Original article

Utility of rapid shallow breathing index in progressive weaning of adult patients from mechanical ventilation using pressure support ventilation

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Abstract

Introduction: Many weaning indices have been proposed to evaluate readiness of a patient to tolerate discontinuation of mechanical ventilation. **Aim:** This study evaluated the utility of these indices in progressive weaning from mechanical ventilation. **Methods:** All patients receiving mechanical ventilation and assessed to be ready to wean clinically were included in the study. They were initially placed on pressure support, positive end expiratory pressure (PEEP) of 5-8 cm H_2O and FiO_2 0.4. Tidal volume, respiratory frequency, minute ventilation and rapid shallow breathing index (RSBI) were measured at baseline, 5 min, 30 min and at 2 h. The patient was also monitored for clinical signs of respiratory distress. If the patient remained stable, the pressure support was reduced by 2 cm H_2O and the weaning process repeated till PSV reached 5-8 cm H_2O. **Results:** Respiratory rate (< 35/min) and tidal volume corrected to weight (> 5 mL/kg) had high sensitivity (100% and 98.5% respectively) but lacked specificity. Minute volume of < 10 L/min lacked both sensitivity (73.1%) and specificity (50%). The RSBI (< 105 b/min/L) had very high sensitivity (99.1%), reasonable specificity (83.3%) with a positive predictive value 98.4% and a negative predictive value 90.9%. RSBI corrected to weight (7 breaths/min/mL/kg) was not useful. RSBI rate of < 20% was found to be a good weaning index even for progressive decrease in ventilatory support. **Conclusion:** RSBI < 105 b/min/L and RSBI rate < 20% are reliable criteria to predict success of progressive weaning from mechanical ventilation using pressure support.

Keywords: Weaning, rapid shallow breathing index, RSBI rate

Introduction

Weaning from mechanical ventilation and extubation should be attempted as soon as the patient can sustain spontaneous breathing with effective gas exchange and clearance of airway secretions. The rapid shallow breathing index (RSBI) as a weaning index was originally developed by Yang and Tobin in 1991 in a prospective study of indices predicting the outcome of trials of weaning from mechanical ventilation. This remains the most widely used indicator for weaning and extubation.[1] The RSBI is the ratio determined by the frequency (f) (breaths per minute) divided by the tidal volume (V_T) in litres. An RSBI <105 breaths/min/L has been widely accepted by healthcare professionals as a criterion for weaning and has been integrated into most weaning protocols. The aim of this study was to evaluate

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RSBI as an index to titrate pressure support during weaning of mechanically ventilated patients.

Methodology

This prospective, nonrandomised study enrolled 34 adult patients with acute respiratory failure receiving mechanical ventilation in the medical and multidisciplinary intensive care units (ICU) at Kasturba Hospital, Manipal between February 2011 and January 2012. This study protocol was approved by the departmental dissertation committee.

All patients, intubated or tracheostomised, receiving mechanical ventilation for > 24 h and were ready for weaning, were included in the study. These patients also satisfied the following criteria before inclusion in the study: partial or complete recovery from acute respiratory failure and clinical signs of improvement from the precipitating cause, adequate gas exchange as indicated by a ratio of the partial pressure of arterial oxygen (PaO_2) to the fraction of inspired oxygen (FiO_2) above 200 with a positive end expiratory pressure (PEEP) of 5-8 cm H_2O and FiO_2 0.4, stable haemodynamics without the need for vasoactive agents, absence of need for sedatives and a core temperature < 38° C. Patients receiving mechanical ventilation for < 24 h were excluded from the study, while those who were discharged against medical advice during the study were excluded from the statistical analysis.

Mechanical ventilators used for ventilating the patients during the study included Dräger Evita 2 or Dräger Evita 4, Engstrom ventilator, Datex-Ohmeda, Hamilton Galileo Classic, Hamilton Medical or Puritan Bennett 840, Covidien.

All intubated or tracheostomised patients receiving invasive mechanical ventilation and ready for weaning were clinically evaluated by the intensivist of respective ICU. Prior to weaning from mechanical ventilation, the patient was ventilated with either assist/control or control mode of ventilation. The weight of the patients was estimated using the ideal body weight formula as follows: Male (lbs): IBW=106 + 6 (Height in inches - 60); Female (lbs): IBW= 105 + 5 (Height in inches - 60). To convert to kilograms, the sum was divided by 2.2. Prior to weaning, the patient's mode of ventilation was changed over to pressure support ventilation (PSV) with a set PEEP of 5–8 cm H_2O and FiO_2 not exceeding 0.4. The initial pressure support level set for the patient was at the level of pressure support targeted as per calculated V_T (7 mL/kg body weight).

