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# Airway pressure release ventilation in comparison to synchronized intermittent mandatory ventilation in acute respiratory failure: a randomized controlled trial

Dalia A. Abdel Rahman[a], Samy M. Alnaggar[b], Ahmed M. Tawfik[c], Waleed Mansour[d]

Departments of [a]Pediatrics, [b]Internal Medicine, [c]Anesthesia, [d]Chest Diseases, Zagazig University, Zagazig, Egypt

Correspondence to Dalia A. Abdel Rahman, MD, PhD, Department of Pediatrics, Faculty of Medicine, Zagazig University, Zagazig, 11865, Egypt. Tel: +20 115 883 2999; fax: +20 552 307 830; e-mail: daabdelrahman@zu.edu.eg, drdalia2811@gmail.com

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**Background**
The main goal of mechanical ventilation is to support the respiratory drive safely and optimally. The authors are always transitioning through modes of mechanical ventilation either traditional or novel modes, trying to find out the optimum for each ventilation purpose. Recently, airway pressure release ventilation (APRV) has been digging through causes of respiratory failure, as a promising and challenging mode with interesting achievements throughout the clinical trials and case reports. Specially in critically ill patients with severe respiratory failure by means of offering a protective lung strategy throughout, recruiting it safely with better outcomes. Thoroughly, the authors aimed from this study to explore the hidden potentials of APRV mode as a safe recruiting mode could improve the gas exchange by increasing the surface area and maintain the opened alveoli for a while to get rid of inflammatory edema in comparison to the default ventilation mode in any type of respiratory failure.

**Patients and methods**
Single-blinded, randomized, controlled trial, which included 152 pediatric patients (56 men and 96 women) in an age range of 8 months to 17 years, who were admitted to the intensive care units either in Pediatrics, Chest Diseases, Anesthesia, or Internal Medicine Departments, Zagazig University Hospitals, Egypt, with acute respiratory failure. Of the patients, 76 were assigned to APRV mode and the other 76 patients were assigned to synchronized intermittent mandatory ventilation mode during a period from April 2017 to Jun 2019. Follow-up of arterial blood gases, ventilatory parameters, and vital signs were recorded. Primary and secondary outcomes including duration of ventilation, weaning outcome, and rate of mortality were documented.

**Results**
No significant difference was found between the APRV group and the synchronized intermittent mandatory ventilation group regarding mortality, complications, and weaning outcome. However, there was significant difference between outcomes of the challenging cases labeled acute respiratory distress syndrome and pulmonary edema connected to APRV.

**Conclusion**
The APRV mode showed superiority in supporting acute respiratory distress syndrome and pulmonary edema patients, with no higher risk of mortality or complications.

**Keywords:**
airway pressure release ventilation, acute respiratory distress syndrome, pulmonary edema, respiratory failure

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## Introduction

Nothing is more common than respiratory causes for sickness and death in critically ill pediatric patients. Also, it takes the largest share in the pediatric ICU admission. Despite the relentless efforts of research and the nonstop clinical trials many of the newer modalities of mechanical ventilation are not specific for the pediatric age group causing that obvious lack of guidelines and protocols [1].

Mechanical ventilation is the intervention aimed to buy some time for the disabled pulmonary drive to take a break for healing and proceed working on its own. Supportive care is the intensivist mission to save the

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child's life as in the situation of acute respiratory failure [2].

Children are not small adults. They need specific guidelines according to their physiological needs. That is why every parameter of mechanical ventilation should be tailored according to their age and body weight [3].

Airway pressure release ventilation (APRV) is one of the new promising modes in the challenging difficult cases of acute respiratory failure. It was first described in 1987 and showed marvelous results in cases of acute respiratory distress syndrome (ARDS) and it replaced the mode of choice in that time for these cases which is high-frequency ventilation in many centers before shifting from mechanical ventilation to extracorporeal membrane oxygenation [4].

APRV works just like continuous positive airway pressure (CPAP), but during expiration this mode allows some escape of air outside the lung carrying $CO_2$ and giving the patient extra unique chance to enjoy spontaneous breathing. The splinting inspiratory pressure walks a mile for the patients during inspiration and spares him some metabolic load [5]. We aimed from this study to explore the hidden potentials of APRV mode as a safe recruiting mode could improve the gas exchange by increasing the surface area and maintain the opened alveoli for a while to get rid of inflammatory edema in comparison to our default ventilation mode in any type of respiratory failure.

