Airway Pressure-Release Ventilation in Pregnant Patients With Acute Respiratory Distress Syndrome: A Novel Strategy

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BACKGROUND: Airway pressure-release ventilation (APRV) is a novel mode of positive-pressure ventilation that has several advantages over low-tidal-volume, assist-control ventilation in patients with acute respiratory distress syndrome, specifically, lower airway pressures, lower minute ventilation, minimal effects on cardio-circulatory function, ability to spontaneously breathe throughout the entire ventilatory cycle, and decreased sedation requirements. APRV is consistent with lung-protective strategies that aim to limit lung injury associated with mechanical ventilation. APRV utilization in obstetrical patients has not previously been reported. CASES: We present 2 cases of pregnant women with severe life-threatening ARDS who were successfully managed with APRV. CONCLUSIONS: APRV may have particular utility in pregnant patients with ARDS. We believe APRV was life-saving in our cases. APRV ventilation should be considered in pregnant patients with ARDS. *Key words: airway pressure-release ventilation, APRV, acute respiratory distress syndrome, ARDS, pregnancy*. [Respir Care 2009;54(10):1405–1408. © 2009 Daedalus Enterprises]

Introduction

Airway pressure-release ventilation (APRV) is a novel mode of positive-pressure ventilation that has a number of advantages over low-tidal-volume (V_T), assist-control ventilation in patients with the acute respiratory distress syndrome (ARDS). APRV, available in the United States since the mid-1990s, differs fundamentally from conventional positive-pressure ventilation. Whereas conventional modes of ventilation begin the ventilatory cycle at a baseline pressure and elevate airway pressure to accomplish tidal ventilation, APRV commences at an elevated baseline pressure and follows with a deflation to accomplish tidal ventilation (Fig. 1). The high pressure (time high) facilitates oxygenation and lung recruitment, while the pressure release (time low) aids in carbon dioxide clearance.

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The authors have disclosed no conflicts of interest.

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APRV, first described by Stock and Downs in 1987,[1] is a time-triggered, pressure-limited, time-cycled mode of ventilation that allows unrestricted spontaneous breathing throughout the entire ventilatory cycle. APRV helps to meet the goals of ARDS management by maximizing alveolar recruitment while limiting the transalveolar pressure gradient and thereby lessening the risk of barotrauma.[2] APRV can be a lung-protection strategy that can minimize lung injury seen with mechanical ventilation.[3]

APRV may have particular utility in pregnant patients, whose lung volumes diminish with advancing pregnancy. APRV has, however, not been previously reported in obstetrical patients. We report a case series of 2 pregnant patients who developed pneumonia and severe life-threatening ARDS and were successfully managed with APRV.

Case Reports

Case 1

A 19-year-old primigravida was transferred from an outside hospital at 30 weeks of gestation, with worsening cough, fever, and shortness of breath. She had been hospitalized with respiratory symptoms for one week at the referring hospital, and was transferred because of worsening status. She was treated initially with ceftriaxone, ampicillin, and azithromycin for pneumonia. Her clinical con-

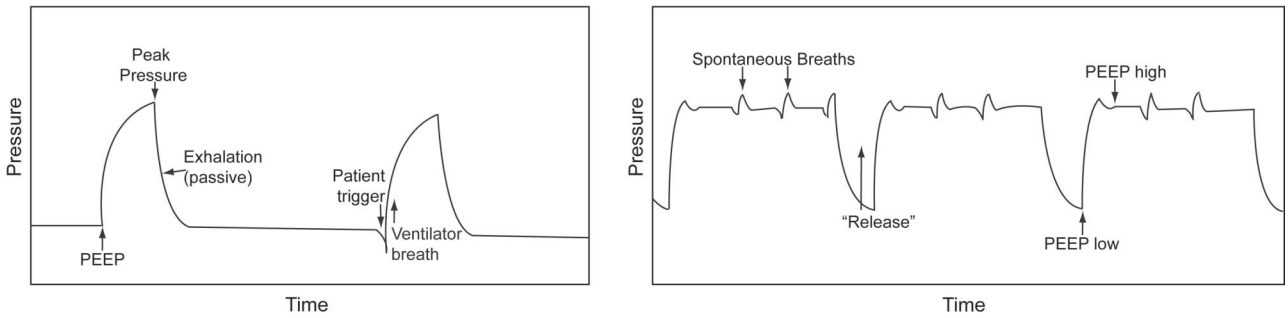

Fig. 1. Typical pressure-time curve of conventional ventilation (left) and airway pressure release ventilation (right). PEEP = positive end-expiratory pressure.