The V_T, respiratory frequency, minute ventilation, RSBI were measured and recorded from mechanical ventilator monitor screen. If the patient was comfortable and the measured parameters were within physiological limits, PSV was continued at that level for at least 2 h. The respiratory rate, V_T, minute volume, RSBI, heart rate, oxygen saturation, FiO_2 and blood pressure were recorded at baseline, 5 min, 30 min and at 2 h. The patient was also monitored for clinical signs of respiratory distress. If the patient remained stable, the pressure support was reduced by 2 cm H_2O and the weaning process repeated *(Figure 1)*.

With each set level of pressure support, a maximum target RSBI threshold value of < 105 breaths/min/L was accepted for each patient. RSBI corrected to weight and RSBI rate (%) was also measured. RSBI rate is the percentage change in RSBI seen 2 h after a reduction in pressure support as compared to before the change. If the increase was ≤ 20%, it was considered as indicative of a successful wean.

Statistical analysis was done with statistical package SPSS version 16, SPSS, Chicago Illinois. All data are reported as mean ± standard deviation (SD) unless otherwise specified. The predictive performance of these parameters were also examined using sensitivity, specificity, positive and negative predictive values and receiver operating characteristic (ROC) curves. The positive likelihood ratio (PLR) was obtained using the formula sensitivity/(1 – specificity). The negative likelihood ratio (NLR) was calculated using the formula (1 – sensitivity)/specificity. A LR of 0.5-2.0 indicates that a parameter is mildly associated with the post-test probability of weaning success or failure. Values of LR of 2.0-5.0 and 0.3-0.5 are weakly but significantly associated with changes in the probability of weaning success

