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EFFECT OF ADJUSTABLE PRESSURE LIMITING VALVE SETTINGS DURING WEANING WITH GENERAL ANESTHESIA AT DR. MOHAMAD SOEWANDI REGIONAL GENERAL HOSPITAL, SURABAYA

Isagiri Natahayu^{1*}, Muhammad Rodli², Widigdo Rekso Negoro³, Agus Budi Prasetyo⁴, Budi Satria⁵

Bachelor of Applied Science in Anesthesia Nursing, ITSK Hospital. dr. Soepraen, Malang, Indonesia

natahayu.19@gmail.com^{1*}, rodli@itsk-soepraen.ac.id², widigdo.wrn@gmail.com³, el.neunzehn@gmail.com⁴, budipandjaitan14@gmail.com⁵

**Corresponding author*

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ABSTRACT

Adequate ventilation management during the weaning phase of general anesthesia is essential for patient safety. The Adjustable Pressure Limiting (APL) valve regulates pressure within the anesthesia breathing circuit and may influence spontaneous tidal volume (VT). Inappropriate APL settings may contribute to inadequate ventilation, respiratory fatigue, atelectasis, or excessive airway pressure. This study aimed to analyze differences in spontaneous VT among APL valve settings of 10, 20, and 30 cmH₂O during anesthesia weaning in adult patients undergoing general anesthesia with endotracheal intubation. This study used an observational analytical design with a repeated-measures approach. Forty adult patients with ASA physical status I–II were selected using consecutive sampling. Each participant was observed under three APL settings during the weaning phase. Tidal volume was recorded for five consecutive breaths at each setting, and the mean value was used for analysis. Data normality was assessed using the Shapiro-Wilk test. Because the data were not normally distributed, differences among the three APL settings were analyzed using the Friedman test. Mean VT was 247.05 mL at APL 10 cmH₂O, decreased to 219.01 mL at 20 cmH₂O, and further decreased to 200.76 mL at 30 cmH₂O. The Friedman test demonstrated a statistically significant difference in VT among the three APL settings ($p < 0.001$). Higher APL settings were associated with lower spontaneous VT and increased PIP. These findings suggest that APL adjustment during weaning should be individualized and accompanied by continuous monitoring of ventilation and airway pressure to support safe and adequate spontaneous breathing.

Keywords: Adjustable Pressure Limiting (APL), tidal volume, anesthesia weaning, general anesthesia, endotracheal intubation.

INTRODUCTION

Adequate airway and ventilation management are key pillars of patient safety during general anesthesia (Buehler et al., 2023), as failure to maintain airway patency, oxygenation, and ventilation are significant contributors to perioperative morbidity and mortality (Avva et al., 2025). In addition, appropriate intraoperative ventilation strategies are important because ventilation parameters are associated with pulmonary complications following general anesthesia (Bolther et al., 2022). This necessitates further understanding of airway management during ventilator weaning to achieve adequate tidal volume (VT).

3 Weaning is defined as the transition from positive pressure ventilation to spontaneous breathing, and failure in this phase can increase mortality, particularly in cases of difficult and prolonged weaning (Na et al., 2022). Therefore, determining the appropriate timing and strategy for weaning is a crucial focus in anesthesia and intensive care practice. Current clinical guidelines emphasize a structured and evidence-based approach to liberation from mechanical ventilation rather than relying solely on individual clinical judgment (Wu et al., 2023).

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6 Weaning readiness assessment is generally performed through a spontaneous breathing trial (SBT), which can be performed using various methods such as a T-piece, pressure support ventilation (PSV), continuous positive airway pressure (CPAP), and automatic tube compensation (ATC) (Akella et al., 2022; Roberts et al., 2024). Various studies and meta-analyses have shown that variations in SBT techniques affect weaning success, reintubation rates, and the duration of mechanical ventilation (Mezidi et al., 2024). Recent systematic reviews and meta-analyses have demonstrated that different SBT techniques may influence SBT and extubation outcomes, although the optimal technique may vary according to patient characteristics and clinical context (Burns et al., 2024). A network meta-analysis has also demonstrated differences among available weaning strategies, emphasizing that the method used during the transition to spontaneous breathing may affect clinical outcomes (Yi et al., 2021). However, most research focuses on ventilator mode settings, while mechanical component settings such as the Adjustable Pressure Limiting (APL) valve have been relatively under-evaluated, particularly during the weaning phase.