Table 1. Patient's Ventilator Mode and Its Effects

	Case 1		Case 2	
	1 h prior to APRV	6 h after APRV	Just prior to APRV	1 h 30 min after APRV
	PEEP 10 cm H_2O V_T 8 mL/kg IBW F_{IO_2} 0.9 Set respiratory rate 18 breaths/min	High PEEP 28 cm H_2O Low PEEP 8 cm H_2O Time low 1.0 s F_{IO_2} 0.9 Set respiratory rate 12 breaths/min	PEEP 14 cm H_2O V_T 7.5 ml/kg IBW F_{IO_2} 1.0 Set respiratory rate 20 breaths/min	High PEEP 33 cm H_2O Low PEEP 10 cm H_2O Time low 0.9 s F_{IO_2} 1.0 Set respiratory rate 14 breaths/min
pH	7.45	7.47	7.24	7.33
P_{aO_2} (mm Hg)	79	131	47	118
P_{CO_2} (mm Hg)	40	36	38	32
P_{aO_2}/F_{IO_2} (mm Hg)	87	145	47	118
Respiratory rate (breaths/min, including spontaneous breaths)	20	24	22	26
Mean arterial pressure (mm Hg)	76	91	67	77
Cardiac output (L/min)	ND	ND	6.8	6.7

APRV = airway pressure-release ventilation
PEEP = positive end-expiratory pressure
V_T = tidal volume
IBW = ideal body weight
ND = no data collected

dition worsened, her ratio of P_{aO_2} to fraction of inspired oxygen (P_{aO_2}/F_{IO_2}) was 87 mm Hg, and she had bilateral parenchymal infiltrates with frank respiratory failure progressing to ARDS, requiring endotracheal intubation and mechanical ventilatory support. In the medical intensive care unit (ICU) she had multiple diagnostic procedures, including a bronchoscopy and bronchoalveolar lavage, which revealed *Enterobacter cloacae* as the pathogen for her pneumonia and ARDS. Cultures of blood, urine, and amniotic fluid were negative.

Her hospital course was complicated by ileus, pancreatitis, and the need for tracheostomy for continued ventilatory support. Her oxygen requirement increased to an F_{IO_2} of 0.9, with a positive end-expiratory pressure of 10 cm H_2O on assist-control ventilation. As her respiratory condition had shown no improvement over the 2-week period at our hospital, it was decided to attempt APRV ventilation, followed by induction of labor. Her ventilatory mode was switched to APRV purely for hypoxia. There was a substantial change in the patient's oxygenation between the 2 ventilatory modes (Table 1). After switching to APRV, her F_{IO_2} requirement decreased to 0.60 over the next 24 hours. There was some reduction in her sedative requirement, and she never was placed on neuromuscular blocking agents. She was transferred (on APRV) to the labor and delivery unit, where labor was induced and she delivered, via forceps, a 1,558-g infant with Apgar scores of 2/6/7 (at 1/5/10 min). In the event of failure to improve we had planned emergency caesarian section to improve lung mechanics. She was subsequently weaned off APRV to tracheostomy collar, and discharged to a rehabilitation facility one week post-delivery. The neonatal course was complicated by mild respiratory distress and jaundice of

prematurity; the infant was discharged home in good condition at 4 weeks of age.

Case 2

A 24-year-old gravida 5, para 2 initially presented to our hospital at 31 weeks gestation, with shortness of breath, fever, palpitations, and gastrointestinal upset. She had previously carried an equivocal diagnosis of hyperthyroidism; however, her free T4 and T3 were normal. When she developed worsening fever, tachycardia, and diarrhea, thyroid storm was initially suspected. However, with normal thyroid function studies the differential diagnosis was expanded to include sepsis. A chest radiograph revealed left-lower-lobe pneumonia. She was started on intravenous fluids and broad-spectrum antibiotics, and transferred to the medical ICU. Soon after transfer, hemodynamic instability developed, requiring vasopressors; norepinephrine alone resulted in deterioration of the fetal heart rate tracing, but a combination of low-dose norepinephrine and dobutamine was successful both in supporting the patient's mean arterial pressure and in preserving a normal fetal heart rate tracing.