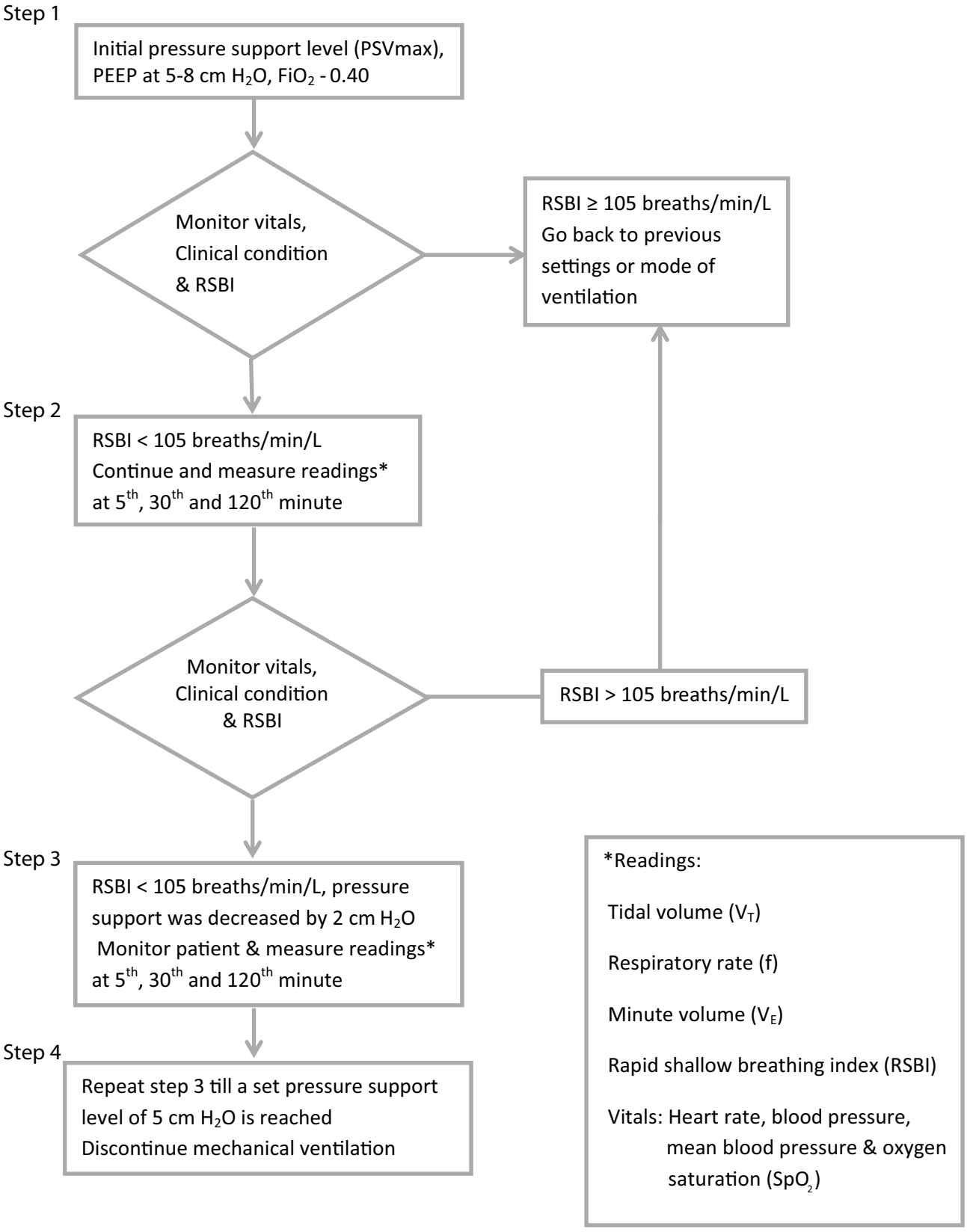

Figure 1: Flow chart used for the weaning process

or failure, respectively. Values of LR of 5.0-10.0 and 0.1-0.3 are more significantly associated with changes in the probability of weaning success or failure, respectively. Values of LR above 10 and below 0.1 are strongly associated with changes in the probability of weaning success or failure, respectively.

Results

Thirty four patients who were admitted to the medical or multidisciplinary intensive care unit (MICU) for mechanical ventilation and had regained ability to tolerate pressure support alone in the course of their weaning from full ventilator support were enrolled in the study. There were 19 male and 15 female patients. The mean (± SD) age of the patients was 51.38 (± 16.14) years and the mean (± SD) weight of the patients was 59.3 (± 14.32) kg. Most of them were medically ill and admitted for various reasons including pneumonia, sepsis, chronic obstructive pulmonary disease, stroke, myocardial infarction and snake bite.

Threshold values for various weaning indices as established in the literature[1] were used and their sensitivity, specificity, positive and negative predictive values were obtained. A total of 136 values were obtained. The accuracy of each of the criteria was examined and is shown in Tables 1 – 2.

Table 1: Comparison of actual weaning, predicted weaning based on respiratory rate, tidal volume and minute volume

		Weaning	
		Possible	**Failed**
Respiratory rate	< 35 bpm	118	13
	≥ 35 bpm	1	4
Tidal volume corrected	> 5 mL/kg	124	7
	≤ 5 mL/kg	2	3
Minute volume	< 10 L/min	87	10
	≥ 10 L/min	32	7

RSBI: A receiver operating characteristic (ROC) curve was constructed for evaluation of the RSBI as an index, useful in progressive weaning from ventilator *(Figure 2)*. The area under the curve was 0.865 with a standard error of 0.05 (95% confidence interval was 0.759 – 0.96) showing moderately accurate correlation between this weaning index and weaning. Thus, the RSBI value of 105 b/min/L was found to be a good weaning index even for progressive decrease in ventilatory support. The specificity of this value was only 0.58.

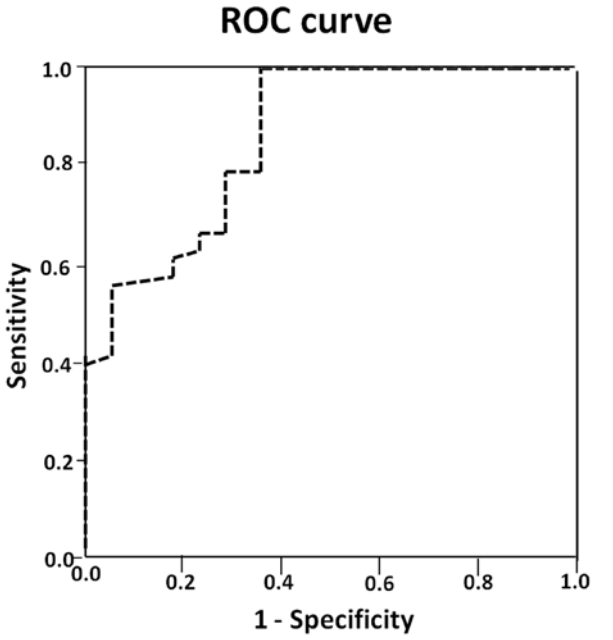

Figure 2: ROC curve for RSBI during progressive weaning. AUC: 0.865

Corrected RSBI: RSBI was corrected to patient's body weight and a threshold value of 7 breaths/min/mL/kg was used. A corrected RSBI value of < 7 breaths/min/ml/kg was assumed to be predictive of successful weaning whereas ≥ 7 breaths/min/mL/kg, predictive of failure to wean *(Table 2)*.