## Patients and methods

This is a sngle-center randomized clinical trial conducted in Pediatric, Chest Diseases, Anesthesia, and Internal Medicine Intensive Care Units of a Tertiary-Care University Hospital in Egypt, in a period between April 2017 and June 2019.

### Patients

The study included 152 patients of both sexes with respiratory failure and indicated for invasive mechanical ventilation, who were admitted to the intensive care unit in the age range of 1 month to 17 years. According to our sample size randomization takes place; the odd numbers were assigned to synchronized intermittent mandatory ventilation (SIMV) and the even numbers were assigned to APRV. Group I included 76 children connected to the conventional mode of mechanical ventilation. Group 2 included 76 children connected to the APRV. If some patients were duplicated those patients were removed.

We excluded patients with air leaks or blood pressure below the normal for age.

We started orientation lectures for the junior and senior staff members of the pediatric ICUs about APRV protocols and guidelines. We gained the consent from the parent's and from our University Ethics Committee.

Ethical Committee Approval No. 3539/23-4-2017.

### Sampling

Assuming that the success rate of the novel method vs the traditional method is 19 and 41%, respectively, the sample size is calculated by Epi-Info to be 152 cases (76 in each group) with the confidence level being 95% and power of the test being 80%.

### Study technique

In the APRV group we followed the latest pediatric guidelines published by Habashi [5]. Some interventions were individualized according to each case scenario. We used Bellavista 1000 intensive care ventilators to implement this work.

Initial P-high was calculated equal to the latest plateau pressure (P-plat) if the case was shifted from SIMV (maximum 30 cm) or according to the age mentioned in Habashi guidelines [5].

P-low is mostly around 0 to ensure adequate release of $CO_2$ and lung evacuation; we were very cautious to avoid the wide gap between P-high and P-low to avoid lung injury.

T-high and T-low were set as per the demanded frequency of releases according to the age and weight. After initial stabilization, P-high was adjusted to maintain adequate saturation, $FiO_2$ started high above 60% and then titrated down gradually according to $O_2$ saturation. Chest radiograph was done to ensure adequate lung aeration with continuous monitoring of hemodynamics. We scaled down the P-high if domes of the diaphragm were visible below the ninth posterior rib or were flattened on chest radiograph.

As patient's clinical condition and oxygenation index (OI) improved, $FiO_2$ levels were eagerly titrated down upon improvement of patient's clinical condition, which is determined by improvement on chest radiograph and $O_2$ saturation. T-low was increased

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by 0.5–2 s to 10–12 s. P-high was simultaneously decreased by 2 cm $H_2O$ to 12–16 cm $H_2O$. We then switched either to CPAP of 8–10 cm $H_2O$ or high flow nasal cannula.

In the SIMV ventilation group, we used lung-protective, low-tidal volume ventilation according to the patient's age and surface area. We observed improvement of lung expansion, oxygenation, and tolerated low $FiO_2$ to guide weaning along with clinical improvement in the work of breathing and laboratory data such as arterial blood gas. Weaning process from the SIMV mode started with reducing PIP 2 by 2 together with reducing $FiO_2$ 5 by 5 and rate alternatively according to the ABG reading and patient's breathing effort. Spontaneous breathing trial starts on CPAP or PSV for 90–120 min and according to ABG reading and work of breathing extubation decision was taken.

Weaning failure is considered if the patient is distressed or there was unacceptable change in ABG readings or $O_2$ saturation during the weaning process or within the first 48 h after extubating him.

All the patient's data were recorded on a preset master sheet. Pediatric index of mortality included PIM2 score, changes in ventilatory settings, arterial blood gases, P : F ratio, OI, sedative agents used, hemodynamic status, fluid balance, chest radiography, and other laboratory parameters. We registered all ventilation parameters such as P-high, P-low, T-high, T-low, mean airway pressures, respiratory rates, hourly for the first 24 h and 24 h thereafter. We used the following equation for mean airway pressure calculation (MAP) in the APRV mode:

$$(\mathrm{P-high} * \mathrm{T-high}) + (\mathrm{P-low} * \mathrm{T-low})/(\mathrm{T-high} + \mathrm{T-low})$$

We also calculate the OI by the following equation:

$$\mathrm{MAP(in\ cmH_2O)} \times \mathrm{FiO_2} \times 100 \div \mathrm{PaO_2}$$

We followed all patients during the whole duration of mechanical ventilation. All data were obtained regarding mortality, length of ICU stay, and complications. If the patient was not improving on one of the initial assigned mode, he was shifted automatically to the other mode and recorded as failed mode of ventilation.