Conversely, the technical aspects of the anesthesia machine, particularly the Adjustable Pressure Limiting (APL) valve, have rarely received attention in the context of spontaneous breathing and weaning. The APL valve regulates the maximum pressure in the anesthesia circuit, thus influencing the tidal volume generated during manual or spontaneous ventilation (Spinney & Sprigge, 2021). Positive pressure regulation via the APL has been shown to improve oxygenation and tidal volume in spontaneously breathing patients (Arslan & Yavuz, 2020). A sharp increase in airway pressure and a large change in inspiratory tidal volume beyond the set pressure are common. This has the potential to impair ventilation and increase the risk of barotrauma or volutrauma (Jiang et al., 2024).

In anesthesia practice, during weaning at the end of general anesthesia with endotracheal intubation, patients are often allowed to breathe spontaneously through an anesthesia machine with the APL partially closed (to provide mild CPAP) before extubation (Mezidi et al., 2024). During this phase, stabilizing spontaneous tidal volume is crucial to ensure adequate ventilation and prevent respiratory fatigue (Rittayamai et al., 2021). Inappropriate APL valve settings during anesthesia weaning may adversely affect spontaneous ventilation. Because APL settings influence the pressure characteristics of the breathing circuit, inappropriate adjustment may result in inadequate or excessive airway pressure and consequently affect spontaneous ventilation and atelectasis (Spinney

& Sprigge, 2021; Zeng et al., 2023). Therefore, appropriate APL adjustment is essential to maintain adequate spontaneous ventilation and ensure safe anesthesia weaning.

The novelty of the present study lies in directly comparing three APL valve settings (10, 20, and 30 cmH₂O) within the same patients during anesthesia weaning under general anesthesia with endotracheal intubation. Unlike previous studies that have primarily evaluated APL valve performance in experimental or technical settings, this study provides clinical evidence of the relationship between APL settings and spontaneous tidal volume during the transition to spontaneous breathing (Spinney & Sprigge, 2021; Buehler et al., 2023). In this phase, the accuracy of APL settings has the potential to influence ventilation adequacy, hemodynamic stability, the risk of lung injury, and the successful transition from controlled ventilation to spontaneous breathing. Therefore, this study aimed to determine the effect of APL valve settings of 10, 20, and 30 cmH₂O on spontaneous tidal volume during the weaning process in patients undergoing general anesthesia with endotracheal intubation.

The findings may assist anesthesia practitioners in selecting and titrating APL settings according to the patient's spontaneous tidal volume and airway pressure response. This approach may support safer and more measurable weaning practice by allowing continuous assessment of ventilation adequacy during the transition to spontaneous breathing.

RESEARCH METHOD

This study employed an observational analytical design with a repeated-measures approach. The study evaluated spontaneous tidal volume at three APL valve settings, namely 10, 20, and 30 cmH₂O, during the anesthesia weaning phase in patients undergoing general anesthesia with endotracheal intubation.

A repeated-measures approach was used because the three APL settings were observed in the same participants, allowing each participant to serve as his or her own reference. Spontaneous tidal volume was recorded at each APL setting after the predetermined stable condition had been achieved.

The application and adjustment of the APL valve during the anesthesia weaning process followed the clinical management of the anesthesiologist. The researcher did not determine the clinical indication for APL adjustment or assign participants to different treatment groups. The researcher only observed and recorded the ventilation parameters displayed on the anesthesia machine according to the study protocol.

This observational study was conducted in the operating room of Dr. Mohamad Soewandi Regional General Hospital, Surabaya, in a surgical installation using an anesthesia machine with tidal volume recording and measured APL settings. The study was conducted from June 8 to June 19, 2026, after obtained ethical approval from Health Research Ethics Commite of Dr. Mohamad Soewandi Regional General Hospital, Surabaya, with ethical clearance number: 028/KE/KEPK/2026.

Target population was adult patients undergoing general anesthesia with endotracheal tube intubation and requiring manual or assisted ventilation during the

anesthetic procedure in the operating room of Dr. Mohamad Soewandi Hospital, Surabaya. The study sample consisted of 40 adult patients who met the inclusion and exclusion criteria and underwent general anesthesia with endotracheal intubation. Patients aged 18–65 years with ASA physical status I–II, requiring manual or assisted ventilation during weaning, and providing informed consent were included. Patients with significant respiratory disease, chest-wall or spinal deformities, hemodynamic instability, severe systemic disorders, or intraoperative complications affecting ventilation were excluded. Participants were recruited consecutively until 40 eligible patients were obtained. The sample size of 40 was predetermined for this repeated-measures observational study, in which each patient was assessed at APL settings of 10, 20, and 30 cmH₂O.