RSBI rate: RSBI was initially measured at the beginning of the weaning process and subsequently, it was measured 2 h after the spontaneous breathing trial on a lower setting (PSV). If the difference in the RSBI was less than 20%, it was assumed to be predictive of successful weaning whereas if it were ≥ 20%, it was assumed to be predictive of failure to wean *(Table 2)*.

A receiver operating characteristic (ROC) curve was

Table 2: Comparison of predicted weaning against actual weaning based on RSBI, RSBI corrected and RSBI rate

		Actual weaning	
		Possible	Not possible
RSBI	< 105 breaths/min/L	118	7
	≥ 105 breaths/min/L	1	10
RSBI corrected	< 7 breaths/min/mL/kg	118	15
	≥ 7 breaths/min/mL/kg	1	2
RSBI rate	< 20%	37	0
	≥ 20%	26	6

constructed for evaluation of the RSBI rate as an index useful in progressive weaning from ventilator *(Figure 3)*. The area under the curve (AUC) was 0.98 with a standard error of 0.05 (95% confidence interval was 0.951 – 1.009). Thus, the RSBI rate of < 20% (increase in RSBI < 20% after two hours of spontaneous breathing trial or weaning attempt) was found to be a good weaning index even for progressive decrease in ventilatory support.

Summary

The sensitivity, specificity, positive and negative predictive values, positive and negative likelihood ratios of all the observed weaning parameters are tabulated in *Tables 3 and 4*.

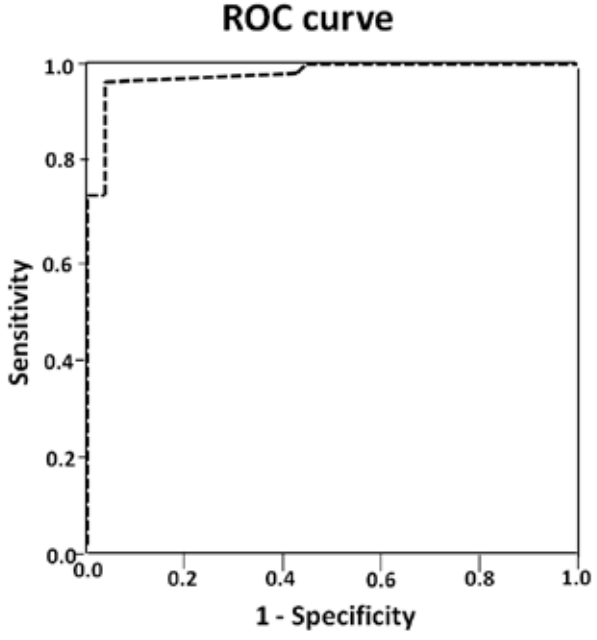

Figure 3: ROC curve for RSBI rate during progressive weaning. AUC: 0.98

Table 3: Sensitivity, specificity, positive and negative predictive values of weaning indices

Sl No		Sensitivity	Specificity	Positive predictive value	Negative predictive value
1.	Respiratory rate (< 35/min)	100	23.5	97.05	100
2.	Tidal volume adjusted to weight (> 5 mL/kg)	98.4	30	94.65	60
3.	Minute volume (< 10 L/min)	73.1	50	92.8	21.8
4.	RSBI (< 105 b/min/L)	99.1	83.3	98.4	90.9
5.	RSBI corrected (< 7 b/min/kg)	99.1	11.7	88.7	66
6.	RSBI rate (≤ 20%)	58.7	100	100	18.7

Table 4: Positive and negative likelihood ratio and area under the curve of weaning indices

Sl No		Positive likelihood ratio (PLR)	Negative likelihood ratio (NLR)	Area under curve (AUC)	Inter-pretation
1.	Respiratory rate (< 35/min)	1.31	0	--	Strong NLR
2.	Tidal volume adjusted to weight (> 5 mL/kg)	1.41	0.053	--	Strong NLR
3.	Minute volume (< 10 L/min)	1.462	0.538	--	Not useful
4.	RSBI (< 105 breaths/min/L)	5.934	0.011	0.865	Strong PLR, NLR, AUC
5.	RSBI corrected (< 7 breaths/min/mL/kg)	1.12	0.077		Strong NLR
6.	RSBI rate (≤ 20%)	Infinity	0.413	0.98	Strong PLR and AUC