### Statistical analysis

Data were statistically analyzed by version 24 of the Statistical Package for the Social Sciences program (SPSS) version 21 (SPSS Data: IBM Corp. released 2011, IBM SPSS statistics for windows, Version 20.0 Armonk, NY: IBM Corp.). Continuous data were described by mean±SD while categorical data were described by number and percentage. We use independent *t*-test to determine if a difference is present between the independent groups. Mann–Whitney *U* test is a nonparametric alternative test for *t*-test. $\chi^2$-test is used in relation of categorical data. *P* value less than 0.05 is statistically significant, *P* value less than 0.01 is highly significant, and *P* value less than 0.001 is considered of very high significance. We use Fisher's exact test as an alternative for $\chi^2$-test when the expected cell count is less than 5.

### Ethics

The study was performed in accordance with the Ethical Standards of the 1964 Declaration of Helsinki, as revised in 2000 and it was approved by the Ethics Committee of Zagazig University (Zagazig, Egypt). Ethics Committee Approval No. 3539/23-4-2017.

## Results

The studied patients were heterogenous groups as it showed nonsignificant difference regarding their age, gender, or weight, so it showed good randomization. But if talking about the cause of ventilation and PIM2 score, data showed significant difference between both the studied patient's groups($P<0.05$). It was noticed that patients ventilated because of overload and pulmonary edema due to renal failure responded more with the APRV mode, while patients ventilated due to neurological causes of respiratory failure showed better improvement on SIMV mode. PIM2 score on initial assessment was higher in cases responded to APRV mode.

Interestingly, the studied data showed nonsignificant difference between both ventilation mode groups when comparing the occurrence of complications and mortality risk. APRV significantly showed a shorter duration of ventilation (median 2 days) in comparison to SIMV patients' group (median 7 days) (Table 1).

Moving on to the arterial blood gas changes, we observed that the SIMV mode showed better wash of $PaCO_2$ than the APRV mode with significant difference between them ($P=0.013$). Also, SIMV was superior than APRV in improving oxygenation parameters with lower MAP and $FiO_2$ requirements, but this did not reach significant difference (Table 2).

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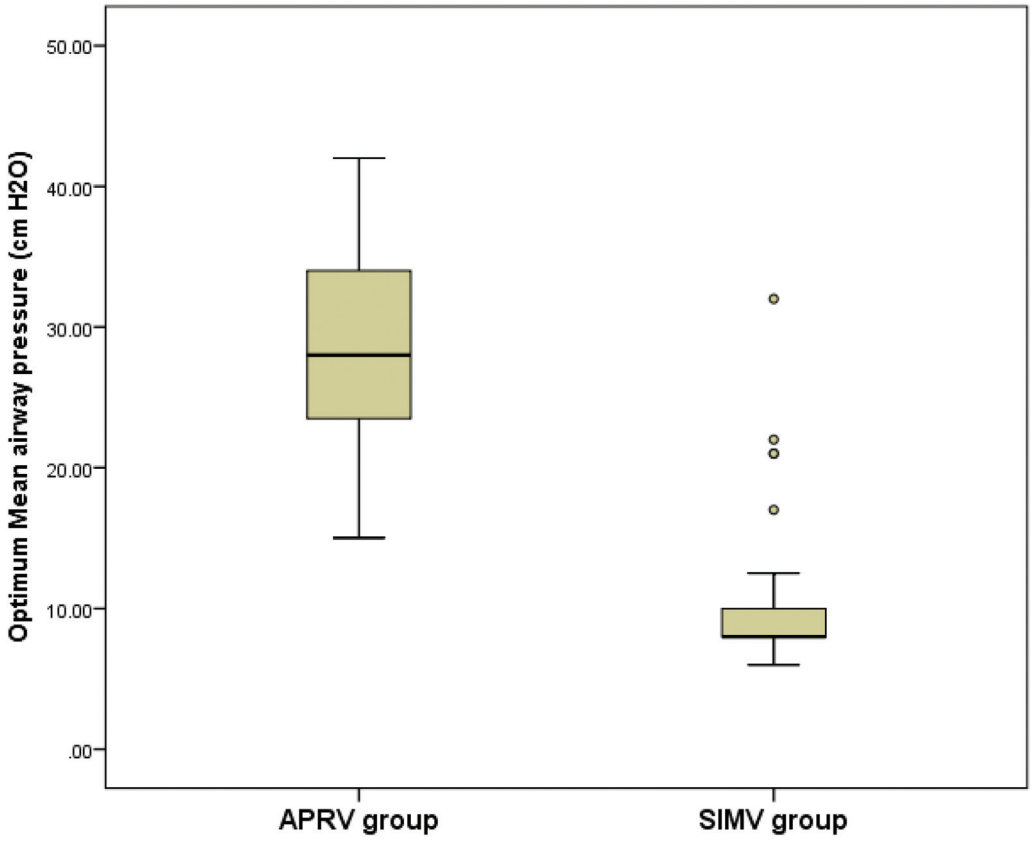
**Table 1 Comparison between the studied groups regarding demographic data, diagnosis, PIM2 score and complications, and duration of ventilation**

