



High frequency percussive ventilation as a rescue mode for refractory status asthmaticus – a case study

David Albecker, T. Glen Boudier & B. Franklin Lewis

To cite this article: David Albecker, T. Glen Boudier & B. Franklin Lewis (2019): High frequency percussive ventilation as a rescue mode for refractory status asthmaticus – a case study, Journal of Asthma, DOI: [10.1080/02770903.2019.1687714](https://doi.org/10.1080/02770903.2019.1687714)

To link to this article: <https://doi.org/10.1080/02770903.2019.1687714>



Accepted author version posted online: 31 Oct 2019.
Published online: 06 Nov 2019.



Submit your article to this journal [↗](#)



Article views: 155



View related articles [↗](#)



View Crossmark data [↗](#)

CASE REPORT



High frequency percussive ventilation as a rescue mode for refractory status asthmaticus – a case study

David Albecker, BS, RRT, RPFT, T. Glen Boudier, MD, and B. Franklin Lewis, MD

Winchester Medical Center, Winchester, VA, USA

ABSTRACT

Introduction: A severe asthma exacerbation is called status asthmaticus when symptoms worsen despite conventional medical treatment in the hospital. If arterial blood gas (ABG) values deteriorate and this is accompanied by respiratory muscle fatigue, the patient will require mechanical ventilation. However, mechanical ventilation of the severe asthmatic presents difficult challenges.

Case Study: We report on High Frequency Percussive Ventilation (HFPV) used along with continuous inhaled albuterol and neuromuscular blockade, as rescue therapy for a case of acute, severe asthma that was refractory to conventional treatment and conventional mechanical ventilation.

Results: This patient's arterial pH was 6.97 when we initiated HFPV, but ten hours post-intubation her ABG values normalized. She was successfully extubated six days later and discharged from ICU the following day.

Conclusion: This case describes the successful use of HFPV for a status asthmaticus patient failing conventional mechanical ventilation. We have anecdotal evidence of other medical centers using HFPV for these patients but larger studies are needed to verify its efficacy.

ARTICLE HISTORY

Received 16 September 2019

Revised 21 October 2019

Accepted 27 October 2019

KEYWORDS

Acute severe asthma; status asthmaticus; HFPV; VDR®-4; high frequency percussive ventilation

Introduction

Acute exacerbation of asthma is a common reason for an Emergency Department visit. If symptoms worsen, despite conventional medical treatment in the hospital, the case is referred to as status asthmaticus which is a medical emergency that can be life threatening (1). If the patient's arterial blood gas values deteriorate dangerously and this is accompanied by respiratory muscle fatigue, the patient will require mechanical ventilation. However, mechanical ventilation of the severe asthmatic presents difficult challenges. We report on High Frequency Percussive Ventilation used along with continuous inhaled albuterol, and neuromuscular blockade, as rescue therapy for a case of acute severe asthma that was refractory to conventional treatment and conventional mechanical ventilation.

Case study

A thirty three year old woman with a history of asthma presented in our Emergency Department with an asthma exacerbation that she could not manage

using her home treatment regimen in mid-morning on August 8th. She was immediately treated with inhaled albuterol/ipratropium aerosols, prednisone oral tablets, and low-flow oxygen through a nasal cannula. She was noted to be tachycardic and afebrile, with bilateral inspiratory and expiratory wheezes. ABG showed mild acidosis and mild hypoxemia. Noninvasive mask BiPAP along with intravenous corticosteroids were started in response to worsening tachypnea, wheezing, and shortness of breath.

She was transferred to the ICU in the early evening of August 8th. Endotracheal intubation was performed due to worsening ABG, diffuse wheezing, and respiratory muscle fatigue. A Drager V-500 ventilator in the Volume Control-Assist Control (VC-AC) mode was started with a tidal volume of 6 ml/kg ideal body weight (see Table 1 for ventilator settings and ABG values). The ventilator was high-pressure limiting with exhaled tidal volumes between 70 and 100 ml within minutes of initiation. A short trial on the Pressure Control mode was equally unsuccessful. She was taken off the Drager V-500 and manually ventilated. It was noted that she had an extremely long expiratory phase. A Percussionaire VDR®-4 ventilator in the

Table 1. Ventilator settings and ABG values.