Data Collection Process

After successful induction of anesthesia and endotracheal intubation, the patient will be connected to the anesthesia machine. Initial ventilation will be set according to the hospital's standard clinical practice. Once the patient's condition is stable and the anesthesiologist decides to perform manual or assisted ventilation, measurements will be initiated. During weaning from the ventilator, a spontaneous breathing trial (SBT) will be performed upon the onset of spontaneous breathing. Tidal volume (VT) will be measured at each adjustable pressure-limiting (APL) valve setting. Manual or assisted ventilation will be performed consistently by a single trained operator to minimize inter-operator variability. After 3–5 breaths for stabilization, the tidal volume (mL) displayed on the anesthesia machine monitor will be recorded for five consecutive breaths, and the mean tidal volume of these five breaths will be used for analysis. Other relevant parameters, such as peak airway pressure (PIP), will also be recorded. All data will be recorded in real time on the data collection form.

Analysis Methods

Numerical data were analyzed using repeated-measures ANOVA or the Friedman test for non-normally distributed data to compare tidal volume (VT) across the three APL settings. Post-hoc tests with correction for multiple comparisons were performed to identify pairs of APL settings that differed significantly. Descriptive data were presented for each APL setting.

RESULTS AND DISCUSSION

Results

The results of this study are presented through descriptive analysis, normality testing, the Friedman test, and post-hoc analysis to evaluate differences in spontaneous tidal volume across APL valve settings of 10, 20, and 30 cmH₂O. The findings are presented in Tables 1-4 and subsequently discussed in relation to the study objectives and relevant literature.

Descriptive Analysis of Tidal Volume Based on APL Settings

Based on the data collected, 40 respondents met the inclusion criteria. The descriptive analysis reveals the variation in tidal volume across the different APL valve settings administered to the patients, as presented in Table 1.

Table 1. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
APL 10 cmH ₂ O	40	205.4	284.2	247.050	24.9588
APL 20 cmH ₂ O	40	174.8	260.8	219.005	26.2563
APL 30 cmH ₂ O	40	160.8	242.8	200.755	25.5219
Responden	40	1	40	20.50	11.690
Valid N (listwise)	40				

As shown in Table 1, the highest average tidal volume was achieved at the APL setting of 10 cmH₂O with a value of 247.05 mL. At the APL setting of 20 cmH₂O, the average tidal volume decreased to 219.01 mL. Furthermore, at the APL setting of 30 cmH₂O, the average tidal volume decreased again to 200.76 mL. The data indicates a tendency for tidal volume to decrease as the APL valve pressure increases.

Test of Normality

The results of the normality test for tidal volume at the three APL valve settings are presented in Table 2.

Table 2. Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
APL 10 cmH ₂ O	.120	40	.150	.924	40	.010
APL 20 cmH ₂ O	.125	40	.120	.942	40	.041
APL 30 cmH ₂ O	.115	40	.200*	.934	40	.022

As shown in Table 2, the significance values for all groups were less than 0.05; therefore, the data were not normally distributed. Consequently, the analysis proceeded using the Friedman test.

Friedman Test

The results of the Friedman test comparing tidal volume across the three APL valve settings are presented in Table 3.

Table 3. Test Statistics

N	40
Chi-Square	80.000
df	2
Asymp. Sig.	<.001

As shown in Table 3, the Friedman test results showed Asymp. Sig. < 0.001 ($p < 0.05$), demonstrating a significant difference in tidal volume among the three APL valve settings in patients undergoing general anesthesia with manual ventilation.

Test Post Hoc Wilcoxon

Pairwise comparisons among the three APL valve settings using the Wilcoxon test are presented in Table 4.

Table 4. Test Statistics

	Z	Asymp. Sig. (2-tailed)
APL 20 cmH ₂ O – APL 10 cmH ₂ O	-5.511 ^b	.001
APL 30 cmH ₂ O – APL 20 cmH ₂ O	-5.511 ^b	.001
APL 10 cmH ₂ O – APL 30 cmH ₂ O	-5.511 ^c	.001

As shown in Table 4, the Wilcoxon test results for all pairs of APL settings indicate a significant difference (Asymp. Sig. < 0.05). The mean tidal volume decreased from 247.05 mL at an APL setting of 10 cmH₂O to 219.01 mL at 20 cmH₂O, representing a reduction of 28.04 mL (11.35%). It further decreased to 200.76 mL at 30 cmH₂O, corresponding to a reduction of 18.25 mL (8.33%) from the 20 cmH₂O setting and 46.29 mL (18.74%) compared with the 10 cmH₂O setting. These findings indicate a progressive decrease in tidal volume as APL pressure increased.