| Variables | APRV (*N*=76) [*n* (%)] | SIMV (*N*=76) [*n* (%)] | Test of significance | *P* value |
|---|---|---|---|---|
| Sex | | | | |
| Male | 30 (39.5) | 26 (34.2) | 0.452 | 0.501 |
| Female | 46 (60.5) | 50 (65.8) | | |
| Age (years) | | | | |
| Median | 2 | 1.5 | −0.882 | 0.378 |
| Range | 0.08–17 | 0.08–17 | | |
| Weight percentiles | | | | |
| <5th percentile | 5 (6.6) | 7 (9.2) | 0.037 | 0.848 |
| 5th to 95th percentile | 65 (85.5) | 60 (78.9) | | |
| >95th percentile | 6 (7.9) | 9 (11.8) | | |
| Diagnosis | | | | |
| Respiratory causes | 40 (52.6) | 42 (55.3) | 0.039 | 0.843 |
| Hematological diseases | 8 (10.6) | 2 (2.6) | 4.15 | 0.098 |
| Endocrine diseases | 0 | 2 (2.6) | 1.118 | 0.497 |
| Neurological disease | 7 (9.2) | 16 (21) | | 0.042* |
| Renal disease | 15 (19.7) | 4 (5.3) | | 0.013* |
| Miscellaneous diseases | 6 (7.9) | 10 (13.2) | | 0.29 |
| PIM2 score | −3.14±0.99 | −3.47±0.64 | 2.4 | 0.018* |
| Mortality percent | 5.86±7.76 | 3.61±3.31 | −0.18 | 0.852 |
| Complications | | | | |
| None | 68 (89.5) | 75 (98.7) | 7.343 | 0.062 |
| Hypercapnia | 6 (7.9) | 0 | | |
| Hypotension | 1 (1.3) | 0 | | |
| Pneumothorax | 1 (1.3) | 1 (1.3) | | |
| Duration of ventilation days | 2 (1–7) | 7 (1–120) | 8.421 | <0.001** |

APRV, airway pressure release ventilation; PIM2, pediatric index of mortality; SIMV, synchronized intermittent mandatory ventilation.

**Figure 1**




Boxplot showing optimum mean airway pressure ($cmH_2O$) among the studied groups.

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**Table 2 Comparison between the studied groups regarding percent change in ABG and MAP findings during the ventilation and weaning process**

| Variables | APRV group | SIMV group | Test of significance | *P* value |
|---|---|---|---|---|
| | Median of percent change | | | |
| PH | 1.42 | 1.66 | −0.932 | 0.351 |
| $PaCO_2$ | −3.47 | −19.64 | −2.489 | 0.013* |
| $PaO_2$ | 79.14 | 77.43 | −0.426 | 0.67 |
| $O_2$ saturation | 15.05 | 22.79 | −1.769 | 0.077 |
| $FiO_2$ | −31.67 | −41.67 | −1.171 | 0.242 |
| $PaO_2/FiO_2$ | 187.1 | 216.28 | −1.544 | 0.123 |
| MAP | −15.3 | −28 | −4.312 | <0.001** |
| OI | −72.82 | −74.13 | −0.824 | 0.41 |

APRV, airway pressure release ventilation; $FiO_2$, fractional of inspired oxygen; MAP, mean arterial pressure; OI, oxygenation index; $PaO_2$, arterial pressure of $O_2$; $PaCO_2$, arterial pressure of $CO_2$; SIMV, synchronized intermittent mandatory ventilation.