Date/Time	8/8 1857	8/8 1916	8/8 1956	8/8 2217	8/9 0104	8/9 0208	8/9 0453	8/9 1547	8/9 2008	8/10 0521	8/10 1355	8/11 1020	8/12 0350
Vent Mode	Man. Resus. ⁹	VDR HFPV	VDR HFPV	VDR HFPV	VDR HFPV	VDR HFPV	VDR HFPV	VDR HFPV	VDR HFPV	VDR HFPV	Drager V-500 VC-AC	Drager V-500 VC-AC	Drager V-500 VC-AC
HF Rate ¹		600	500	450	450	450	450	450	450	500			
Conv. Pressure ²		0	10	10	10	8	0	0	0	0			
I-Time ³		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.9	0.9	0.9
E-Time ⁴		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0			
PIP ⁵		34	34	34	34	34	40	35	32	28			
FiO ₂ ⁶	1.0	0.5	0.5	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3
PEEP		10	3	3	3	3	8	8	8	8	8	8	8
Tidal Vol. ⁷										330	330	330	330
Resp. Rate ⁸		15	15	15	15	15	15	15	15	20	20	18	18
ABG pH	7.07	6.97	7.05	7.17	7.26	7.29	7.35	7.45	7.48	7.38	7.33	7.34	7.40
pCO ₂	84	101	82	61	39	36	32	29	26	39	39	46	43
pO ₂	499	151	62	108	204	135	138	141	144	140	75	88	72
HCO ₃	24	23	23	22	17	17	18	21	20	23	21	25	27
SaO ₂ %	100	97	80	96	100	99	99	99	100	100	94	96	94

1 - HF Rate = high frequency rate in cycles per minute.

2 - Conv. Pressure = convective pressure rise above PIP in cm H₂O.

3 - I-Time = inspiratory time in seconds.

4 - E-Time = expiratory time in seconds.

5 - PIP = peak inspiratory pressure in cm H₂O.

6 - FiO₂ = fractional inspired oxygen.

7 - Tidal Vol. = tidal volume in mls.

8 - Resp. Rate = set respiratory rate per minute (for the VDR®-4, it's $[60/(I\text{-Time plus } E\text{-Time})]$).

9 - Man. Resus. = manual resuscitation bag attached to the endotracheal tube after endotracheal intubation.

HFPV mode was then started. Her blood pressure at that time was 89/56 mm Hg with a heart rate of 133/min. Her pH on ABG was 6.97 and she had severe bilateral inspiratory and expiratory wheezes. Extracorporeal Membrane Oxygenation (ECMO) was being considered for CO₂ clearance.

After the VDR®-4 ventilator was initiated, a Ketamine infusion was added primarily for the bronchodilator effect. A continuous albuterol aerosol was also started at 12 mg/hr and delivered through the entrainment port of the VDR®-4 phasitron. After adequate pain management and sedation were established, neuromuscular blockade was initiated in order to better ventilate and manage her care.

At approximately 3am on August 9th, the decision was made to stop the paralytic, but she was noted to be coughing uncontrollably and fighting the VDR®-4 ventilator so the paralytic was restarted. She stabilized somewhat overnight on the VDR®-4 with a continuous albuterol aerosol and a paralytic. The paralytic was successfully discontinued later that day. During her time on the VDR®-4, peak inspiratory pressure (PIP) and FiO₂ were adjusted downward when improving ABG values made those changes possible (see Table 1).