Discussion

Weaning a critically ill patient from mechanical ventilation takes as much as 40% of the time spent in the ICU and on ventilator. Although mechanical ventilation is the mainstay of supporting a patient

in respiratory failure, it is not without adverse effects. One of the important requirements to discontinue mechanical ventilation is the mitigation or reversal of the disease process that necessitated it. Several objective criteria have been proposed to assess whether a patient is ready to be weaned off a ventilator.

The primary aim of this study was to evaluate the usefulness of these indices in progressive weaning from mechanical ventilation. Both respiratory rate (< 35/min) and tidal volume corrected to weight (> 5 mL/kg) had high sensitivity (100% and 98.5% respectively) and positive predictive value (97% and 94.65% respectively) but lacked in specificity. Minute volume of < 10 L/min lacked both sensitivity (73.1%) and specificity (50%). Thus, none of these were reliable weaning indices.

The RSBI (< 105 breaths/min/L) had very high sensitivity (99.1%), reasonable specificity (83.3%), positive predictive value of 98.4% and a negative predictive value of 90.9%. The AUC was 0.869. These results are very similar to the results obtained by Yang and Tobin.[2] In their study, RSBI had a sensitivity of 0.97 and specificity of 0.64. The area under the ROC curve was 0.89. They concluded that rapid, shallow breathing as reflected by the f/VT ratio was the best predictor of success as well as failure of weaning from mechanical ventilation. They had used the index as a criterion for weaning off ventilator. In the present study, the utility of RSBI for progressive weaning with the same threshold of 105 breaths/min/L was examined. This study confirms that the RSBI is useful for progressive weaning from ventilator using pressure support also.

El Khatib *et al*[2] concluded from their study that the administration of 5 cm H_2O of CPAP can influence the determination of the RSBI. They speculated that using the RSBI during CPAP may mislead the clinician into premature discontinuation of mechanical ventilation and so, different threshold values for the RSBI should be derived for different ventilatory support levels. Meade *et al*[3] found that the most promising predictors were a rapid shallow breathing index (RSBI) < 65 breaths/min/L for stepwise reductions in mechanical ventilator support. The present study did not use different thresholds for different ventilator support levels.

To increase the value of RSBI, an attempt was made to correct it to body weight and a threshold of < 7 breaths/min/kg was used. A previous study[4] had shown 100% sensitivity and specificity for this value but this study could not confirm those findings as the specificity was reduced to 11.7% at this threshold making it unreliable. One of the problems was that the weight of the patient was estimated using formulae, as facilities for weighing a critically ill patient are not available at this centre. However, standard formulae were used which is the next best to weighing patients.

Kuo *et al*[5] investigated the value of RSBI measured at the beginning and termination of SBT as a predictor of weaning outcome. They concluded that the RSBI measured at the completion of SBT was superior to that measured at the start, in predicting weaning outcome in critically ill patients. This was further refined by Segal *et al*[6] who studied the RSBI rate. They showed that RSBI rate of less than 20% was > 90% sensitive and 100% specific for predicting weaning success. It had a positive predictive value of 100% and a negative predictive value of over 81%.[6] In this study, this threshold of 20% for RSBI rate had a specificity of 100% unlike all other indices, although its sensitivity was only 58.7%. It also had a positive predictive value of 100%, although it had a very low negative predictive value of 18.7%. Thus, from the present study, it is apparent that using RSBI in combination with RSBI rate would maximise sensitivity, specificity, positive and negative likelihood ratios and accuracy of predicting success of weaning from mechanical ventilation during progressive reduction of pressure support.

Weaning from mechanical ventilation requires that the patient's ability to sustain the work of respiration must be regained. This would depend on adequate gas exchange (minimal shunt and dead space) and adequate respiratory mechanics (acceptable compliance and resistance) apart from recovery from the disease process that precipitated the respiratory

failure. Considering that multiple factors are involved, no single criterion is likely to be entirely satisfactory. It may be foreseen that a composite scoring system must be evolved encompassing all these individual factors to more accurately predict weaning from mechanical ventilation.

Conclusion

The rapid shallow breathing index (RSBI) < 105 breaths/min/L and RSBI rate < 20% are reliable criteria to predict success of progressive weaning from mechanical ventilation using pressure support.

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