**Table 3 Relation between the type of respiratory failure and patient outcome among the studied groups**

| Outcomes | APRV [*n* (%)] | | | | SIMV [*n* (%)] | | | |
|---|---|---|---|---|---|---|---|---|
| | Hypercapnic (*N*=2) | Hypoxic (*N*=58) | Mixed (*N*=16) | *P* | Hypercapnic (*N*=4) | Hypoxic (*N*=56) | Mixed (*N*=16) | *P* |
| Death | 0 | 19 (32.8) | 3 (18.8) | | 0 | 17 (30.4) | 4 (25) | |
| Failed weaning | 2 (100) | 9 (15.5) | 5 (31.2) | 0.04* | 0 | 5 (8.9) | 1 (6.2) | 0.61 |
| Successful weaning | 0 | 30 (57.1) | 8 (50) | | 4 (100) | 34 (60.7) | 11 (68.8) | |

APRV, airway pressure release ventilation; SIMV, synchronized intermittent mandatory ventilation.

**Table 4 Comparison between cases of acute respiratory distress syndrome regarding the change in oxygenation over time and subsequent patients' outcome among the studied groups**

| | Mean±SD | | *P* value |
|---|---|---|---|
| Variables | APRV (*N*=45) | SIMV (*N*=21) | |
| $PaO_2$ | 100.47±88.6 | 100.5±51.46 | 0.5 |
| $O_2$ saturation | 85.78±6.73 | 84.67±10.57 | 0.443 |
| $PaO_2/FiO_2$ | 217.39±103.76 | 175.57±95.64 | 0.007* |
| OI | 58.76±29.47 | 50.58±17.11 | 0.039* |
| Outcome | ARDS | | |
| Death | 16 (35.6) | 7 (33.3) | |
| Failed weaning | 5 (11.1) | 14 (66.7) | <0.001** |
| Successful weaning | 24 (53.3) | 0 | |

APRV, airway pressure release ventilation; ARDS, acute respiratory distress syndrome; $FiO_2$, fractional of inspired oxygen; MAP, mean arterial pressure; OI, oxygenation index; $PaO_2$, arterial pressure of $O_2$; $PaCO_2$, arterial pressure of $CO_2$; SIMV, synchronized intermittent mandatory ventilation.

The APRV mode created higher MAP values (mean ±SD=28.12±6.12 mmHg) than the SIMV mode (mean±SD=9.64±4.01 mmHg) with significant difference between both modes ($P<0.001$**). Data are represented in Fig. 1, Table 2.

We noticed a significant relation between patient outcome on each mode and type of respiratory failure; cases on APRV group (all patients with hypercapnic respiratory failure) had failed (100%) while the largest percentage of those with hypoxic (30%) or mixed respiratory failure (8%) had successful progress to weaning. Moving to cases plotted on SIMV mode it did not show any significance difference or superiority of the outcome in relation to the type of respiratory failure. Data are summarized in Table 3.

Patients who fulfilled the criteria of ARDS and had reached successful ventilatory goals were higher in the APRV group (45%) compared with the SIMV group (21%), with significant difference between them ($P<0.001$). If we looked at the oxygenation parameters and arterial blood gas changes among those patients 'who had special interest working on it,' we found that there was significance difference between both modes regarding OI and $PaO_2/FiO_2$ improvement ($P$=0.039 and 0.007), respectively. Also, ARDS patients on APRV mode showed better outcome, as 53.3% of them had successful weaning to 0% on the SIMV group; 66.7% of patients faced

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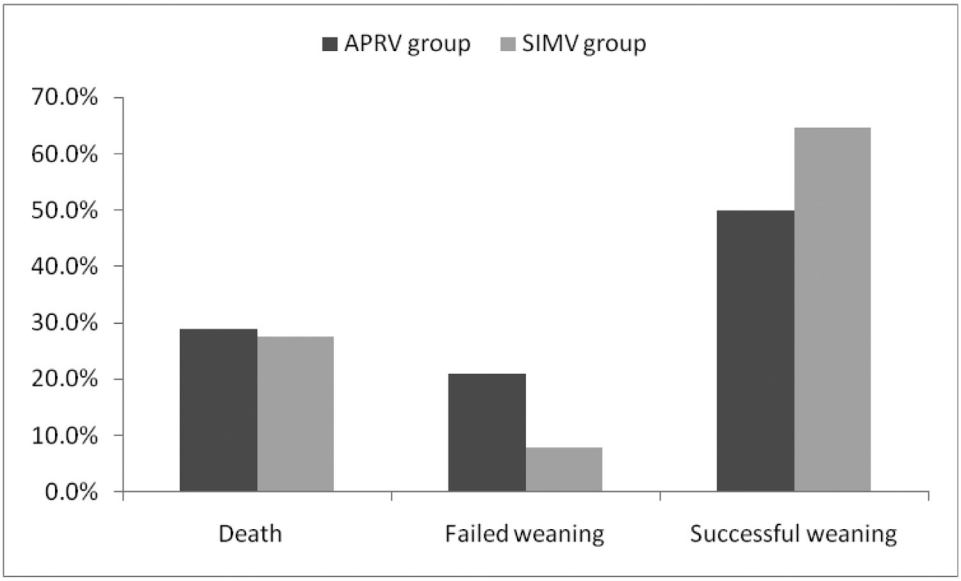
**Figure 2**




Combined bar chart showing distribution of the studied groups according to the patient outcome.