On August 10th, she was transferred back to a Drager V-500 ventilator. Increased wheezing was noted at that time. The continuous albuterol aerosol was stopped six hours after she was transferred back to the V-500 ventilator and albuterol/ipratropium aerosols were started every two hours around the

clock. The Ketamine infusion was stopped three days later. Daily chest x-rays were done while she was intubated (see Figure 1). On the morning of August 15th, she was successfully extubated, given a one-time racemic epinephrine aerosol, and then managed on albuterol/ipratropium aerosols every two hours and low flow oxygen through a nasal cannula. She was discharged from ICU the next day and her treatment regimen was adjusted downward accordingly.

Results

With our patient's arterial pH at 6.97 and evidence that conventional mechanical ventilation was not working for her, we had very little time to establish a treatment plan that was effective. ECMO was being prepared as we were setting up the VDR®-4 ventilator. Fortunately, the VDR®-4 reversed the downward clinical trend and her ABG values steadily improved. Ten hours after starting the VDR®-4, her ABG values normalized (see Table 1). She was transferred back to the conventional ventilator two days later, and successfully extubated six days later. She was discharged from ICU the day after extubation.

Discussion

We chose the VDR®-4 ventilator in this case because it has a passive expiratory phase (2) and it stacks high-energy, subtidal volumes that travel down the centers of airways where airway resistance is lowest

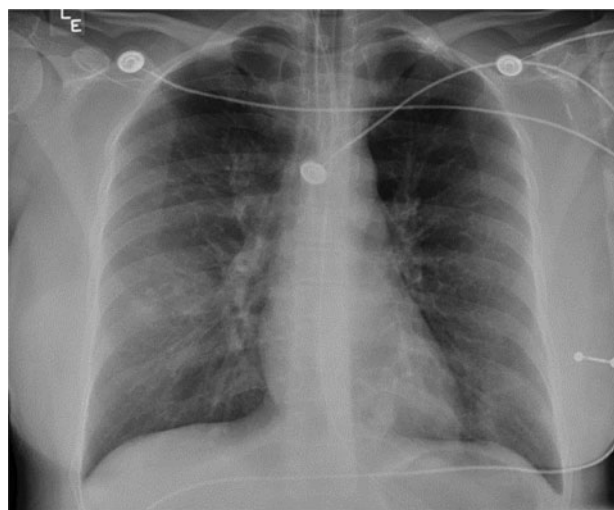


Figure 1. Chest x-ray taken at 0700 h. August 9th after the first night on the VDR®-4 ventilator.

(2). Luckily, our patient did not have a high FiO_2 or PEEP requirement so we could decrease PEEP and increase PIP to widen out ΔP (PIP minus PEEP) in order to ventilate her better. Although there is good evidence for keeping plateau pressure less than 30 cm H_2O and driving pressure low for Acute Respiratory Distress Syndrome (ARDS) patients (3,4), we reasoned that most of the high peak pressure with status asthmaticus is due to increased airway resistance and therefore those higher pressures would attenuate in large part before reaching the alveoli where damage could be done. Daily chest x-rays were done while she was intubated. Other than the one in Figure 1, with the primary interpretation statement of: “developing airspace disease on the right suspicious for inflammation”, they were mostly unchanged. What was shown by the x-ray in Figure 1 was that, despite her severe airflow obstruction and bronchospasm, the VDR®-4 was not causing notable hyperinflation of her lungs. Dynamic hyperinflation of the lungs is a dangerous complication of mechanical ventilation for the severe asthmatic (5). No pneumothorax or subcutaneous free air was noted during her ICU stay.

The Percussionaire VDR®-4 ventilator is classified as a pneumatically-powered, time-cycled, pressure-limited, high-frequency flow interrupter. The mode of ventilation that it provides was originally called High Frequency Percussive Ventilation by its inventor, Dr. Forrest Bird (6). Over the past several years, studies have shown this mode to reduce time on ECMO for H1N1 pneumonia patients (7), enhance separation from ECMO (8,9), be a rescue mode that improves $\text{PaO}_2/\text{FiO}_2$ (P/F) ratios for morbidly obese patients failing conventional mechanical ventilation (10), improve P/F ratios for non-cardiac surgery patients failing

conventional mechanical ventilation (11), and improve hemodynamics and oxygenation for ARDS patients (12).

