CS, Fessler HE. A prospective, controlled trial of a protocol-based strategy to discontinue mechanical ventilation. *Am J Respir Crit Care Med* 2004;169:673-8.
12. Madani J, Saghafinia M, Nezhad H, Ebadi A, Ghochani A, Tavasoli F, *et al.* Validity of integrative weaning index of discontinuation from mechanical ventilation in Iranian ICUs. *Thrita* 2013;2:62-8.
13. Yang KL, Tobin MJ. A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. *N Engl J Med* 1991;324:1445-50.
14. Aboussouan LS, Lattin CD, Anne VV. Determinants of time-to-weaning in a specialized respiratory care unit. *Chest* 2005;128:3117-26.