**Table 5 Comparison between changes of ABGs, oxygenation indices, and outcome of pulmonary edema cases on APRV and SIMV modes**

| | Mean±SD | | *P* value |
|---|---|---|---|
| Variables | APRV (*N*=16) | SIMV (*N*=21) | |
| $PaO_2$ | 78.06±34.15 | 66.37±60.43 | 0.326 |
| $O_2$ saturation | 15.65±24.05 | 7.79±20.38 | 0.461 |
| $PaO_2/FiO_2$ | 238.38±226.3 | 159.37±155.7 | 0.231 |
| OI | –58.37±37.41 | –31.46±43.91 | 0.038* |
| Outcome | Pulmonary edema | | |
| Death | 2 (12.5) | 0 | |
| Failed weaning | 5 (31.3) | 16 (76.2) | 0.015* |
| Successful weaning | 9 (56.2) | 5 (23.8) | |

APRV, airway pressure release ventilation; $FiO_2$, fractional of inspired oxygen; MAP, mean arterial pressure; OI, oxygenation index; $PaO_2$, arterial pressure of $O_2$; $PaCO_2$, arterial pressure of $CO_2$; SIMV, synchronized intermittent mandatory ventilation.

failure of ventilation on SIMV mode to 11.1% on APRV mode with significant difference between both groups ($P<0.001^{**}$). Data are summarized in Table 4.

As for the outcome of the overall cases regarding failure or success of weaning, nonsignificant difference was found between the two modes. However, there was slightly higher number of patients weaned successfully on SIMV 64.5–50% on APRV. Also, there was no significant difference in mortality on APRV there was 28.9% mortality vs 27.6% on SIMV (Fig. 2).

During the study, we faced a finding that we did not expect which concluded a very good outcome of cases presented with pulmonary edema due to overload especially those of renal failure origin. There was significant difference in the degree of OI improvement and outcome between those cases assigned to APRV in comparison to SIMV (APRV: 58.37±37.41), (SIMV: 31.46±43.91) with higher weaning success rate. And this difference was statistically significant ($P<0.05$) (Table 5).

## Discussion

All intensivists always familiar with conventional modes of ventilation delivered a predetermined tidal volume generated by a preset inspiratory pressure, which is much different from the APRV mode which delivers a constant pressure at the inspiratory cycle and then suddenly drops that pressure during expiration to allow some exhalation of expiratory volume, hence clearing of the airway and exhalation occurs rapidly, then again inflates the lungs maximally. That is what makes APRV so unique in recruiting the diseased lung [6].

Going through the literature we had a lot to compare and to discuss. We have carried in our minds upon performing this study to try to find the best protocols and approaches for APRV settings in the pediatric population, in order to know in which disease entity APRV is superior, and what are the complications vs opportunities of APRV.

We are very proud to say that ours is the largest pediatric clinical trial done to compare APRV mode with the conventional mode of mechanical ventilation. And the third largest one in both pediatrics and adults after a study done by Gonzale *et al.* [7], which included

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468 cases and another study done by Maung *et al*. [8] which included 362.

By looking to the changes in ABG readings and compare them in the two groups, we found that the APRV mode creates more MAP for better improvement in oxygenation parameters in comparison to SIMV which showed superiority in $CO_2$ clearance.

A similar study by Zhou and colleagues concluded that APRV is superior to SIMV in improving oxygenation. Also, a case series done by Garcia showed improvement of oxygenation only in cases that were plotted electively to APRV, but not in rescue cases [6,9].

However, a study conducted by De Carvalho and colleagues did not report any difference in oxygenation between APRV and SIMV cases [10].

Cases on APRV required more $FiO_2$ to improve oxygenation that can be explained by the fact that most of the cases on APRV mode were assigned to it in rescue mode, so typically those cases have much worse lung condition and in need of higher parameters to achieve the minimal improvement in oxygenation. This is in contrast to the Zhou *et al*. [6] study which displayed a lower $FiO_2$ in the APRV group, but that study was a case-matched one. However, both cases were similar in their initial parameters. Another study by Maxwell stated that no difference was observed in $FiO_2$ requirement for cases on APRV and SIMV [11]. That would guide us once again to use more case-matched studies and to encourage more elective use of APRV.