The VDR®-4 utilizes a sliding venturi tube that Dr. Bird called the Phasitron. This Phasitron has an entrainment port which entrains heated, humidified, blended gas, to provide a tidal volume to the patient that is volume-limited by a principle termed “fluidic clutching” (6). As the lungs fill, the increasing intrapulmonary pressure causes a proportionally increasing back-pressure on the phasitron. This, in turn, causes a reduction in entrained gas and therefore a tidal volume to the patient that is partly determined by the lung itself. Decreases in lung compliance and increases in airway resistance also increase the back-pressure on the phasitron so the actual delivered tidal volumes vary in real time based on changing lung characteristics and dynamics.

The VDR®-4 stacks very small subtidal volumes to produce a step-wise inflation of the lungs during the set inspiratory time (6). These subtidal volumes are high-energy mini-bursts of gas that travel down the centers of the airways because that path is the path of least resistance. Exhaled gas then travels in a counter-current path along the inside walls of the airways (2). Coupled with adequate humidification, this flow pattern gives the VDR®-4 the ability to clear pulmonary secretions and debris from airways (13). It is used in some burn treatment centers partly for this reason (13,14).

As in pressure control ventilation, two pressure levels are typically employed with the VDR®-4, PIP and PEEP. But the VDR®-4 also has the option of a third oscillatory pressure level above PIP that is often used as a recruitment maneuver. The idea is that larger airways are stented open during the PIP (2nd pressure level) and then alveoli are recruited during this 3rd convective pressure level above PIP (see Table 1) (6).

In looking back at this case, what we could have done differently with the VDR®-4, which may have enhanced a return to normal ABG values sooner, was to shorten I-Time to 1.5 s. and lengthen E-Time to 2.5 s. rather than leaving them at 2 s. each. This would have matched her very long expiratory phase better and may have provided better CO_2 clearance.

Conclusion

Status asthmaticus patients that require mechanical ventilation present very difficult challenges to the critical care team. The associated severe airflow obstruction makes ventilation very difficult and increases the

likelihood of respiratory acidosis and lung injury due to dynamic hyperinflation (5). Various attempts to improve ventilation in these cases have been tried including changing the gas mixture for a conventional ventilator from air/oxygen to Heliox/oxygen (15). These attempts have shown mixed results.

This case report describes the successful use of HFPV for a status asthmaticus patient failing conventional mechanical ventilation. We have anecdotal evidence of other medical centers using HFPV for these patients but larger studies are needed to verify its efficacy, and define the best care pathway for these patients.

Declaration of interest

The authors declare that there is no conflict of interest regarding the publication of this case study. Further, the authors have no financial interest in any ventilator, corporation, medication, or therapy, mentioned in this case study.