The patient's respiratory status declined within 2 days after admission, requiring endotracheal intubation and mechanical ventilatory support. Her chest radiograph revealed lobar collapse and worsening consolidation. Despite mechanical ventilation with positive end-expiratory pressure of 14 cm H_2O and an F_{IO_2} of 1.0, hypoxemia persisted, with a P_{aO_2}/F_{IO_2} ratio of 47 mm Hg. Her ventilatory mode was switched to APRV for hypoxia, which resulted in an immediate improvement of oxygenation, and within the next 2 hours her P_{aO_2}/F_{IO_2} ratio improved to 118 mm Hg. Respiratory and blood cultures were negative. *Mycoplasma pneumoniae* immunoglobulin M antibodies returned positive on day 2 of her medical ICU stay, and antibiotics were tailored accordingly.

At 32 weeks gestation, 4 days after admission, she went into spontaneous labor, and a 2,200-g infant was delivered spontaneously with minimal expulsive effort by the mother, who was still on APRV. Apgar scores were 8/9 (at 1/5 min). Two days postpartum, (day 6 of mechanical ventilation) the patient was weaned off the ventilator and discharged to the postpartum floor, where she continued to improve. She was discharged home on postpartum day 4 on azithromycin and prednisone. The infant's course was complicated by jaundice and some minor issues related to prematurity, and she was discharged home at 2 weeks of age.

Discussion

ARDS is a frequent cause of admission to the ICU and makes up as many as 19% of obstetrical ICU admissions.[4] The current standard ventilatory mode for (nonpregnant) patients with ARDS is volume-controlled ventilation, using a low-V_T lung-protective strategy (6 mL/kg ideal body weight).[5] There are no published studies applying a low-V_T ventilatory strategy in the subgroup of pregnant women with ARDS. However, observational data on the higher-V_T ventilation technique that predated the current standard suggest that pregnant women with ARDS are even more susceptible to barotrauma than the nonpregnant population.[6,7] In a subset of patients with severe ARDS, a low-V_T ventilatory strategy may be unable to maintain adequate arterial oxygenation. In addition, there are theoretical concerns for fetal CO_2 transport and the development of fetal acidemia in the setting of maternal acidemia due to permissive hypercapnia. There is no previous literature on APRV in pregnant women with ARDS. Given the difficulty in oxygenation, we believe that the use of APRV in our patients resulted in improved oxygenation and ventilation. The improved oxygenation facilitated the definitive surgical procedures. Given the short duration of APRV, the delivery might have also contributed to improve the lung mechanics and help in faster recovery postpartum.

APRV is well tolerated by patients, requiring minimal sedation and allowing spontaneous breathing, which improves ventilation-perfusion mismatching and cardiac performance.[8] Another important attribute of APRV, as compared to other modes of advanced ventilation, is the reduced need for sedative agents.[9] APRV with spontaneous breathing in multiple animal studies has shown improved systemic and organ blood flow, including intestinal blood flow.[10,11] It has also shown to decrease respiratory work, with improved gas exchange.[12-14] Both of our patients were also able to take spontaneous breaths on the APRV mode and had decrease in sedative requirements.

Pregnancy has important effects on the respiratory system, which impacts the ventilatory management of these patients.[15] The respiratory rate is modestly changed during pregnancy, but the V_T, minute ventilatory volume, and minute oxygen uptake increase significantly as pregnancy advances. The maximum breathing capacity and forced vital capacity are not altered appreciably. The functional residual capacity and the residual volume are decreased. The fall in expiratory reserve volume is presumably due to small-airway closure, particularly in the dependent areas of the lung. In addition, the mechanical effect of pregnancy causes a decrease in chest wall compliance. The effects of pregnancy on the respiratory system are compounded in patients with acute lung injury, who have decreased lung compliance; therefore, mechanical ventilation with low V_T may result in severe lung derecruitment. APRV may be an ideal ventilatory mode in pregnant patients with severe ARDS, as the increased mean alveolar pressure with short release time (time low) will recruit collapsed dependent lung while preventing over-distention

of ventilated alveoli. We believe that APRV should be considered as an alternative ventilatory strategy in pregnant patients with severe ARDS.

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