By observing the difference in improvement of $PaO_2/FiO_2$ and OI and their change over time, there was no significant difference between the cases plotted to APRV and SIMV. SIMV showed a little higher reading regarding $PaO_2/FiO_2$, while APRV showed better improvement in OI. But that change did not reach any significant statistical difference.

In other words, it means that even though cases assigned to APRV were worse than those assigned to SIMV, SIMV did not manage to show any higher superiority regarding those two parameters and APRV did not prove a failure.

By revising the literature, a study by Ganesan showed a higher $PaO_2/FiO_2$ by APRV mode vs SIMV mode. Also, the same was noticed in a study conducted by Hanna and colleagues [12,13].

Moving to the duration of mechanical ventilation. Cases plotted to APRV showed shorter duration of mechanical ventilation, a mean of 2 days vs a mean of 7 days in cases plotted to SIMV.

However, much lies beneath this finding. First, is the rescue mode used in APRV cases that succumbed to death early, especially those cases plotted in a terminal illness or crossed over after SIMV consumption of time and failure. However, even cases plotted initially to APRV required much shorter duration than those on SIMV according to its guidelines. Second, a few number of cases plotted to SIMV were of chronic nature like SMA or peripheral neuropathy.

Maung Adrian and colleagues and Maxwell and colleagues agreed with us regarding the duration of ventilation in APRV cases which stayed longer on mechanical ventilation [8,14].

Another study by Varpula *et al*. [15] showed no difference between the length of stay on mechanical ventilation between APRV and SIMV modes.

APRV has been incriminated for a higher rate of complication in the studies done throughout literature [16]. Those complications included mainly pneumothorax, hypercapnia, or hypotension, and we indeed encountered them, but we have to say that it did not reach any statistical difference. There was only two cases of hypotension and pneumothorax and six cases developed hypercapnia. Maung Adrian *et al*. [8] and Lim *et al*. [16] reported complications such as pneumothorax.

Regarding the overall outcome of the studied cases, weaning failure or success and mortality rate in both modes were insignificantly different.

A study by Ganesan and colleagues showed higher failure rate in APRV cases. Also, another study done by Maxwell and colleagues showed increased mortality in cases assigned to APRV; however, this was justified by them that APRV cases were worse than SIMV [11,12].

But the literature did not stop here as many studies showed a lower mortality rate with the APRV mode, especially those in case-matched studies. Zhou and colleagues and other studies observed similar mortality rates [6,13,15,17].

In our study, we had a special interest in observing cases that fulfilled the criteria of ARDS regarding the

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outcome and the improvement in blood gas parameters on both APRV and SIMV.

Cases assigned to APRV have a higher percentage of achieving the ARDS criteria, 45% vs 21% in cases on SIMV and that was a significant difference. It was observed that the APRV mode showed better improvement in $PaO_2$ saturation in ARDS cases, and OI but did not reach significant difference. However, SIMV showed more improvement in non-ARDS cases.

APRV has higher success rate regarding weaning with lower mortality rate in ARDS cases. In contrast, a study by Ganesan et. al. observed higher mortality rate with the APRV mode, while the Zhou and colleagues study was similar to our study results [6,12]. Another comparative study by Kawaguchi *et al.* [17] concluded an improvement in ARDS cases on APRV than the SIMV mode.

Our study is the first to document the superiority of APRV in cases of pulmonary edemas apart of overload due to acute renal failure. This finding clearly needs more studies to be validated and it can be explained according to the technique of APRV and its opportunity in maximum expansion of the alveoli for the maximum time could allow the maximum gas exchange with splinting the lung to a more favorable area on the pressure volume curve. Cases with fluid overload clearly have more fluid inside and outside the lungs. The ability of APRV to remove excess fluid during each release, as we noticed in our patient, played a role. The improved renal perfusion due to less cardiovascular impedance and liberated cardiac motion could also be a factor. That also could be facilitated by more spontaneous breathing chances that patients enjoyed on APRV.

### Study limitation

Lack of a standardized approach to follow to the extent that we had to improvise and individualize the decision for each case and that held us from using an elective mode for APRV as we were not sure of what to expect.