Research Limitations

The study was conducted at only one hospital, so the generalizability of the results is limited. Measurements were conducted on patients with ASA status I–II, so they may not reflect patients with severe comorbidities. Clinical variation during the weaning phase, so there is potential for clinical variation between patients. Individual factors such as lung compliance and spontaneous breathing strength could not be fully controlled. The study only measured tidal volume without assessing its effect on other parameters such as EtCO₂. The sample size was limited, so further research with a larger sample size is needed.

Discussion

The results showed a significant effect of each APL valve setting on spontaneous tidal volume during general anesthesia weaning. The highest average tidal volume was 247.05 mL at an APL setting of 10 cmH₂O, then decreased to 219.01 mL at an APL setting of 20 cmH₂O, and then to 200.76 mL at an APL setting of 30 cmH₂O. The Friedman test showed a p-value of <0.001, indicating a significant difference between the APL setting groups.

In adult patients undergoing spontaneous weaning using an anesthesia machine, higher APL settings (20–30 cmH₂O) tended to decrease VT and increase PIP compared to an APL setting of 10 cmH₂O. This relates to the theory that a more closed APL valve increases pressure and the risk of barotrauma/volutrauma, while one that is too open can decrease VT and trigger hypoventilation or atelectasis.

Physiologically, increased APL valve pressure increases resistance to gas flow in the anesthesia circuit. This increased resistance results in the patient requiring greater inspiratory effort to produce the same volume of air. During the weaning phase, when the patient begins to take over spontaneous ventilation, this increased resistance can reduce the patient's achievable tidal volume.

The present study demonstrated that changes in APL valve settings were associated with significant changes in spontaneous tidal volume during anesthesia weaning. This finding is consistent with recent evidence showing that APL valves may exhibit variable flow-pressure characteristics and that their performance can influence airway pressure and tidal volume. Buehler (2023) demonstrated clinically relevant variability in APL valve performance, including nonlinear pressure behavior, emphasizing that the relationship between APL setting and airway pressure may not always be strictly linear. Similarly, Spinney and Sprigge (2021) reported differences in flow-pressure characteristics among APL valves, indicating that valve setting and valve characteristics may influence pressure regulation within the breathing circuit. These findings support the physiological interpretation of the present study, in which increasing APL settings from 10 to 20 and 30 cmH₂O were accompanied by progressive reductions in mean spontaneous tidal volume.

The novelty of this study lies in the direct clinical comparison of three APL valve settings (10, 20, and 30 cmH₂O) within the same patients during the anesthesia weaning phase. Recent research on APL valve performance has included experimental lung-model testing evaluating airway pressure and inspiratory tidal volume at different APL settings. Buehler et al. evaluated an adapted APL valve using baby and adolescent lung models and demonstrated changes in airway pressure and tidal volume associated with valve adjustment (Buehler et al., 2023). In contrast, the present study provides clinical data obtained from the same patients at three different APL settings during the transition toward spontaneous breathing. This within-patient comparison provides additional clinical evidence regarding the relationship between APL settings and spontaneous tidal volume during anesthesia weaning.

From a clinical perspective, these findings suggest that APL valve adjustment during anesthesia weaning should be considered in relation to tidal volume and airway pressure rather than relying solely on a fixed valve setting. Recent clinical research in adult patients compared pressure-controlled facemask ventilation with manual facemask ventilation during induction of general anesthesia, with the APL valve set at 11 cmH₂O in the manual ventilation group (Edmark et al., 2023). Therefore, the findings of the present study provide additional clinical information regarding APL valve adjustment during the transition from controlled to spontaneous breathing and support consideration

of tidal volume and airway pressure when evaluating ventilation during anesthesia weaning.

CONCLUSION

There is a significant difference in spontaneous tidal volume resulting from variations in APL valve settings (10, 20, and 30 cmH₂O), with tidal volume being inversely proportional to the APL pressure level. Conversely, increasing the APL setting is directly proportional to the rise in Peak Inspiratory Pressure (PIP). Clinically, these findings underscore that using high APL valve pressures during weaning risks limiting the patient's tidal volume and increasing the PIP load, thereby necessitating closer observation and caution when weaning process.

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