References

- Shah R, Saltoun CA. Acute severe asthma (status asthmaticus). *Allergy Asthma Proc.* 2012;33(3):47–50. doi:[10.2500/aap.2012.33.3547](https://doi.org/10.2500/aap.2012.33.3547).
- Lucangelo U, Fontanesi L, Antonaglia V, Pellis T, Berlot G, Liguori G, Bird FM, Gullo A. High frequency percussive ventilation (HFPV). *Principles and technique.* *Minerva Anesthesiol.* 2003;69(11):841–848.
- Narendra DK, Hess DR, Sessler CN, Belete HM, Guntupalli KK, Khusid F, Carpati CM, Astiz ME, Raouf S. Update in management of severe hypoxemic respiratory failure. *Chest.* 2017;152(4):867–879. Epub 2017 Jul 14. doi:[10.1016/j.chest.2017.06.039](https://doi.org/10.1016/j.chest.2017.06.039).
- Amato MB, Meade MO, Slutsky AS, Brochard L, Costa EL, Schoenfeld DA, Stewart TE, Briel M, Talmor D, Mercat A, Richard JC, et al. Driving pressure and survival in the acute respiratory distress syndrome. *N Engl J Med.* 2015;372(8):747–755. doi:[10.1056/NEJMsa1410639](https://doi.org/10.1056/NEJMsa1410639).
- Laher AE, Buchanan SK. Mechanically ventilating the severe asthmatic. *J Intensive Care Med.* 2018;33(9):491–501. Epub 2017 Nov 5. doi:[10.1177/0885066617740079](https://doi.org/10.1177/0885066617740079).
- The VDR-4 User's Manual (Manual of Understanding). Percussionaire corporation and bird institute of biomedical technology. Sandpoint, Idaho. Revised 10/29/2009.
- Michaels AJ, Hill JG, Long WB, Sperley BP, Young BP, Park PK, Rycus PT, Bartlett RH. Reducing time on for extra-corporeal membrane oxygenation for adults with H1N1 pneumonia with the use of the volume diffusive respirator. *Am J Surg.* 2013;205(5):500–504. doi:[10.1016/j.amjsurg.2013.01.024](https://doi.org/10.1016/j.amjsurg.2013.01.024).
- Gulkarov I, Schiffenhaus J, Wong I, Afzal A, Khusid F, Worku B. High-frequency percussive ventilation facilitates weaning from extracorporeal membrane oxygenation in adults. *J Extra Corpor Technol.* 2018;50(1):53–57.
- Boscolo A, Peralta A, Baratto F, Rossi S, Ori C. High-frequency percussive ventilation: a new strategy for separation from extracorporeal membrane oxygenation. *A&A Case Rep.* 2015;4:79–84. doi:[10.1213/XAA.0000000000000131](https://doi.org/10.1213/XAA.0000000000000131).
- Korzhuk A, Afzal A, Wong I, Khusid F, Worku B, Gulkarov I. High-frequency percussive ventilation rescue therapy in morbidly obese patients failing conventional mechanical ventilation. *J Intensive Care Med.* 2018;885066618769596. doi:[10.1177/0885066618769596](https://doi.org/10.1177/0885066618769596).
- Wong I, Afzal A, Cinelli M, Spagnola J, Housman B, Worku B, Fahoum B, Weingarten J-e, Khusid F, Gulkarov I. Rescue therapy with high frequency percussive ventilation in non-cardiac surgical patients failing conventional mechanical ventilation. *J Surg.* 11:1218. doi:[10.29011/2575-9760.001218](https://doi.org/10.29011/2575-9760.001218).
- Godet T, Jabaudon M, Blondonnet R, Tremblay A, Audard J, Rieu B, Pereira B, Garcier J-M, Futier E, Constantin J-M. High frequency percussive ventilation increases alveolar recruitment in early acute respiratory distress syndrome: an experimental, physiological, and CT scan study. *Crit Care.* 2018;22(1):3. doi:[10.1186/s13054-017-1924-6](https://doi.org/10.1186/s13054-017-1924-6).
- Guo B, Bai Y, Ma Y, Liu C, Wang S, Zhao R, Dong J, Ji HL. Preclinical and clinical studies of smoke-inhalation-induced acute lung injury: update on both pathogenesis and innovative therapy. *Ther Adv Respir Dis.* 2019;13:175346661984790. doi:[10.1177/1753466619847901](https://doi.org/10.1177/1753466619847901).
- Al Ashry HS, Mansour G, Kalil AC, Walters RW, Vivekanandan R. Incidence of ventilator associated pneumonia in burn patients with inhalation injury treated with high frequency percussive ventilation versus volume control ventilation: a systematic review. *Burns.* 2016;42(6):1193–1200. Epub 2016 Mar 26. doi:[10.1016/j.burns.2016.02.024](https://doi.org/10.1016/j.burns.2016.02.024).
- Leatherman JW, Romero RS, Shapiro RS. Lack of benefit of heliox during mechanical ventilation of subjects with severe air-flow obstruction. *Respir Care.* 2018;63(4):375–379. Epub 2017 Dec 26. doi:[10.4187/respcare.05893](https://doi.org/10.4187/respcare.05893).