## Conclusion

APRV mode is an optimum mode in cases with ARDS and pulmonary edema as it dramatically improves oxygenation and provides miraculous weaning success in a short time with maintaining gas exchange balance and hemodynamic stability during the management of the underlying cause.

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All authors agreed for publication in journal.

The datasets generated or analyzed during this study are available from the corresponding author on reasonable request.

Dalia A. Latif put the study idea and design, collected cases, wrote the manuscript, and prepared it for publication; Samy El-Naggar shared in cases enrollment, revised the manuscript, and shared in publication; Ahmed Mostafa shared in cases enrollment, revised the manuscript, and shared in publication; Waleed Mansour manuscript revision, shared in the publication process; all authors read and approved the final manuscript.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

## References

1 Conti G, Piastra M. Mechanical ventilation for children. Curr Opin Crit Care 2016; 22:60–66.

2 Newth CJ, Khemani RG, Jouvet PA, Sward KA. Mechanical ventilation and decision support in pediatric intensive care. Pediatric Clin 2017; 64:1057–1070.

3 Jain SV, Kollisch-Singule M, Sadowitz B, *et al.* The 30-year evolution of airway pressure release ventilation (APRV). Intensive Care Med Exp 2016; 4:11.

4 Modrykamien A, Chatburn RL, Ashton RW. Airway pressure release ventilation: an alternative mode of mechanical ventilation in acute respiratory distress syndrome. Cleve Clin J Med 2011; 78:101–110.

5 Habashi M. Other approaches to open-lung ventilation: airway pressure release ventilation. Crit Care Med 2005; 33:S228–S240.

6 Zhou Y, Jin X, Lv Y, Wang P, Yang Y, Liang G, *et al.* Early application of airway pressure release ventilation may reduce the duration of mechanical ventilation in acute respiratory distress syndrome. Intensive Care Med 2017; 43:1648–1659.

7 González M, Arroliga AC, Frutos-Vivar F, Raymondos K, Esteban A, Putensen C, *et al.* 'Airway pressure release ventilation vs assist-control ventilation: a comparative propensity score and international cohort study. Intensive Care Med 2010; 36:817–827.

8 Maung AA., Luckianow G, Kaplan LJ. Lessons learned from airway pressure release ventilation. J Trauma Acute Care Surg 2012; 72:624–628.

9 Garcia P, Henry J, Hughes S, Boylan C. A case series of infants on APRV in the neonatal ICU.1 página. Recuperado el 2000; 2: Acta méd. costarric vol. 55 n.2 San José Apr./Jun. 2013.

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**10** De Carvalho WB, Kopelman BI, Gurgueira GL, Bonassa J. Airway pressure release ventilation in post-operative cardiac surgery in pediatric patients. Rev Assoc Méd Bras 2000; 46:166–173.

**11** Maxwell RA, Green JM, Waldrop J, Dart BW, Smith PW, Brooks D, *et al.* A randomized prospective trial of airway pressure release ventilation and low tidal volume ventilation in adult trauma patients with acute respiratory failure. J Trauma Acute Care Surg 2010; 69:501–511.

**12** Lalgudi Ganesan S, Jayashree M, Chandra Singhi S, Bansal A. Airway pressure release ventilation in pediatric acute respiratory distress syndrome.A randomized controlled trial. Am J Respir Crit Care Med 2018; 198:1199–1207.

**13** Hanna K, Seder CW, Weinberger JB, Sills PA, Hagan M, Janczyk RJ. Airway pressure release ventilation and successful lung donation. Arch Surg 2011; 146:325–328.

**14** Dart BW 4th, Maxwell RA, Richart CM, Brooks DK, Ciraulo DL, Barker DE, *et al.* Preliminary experience with airway pressure release ventilation in a trauma/surgical intensive care unit. J Trauma Acute Care Surg 2005; 59:71–76.

**15** Varpula T, Valta P, Niemi R, Takkunen O, Hynynen M, Pettilä V. Airway pressure release ventilation as a primary ventilatory mode in acute respiratory distress syndrome. Acta Anaesthesiol Scand 2004; 48:722–731.

**16** Lim J, Litton E, Robinson H, Gupta MD. Characteristics and outcomes of patients treated with airway pressure release ventilation for acute respiratory distress syndrome: a retrospective observational study. J Crit Care 2016; 34:154–159.

**17** Kawaguchi A, Guerra GG, Duff JP, Ueta I, Fukushima R. Hemodynamic changes in child acute respiratory distress syndrome with airway pressure release ventilation: a case series. Clin Respir J 2015; 9:423–429.